PRODUCT
DEVELOPMENT & QUALITY
ASSURANCE

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CONTENTS

CHAPTER 3. Product development

Dear Readers!

Presented multiple-author monograph was written in 22 sub-chapters divided into 3 main chapters:
Chapter 1. Consumer Preferences
Chapter 2. Quality and Sensory Properties of Food
Chapter 3. Product Development

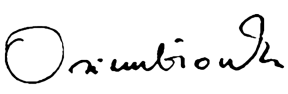
We should take into account, as it was written in the first sub-chapter, that "consumers' preferences have a great impact on making decision of purchase food products. Preferences are determined as a system of estimation and priorities, after which some products are estimating higher than others". Labels and information on the product are one of the most important factors for the consumer during food purchasing what was described in the second sub-chapter. Many useful details about validation of labeling meat product were given by authors of the third sub-chapter. All these information have been written in the first part "Consumer Preferences" and is helpful to better understand the significant factors influencing the consumers' decisions during food buying.

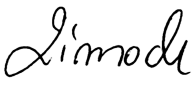
Different food products, mainly in the context of the sensory evaluation, are described in the second chapter "Quality and Sensory Properties of Food". All sub-chapters can be divided into two groups describing plant and animal origin food products. The first group of sub-chapters is focused on such plant raw materials or products like carrot, beetroot and agar jellies and the second group described meat products. The most important conclusion obtained from all these sub-chapters confirms that sensory analysis is very important factor of the overall food evaluation.

The third chapter "Product Development" describes relationships between different food products and the main factors influencing the final quality of these products. Many such "pairs" can be find in the described sub-chapters like: "milled maize – worts", "genotype – pork intermuscular fat", "durum wheat – pasta", "organic methods – eggs", "resistant starch – wheat bread", "laying hens – eggs", "boar meat – smoked products", "emulsion and colour stabilization", etc. Although, the "pairs" described were plant or animal origin, the most important conclusion is that the high quality of final food product is strongly connected with high quality of raw material or genotype used in production processes.

The present publication does not exhaust the multitude of issues in described fields but indicates connected scientific studies.

Andrzej Jarmoluk 

Maciej Oziembłowski 

Anna Zimoch 

CHAPTER 1

CONSUMER PREFERENCES

1

THE IMPACT OF PERSONALITY ON CONSUMER BEHAVIOR IN THE LIGHT OF SELF-CONTROL IMPAIRMENTS

Introduction

Since the Antiquity, the nature of human selfhood has incessantly been explored by many greatest intellects [Suls, Tesser, Felson 2004, Freud 1920/2000]. According to Baumeister [2004], human self is rooted in *reflexive consciousness* (which is helpful in getting aware knowledge about the self), *interpersonalmembership* (which reflects the need of belonging to others) and *executive function* (which plays the essential role in goal-directed behaviors including control, altering behavior or planning).

The self system is vital and probably the most complex element of human personality. Personality and individual differences refer to well-established specific tendencies that affect or facilitate one's behavioral patterns [Bruijn, Brug, Lenthe 2009]. The nature of these individualized patterns is formed mainly during life experiences, being rooted in biological make-up in part [Kofta, Doliński 2004]. Among other determinants, personality is reflected in tendency to maintain one's self-regulation and self-control [Hoyle 2006]. However, the knowledge on this subject has relatively been little studied in past decades.

Hence, this paper addresses to the broad question about personality-driven mechanisms explaining why some people tend to consume unhealthy food, use drugs, drink excessive amount of alcoholic beverages or buy unwanted goods. As observed in many countries [see e.g. Bruijn, Brug, Lenthe 2009], these inadequate, repeated consumer patterns are related to several individual and social problems: impulsive behaviors, addictions, or alarming overeating. Yet, there is evidence from the personality research area that indicate the usefulness of studying personality determinants in alcohol intake.

Personality determinants of alcohol use

In a lot of research studies, alcohol drinking has usually been associated with negative consequences: aggression including physical violence, rapes or damage of material goods, interpersonal and legal problems, greater risk of HIV infection, elevated risk of liver, stomach, and heart diseases, and one of the most precarious outcome – the addiction. However, Baumeister, Heatherton and Tice [2000] mentioned that overall attitude towards alcohol has been ambivalent across contemporary Western cultures.

First of al. the majority of people enjoy drinking small amounts of alcohol. There is also stated in the society that heavy alcohol drinkers are psychically weak and fully responsible for their unhealthy behavior, but in the same time it is reasoned that alcoholism is the disease and this is why the addicted individuals are not able to control themselves.

According to Baumeister, Heatherton and Tice [2000], there are social and individual reasons of alcohol consumption. Drinking during social events is perceived as normative. Taking individual perspective into consideration, alcohol is used for relaxation, reward, or mood improvement. Patric and colleagues [2011] investigated that especially women drink alcohol when they feel distressed. These researchers also detected that alcohol used for relaxation, unique taste, sleep increases, with age. Besides that, the motivational aspect plays a role: people drink more often when they expect that alcohol will lead them to the desired outcome.

As Sugarman, DeMartini and Carey detected [2009], in comparison to men, women shift more rapidly from drinking onset to problematic drinking which is called the "telescoping effect". In addition, women more often experience damages to self resulting from drinking (vomiting, blackouts), whereas men suffer mainly from antisocial behaviors and damage to others (attending school whilst drunk, fights).

Other researchers considered the relation between alcohol consumption understood as risky behavior and personality traits. Following the review of literature in this field, Skeel, Pilarski, Pytlak and Neudecker [2008] distinguished that personality-related predictors of alcohol use are: extraversion and high sociability, sensation seeking and impulsivity, emotional stability, aggression-hostility and disinhibition.

Interestingly, there are also geographical differences in drinking habits. "Europe has the highest level of alcohol consumption in the world", as Sieri and her colleagues published in 2009 after their examination of the large sample of adults in 10 European countries. Drinking patterns depend on total amount of alcohol consumed, type of beverage (e.g. wines, beer, spirits, cocktails/punches), time (e.g. morning, before dinner, in the evening etc.), and context of drinking (friend's home, bar, restaurant). Amongst many others, the data collected by Sieri and her team revealed (unsurprisingly enough) that Mediterraneans choose wine, whereas Northern Europeans preferred beer. Men coming from Northern and Central Europe drink alcohol mainly at friend's homes, but men in Spain prefer drinking in bars. Spanish women as well as those who live in the United Kingdom also prefer drinking outside the home, in bars, whereas women in other centers consume alcohol mainly at friends' houses.

In spite of the existing great deal of evidence on alcohol intake, future research should make consecutive contribution to the prevention and treatment of alcohol-related social problems and diseases. Similarly enough, a number of researchers have dealt with revealing personal reasons for other stimulants use which, in majority of cases, also lead to poorer psychological functioning or addictions.

Personality and other stimulants taking

In psychological literature, assorted personality dimensions and traits were investigated as significant individual factors underlying healthy versus unhealthy behavior related to substance use. Some important findings derived from longitudinal and experimental studies. Taking drug use into account, in Block's study [Pervin 2002] the role of two vital personal constructs was emphasized. In particular, ego-control (EC) and ego-resilience (ER) were investigated in childhood as predictors of drug use in adolescence. The EC is the dimension referring to one's ability in overcoming impulses, delaying gratification, controlling his or her desires or affect in spite of external distraction. High-level EC individuals demonstrate a tendency to inhibit behavior, show poor emotional expression and far too strong, thus maladaptive, delay of gratification. In comparison, full of expression, feeble low-level EC indi-

viduals are not able to delay gratification in the desired level. As noted by Hoyle [2006], EC construct is showing that individuals can be over- and undercontrolled. Hence, the middle location on EC dimension is the most adaptive. The next personal construct postulated by Block was ER (ego-resilience) which describes a capacity to modulate one's level of ego-control in dissimilar contexts. Merely people high in ER are flexible in response to external affordances. Generally, it was revealed in Block's study that low level of EC in adolescents in age 14 was related to marijuana use. Moreover, low level of both, EC and ER predicted the hard drugs use. Thus, personal constructs related to self and control may predict drug use amongst young individuals.

Other research on communication strategies developed in mass media campaigns [see Bruijn, Brug, Lenthe 2009 for details] revealed another personality trait associated with marijuana use in adults, which was sensation seeking. Linked to risky behavior, that genetically based personality trait depicts the tendency to seek fear-inducing adventures including physical, social, legal and financial risk. The trait sensation seeking consists of four factors: thrill and adventures seeking, experience seeking, disinhibition and boredom susceptibility [see e.g. Strelau 2003]. According to research, seeking out high-sensational experiences increases marijuana use. It showed that biologically driven personality trait may affect substance abuse in adulthood.

Some researches focused on personality and individual differences underlying problematic behavior, whereas some others gained deeper insight into self-perceived reasons or gender and age-related changes of using drugs.

As Patric et al. noted [2011], it was found in some previous studies that women and men are used to use drugs from different reasons, depending on age. In general, women coped with their negative affect or emotions (anger, frustration), while men were motivated to use drugs to modulate the effects of other drugs or because they were addicted. Recent nationally representative longitudinal study by Patrick and her colleagues [2011] showed more precisely that marijuana users are motivated by negative affect, wanted to get high or to relax, significantly with age. If younger users rather experimented with marijuana or wanted to fit in, they might demonstrate fewer marijuana-related problems afterwards. In comparison to women, men used it to use it for a good time or seeking insight, but no gender differences in reasons were found amongst the consistent marijuana users. That research shed a new light on the reasons and its possible consequences of the soft drug use.

The existing evidence for gender effects on substance use were comprehensively reviewed by Gailliot, Hildebrandt, Eckel and Baumeister [2010]. These authors studied the link between menstrual cycles and intake of stimulants (e.g. caffeine, tobacco, nicotine, cocaine, marijuana). There are some findings showing that addictive and producing euphoria stimulants intake increase during the luteal phase, whereas less addictive like marijuana were not related to menstrual cycle phase. These findings generally supported the idea that substance abuse may be driven by biology and personality.

In other studies testing a relation between personality and substance use, a careful attention has been paid to the role of trait narcissism and narcissistic personality. As proposed by Besser and Priel [2010], narcissism as a personality trait means a form a functioning organized around inflated sense of self, characterized by emotional lability and often unhealthy reactions, especially to critic. Two common forms of narcissism, grandiose and vulnerable stress threat conditions to achievement failure and interpersonal rejection [Besser, Priel *op. cit.*]. Thus under threat, feeling underappreciated or temporarily depressed, narcissistic in-

dividuals may use drugs making an attempt at lessening their ego-threatening experiences [Millon, Davies 2005]. The stimulants may also exacerbate euphoria accompanying feeling of power, selfishness, and greatness, typically maintained by the narcissistic self-image. Yates, Fulton, Gabel and Brass [1989] investigated that narcissistic personality creates the risk factor in cocaine abuse.

Among several other factors, personality and the self may explain the mechanisms responsible for substance abuse. Individual differences in personality may directly refer to that mainly problematic behavior, but the role of gender, age and motivation seems also to be essential in this field. Recently, several research studies focused on another engrossing problem which is the excessive eating. The novel findings suggest that food may be addictive as well.

Self and excessive eating

As observed in many countries, thousands dollars are spent on goods promising weight loss, however the obesity became the second leading cause of death in the United States at present [Gearhardt, Corbin 2010]. Obesity is associated with several serious medical and social complications (e.g. cardiovascular disease, orthopedic problems, diabetes), shortening life expectancy [Levitan, Davis 2010]. However, all the authorities stress that the preventive triggers for *obesity epidemic* are insufficient, showing no signs of slowing, unfortunately.

As noted by Baumeister, Heatherton and Tice [2000], on the one hand, people excess eating because of a conflict they experience while choosing between palatable versus healthy ("tasteless") products. High-fat foods (pizza, chips, French fries, hamburgers) and high-carbohydrate products (chocolate, ice-creams, donuts) are perceived as more tasty than low-caloric, healthy vegetables or fruits. Adults and children especially are suspicious about these "tasteless" healthy foodstuffs. Actually, increased consumption of highly palatable food is one of the major causes of obesity in recent years [Levitan, Davis 2010].

On the other hand, some people choose high-caloric foods while experiencing negative emotions (fatigue, frustration etc.). Nonetheless, those vulnerable adult individuals may suffer from anxiety or depression which in fact may primary drive their emotional eating. Definitely, emotions play the essential role in food choices. Recent investigations noticeably revealed that stressed emotional eaters consume more caloric food than non-stressed versus non-emotional eaters [see Levitan, Davis 2010 for details]. A highly stressful period of time which is critical for weight gain and eating habits with related medical complications is adolescence. However, Levitan and Davis found that emotional eating is typical rather for young girls, whereas young boys eat in response to plausibly non-emotional causes or they may be less aware of their emotional states and eating.

Recently, some researchers have claimed that obesity may be driven by similar factors as it happens in addictive behavior in the whole [Levitan, Davies, *op. cit*.,]. Gearhardt and Corbin [2010] wrote: "Both biological and behavioral evidence suggest that food may be addictive" (p. 1). Numerous research studies with the use of neuroimaging techniques revealed that excess food consumption and drug use are associated with changes in the parallel systems of the brain. Moreover, lack of "addictive" foodstuff exacerbates so-called dependence symptoms: continued use despite harmful costs, uncontrollability and irrational beliefs about inability to limit eaten calories [Gearhardt and Corbin, *op. cit*.].

CHARACTERISTIC DEPRESSION SYMPTOMS IN ADULTS

A person must have experience five (or more) of the following symptoms present during the same 2-week time, one of the symptoms should be either (1) depressed mood nearly every day, most of the day or (2) anhedonia – a loss of ability of enjoy things

depressed mood nearly every day, most of the day
anhedonia – a loss of ability of enjoy things
significant increase or decrease of weight, changes in appetite
troubles with sleeping, almost everyday (insomnia or hypersomnia)
changes in psychomotor behavior (agitation vs retardation), also observable by others
constant fatigue
feeling of worthlessness or excessive or inappropriate guilt (but not about being ill)
cognitive problems (with concentration, memory, making daily decisions)
recurrent thoughts of death, suicidal ideations or plans

Fig. 1. Symptoms of depression according to DSM-IV-TR (2000)
Note: The symptoms of depression in children may very in some cases

Enlarging evidence showing worsened eating habits in adult population and increasing obesity even in childhood, created a room for practical implications and prevention. Nowadays, children eat more fast food and spent more time on eating in restaurants than before [Stutts, Zank, Smith, Williams 2011]. Interestingly, their food selection for fast food menus, high versus lower caloric, may depend on a sort of information format placed on offered items. Like adults, children may sometimes draw attention to nutrition information on packaging products which they would like to choose or not. In Stutts' and colleagues experiment [2011], children in ages 8–11 were exposed to two types of product information.

The first one included typical nutrition description about the content, whereas the second one presented a healthy symbol, a heart. The data revealed that children exposed to the heart symbol choose healthier menus in comparison to children exposed to the typical nutrition description versus no information on foodstuffs at all. Thus, healthier food choices are plausible even in childhood depending on information format which should be easily recognizable for young consumers.

Nevertheless, the fact is that excessive eating currently led to the obesity epidemic. Novel research on promoting healthier lifestyle merits thus thorough consideration. Especially, studies in children and young consumers might play a key role in healthy eating habits teaching programs. Prevention and intervention techniques might also benefit from self-regulation and self-control research, as the self-control capacity visibly determines people's everyday endeavors.

Impaired self-control and problematic consumption

Since last decade, some researchers put greater attention to another vital aspect of personality structure and the self, which is self-control. According to Gailliot et al. [2007], self-control (or self-regulation) is one's ability to override impulses, emotions, thoughts, or variety of habitual distractors. Self-regulation is a compulsory factor in both, goal attain-

ment and socially desirable behaviors. Gailliot and his colleagues (*op. cit.*) stressed that the capacity for self-control is beneficial. On the one hand, self-controlled individuals have better mental health and interpersonal relationships, higher academic achievements, and less susceptibility to substance abuse and problematic eating. On the other hand, self-control failures are linked to many individual and social problems, e.g. drug and alcohol use, smoking, overeating, money problems, violence, crime and psychopathology [Vaughn et al. 2007, Baumeister 2004].

Self-regulation operates in the service of the human executive function [Baumeister, *op. cit.*]. This vital adaptive mechanism is responsible for making choices, taking initiative, altering behavior, and other acts which include higher cognitive processes within the brain.

Some empirical findings suggest that self-control may rely on some kind of energy or resource which is scarce and limited. This fact implies the depletion of that resource with use up which leads to negative consequences [Gailliot 2007, Baumeister 2004]. In other words, it should be expected that one initial self-control act (e.g. overriding an aggressive impulse) would impair a subsequent self-related duty (e.g. overriding an impulse to drink too much of alcohol) because it has tired common limited resource. This naturally occurring outcome is called *ego-depletion*. Its function is a conservation of the volitional resource for future choices and initiatives.

The impact of an initial effort on the subsequent activity and the resulting depletion has been tested in several experiments, also with the use of food. In one study, Baumeister et al. [1998] asked the participants not to eat for three hour before the examination to ensure that all of volunteers were during the tests hungry. The air in the lab was full of freshly baked cookies aroma and at a table some tasty cookies and chocolate candies were displayed. The participants were also exposed to a bowl with radishes. In the crucial test condition, the experimenter allowed to try some radishes merely and left the room for five minutes. The participants who could try bowls, could not eat chocolate foodstuff, thus in fact, they resisted the temptation to try luscious candies. After return, the experimenter gave (ostensible) resolvable cognitive task and started to discretely measure time spent on that unfruitful and effortful duty. The results showed that those who resisted temptation of eating candies quit sooner in comparison to controls who's the only activity during the whole study was cognitive tasks solving. Resisting temptation by hungry individuals depleted some volitional resource and then worsened the level of subsequent activity which also demanded self-control expenditure.

That pattern based on the strength self-control model was confirmed by many other contributors. Interestingly enough, Houben [2011] recently demonstrated that boosting level of control may be helpful in regaining control over the consumption of caloric food.

Broadly exploring the link between control and eating, Hoffmann and Friese [2008] revealed factors disrupting the control of eating behaviors: ego-threat, emotional distress, anxiety and depression. This may explain why people with lower mood usually get worse with their eating habits. Additionally it was found that *impulsivity* and low *self-control* as personality traits may also affect eating behaviors.

Hoffman and Friese [*op. cit.*] indicate that typically, alcohol has been related to failure of inhibitory control. Drinking alcohol causes difficulties in limiting alcohol consumption. Drunk people are more impulsive and have more impulsivity-related problems (aggression, driving after drinking, problems with his or her partner). Having lower ability to control, drunk people are not able to effectively monitor their behavior in accordance with standards.

Thus, their perception of norms is changed. Moreover, alcohol may intensify preexisting inner conflicts, leading to impulsively taken inappropriate decisions. These problems Hoffman and Friese partly explain in terms of physiology. Alcohol affects the functioning of the prefrontal cortex within the brain. This region is responsible for the control of impulses driven by other parts of the brain (e.g. amygdala).

Biology and self-control impairment in the relation to eating habits and substance use were also considered by Gailliot, Hildebrandt, Eckel and Baumeister [2010]. These authors are convinced that premenstrual syndrome may indicate poorer self-control in line with assumptions of the strength self-control model [Baumeister, Bratslavsky, Muraven and Tice 1998]. Gailliot et al. [2010] assumed that biological processes during the luteal phase demand greater energy which may affect latter self-control in women. The increased energy level is associated with more caloric food intake. Gailliot, Hildebrandt, Eckel and Baumeister found in one study, that larger (810 calorie) lunches were consumed by women in the luteal phase in comparison to women in another menstrual phase (638 calorie). More, increasing energy demands of the luteal phase affected food choices. The data also showed that women in that phase reported increased cravings for more palatable, high-fat foods. Finally, impaired control may also intensify nicotine and (weaker, however) caffeine intake.

In sum, contemporary approaches to self-control and self-regulation may explain several problems important in today societies. However, little is known about developmental aspects of self-control during life-span. Yet, it is visible that consistent body of research creates a promising platform for future studies on overcoming self-control failures in the area of substance use, eating habits and other problematic consumer behaviors, including impulsive buying.

Control and shopping behaviors

In Western societies a lot of people may decide what they want to buy and eat. People are alluring by thousands type of foodstuffs offering in diverse environments created by more or less inventive marketing specialists. Choices and decisions about "buy or not to buy" demands self-control efforts, however its processes run sometimes ineffectively, as noticed by Faber and Vohs [2004].

The authors analyzed so-called ‘impulse buying’ in regard to the strength self-control model. On the one hand, the term *impulse buying* is referring to any unplanned purchase indicating that a consumer’s buying decision was prompted mainly by the specific features of the product or by the special store attributes and its milieu. On the other hand, the impulsive purchase may be affected by a strong desire to buy and inefficient cognitive control in overwhelming such a strong temptation. Baumeister, Heatherton and Tice [2000] wrote that the majority of impulsive buyers does not have problem with self-regulation. That problem occurs when some buyers consecutively spend more money that they posses or buy goods which they entirely do not need, in fact.

Psychologists tested body weight, food deprivation, food priming, and proximity as determinants of impulsive shopping. As Faber and Vohs [2004] underlined, desires are influencing by the proximity. Desires more often lead to purchase while they are engaging one’s sensory system: smell (baking cookie in the restaurant), touch (fresh big apple given at hand), or taste (mini-coffee cup offered at the supermarket). This may explain why so many well-know cooks (like Magda Gessler in Poland in one popular TV program) insist on direct cooking just in front of restaurant guests. According to Faber and Vohs [*op. cit.*], experiencing an

item increases the purchase. Thus, many companies add easy-to-use free samples directly in shops, together with newspapers, during visits at hair-dresser etc. This sort of endeavors may function as specific item priming which makes future purchase more probable. The proximity makes the purchase even easier when consumers (particularly children) move toward or stay physically closer to the desired objects, being less able to delay gratification connected with buying (or eating) the item. This explains why buyers who have to wait in line in the shop may get more goods including sweets that they had previously been planned.

The next factor, food deprivation, has dissimilar impact on purchase depending on buyer's body weight. Baumeister, Heatherton and Tice [2000] cite interesting data collected in 1969 by Nisbett and Kanouse, who directly asked clients in a supermarket when they last ate to calculate deprivation measure. They also asked clients how much they expect to spend that time on shopping. The body weight of each interviewed individual was then categorized. On the next stage, the real spending was checking-out and compared with previous expectations to estimate impulsive buying factor. The results showed that food deprivation had no effect on obese buyers, because overweighed clients bought fewer foodstuffs while being hungry. People with normal weight were influenced by the increasing impulse buying and bought more foodstuffs when they were hungry.

Taking the obtained results into account, Steinberg and Yalch [1978] conducted another field study in this area. They offered free food sample and observed consumers natural reactions in a supermarket. The researchers revealed that consuming free food sample differently affected market purchase of obese and normal weight individuals (in spite of one more result demonstrating that the specific sample used in the study increased sale of other products in the tested supermarket). People with normal weight who took and consumed the sample while being hungry were not affected by food. Probably, the eaten sample satisfied their hunger. However, overweighed individuals slightly more were engaged in purchase than they previously planned after taking and consuming the offered food trial. Probably, those shoppers were more susceptible to product taste which prompted them to exert their effort to get more food.

Concluding, contemporary approaches in the area self-control theory and research made much of contribution to the understanding buying behaviors and purchasing decisions. On the one hand, self-control is the ability which is helpful in making appropriate choices and realized one's needs and goals. On the other hand however, the well-established examples of impulsive buying revealed the darker side of self-control failures.

Conclusions and practical implications

The aim of this paper was to make an attempt to integrating latest research investigated the relation between personality and consumer behavior. The gathering data revealed that there are traits (e.g. narcissism), individual differences (e.g. trait self-control) or personality factors (e.g. extraversion or sensation seeking) which are predictors of problematic consumption or substance use.

Research on self-control failures resulted from depleted volitional resource are especially distinctive in this field, because they precisely explain the interplay between external demands (e.g. temptation) and individual abilities (e.g. cognitive action). On the one hand, some investigations underlined the adaptive value of human executive function important for goal-directed behavior. On the other hand, the self-control theory and research interestingly explained why people are getting involved in unhealthy or problematic behaviors.

Summarizing, the rich body of evidence revealed comprehensive relationships between self-related phenomena, biological make-up and consumer behaviors suggesting that the outcomes might especially be valuable for health behavior change specialists. Visibly, segmentation of personality profiles should be considered in future interventions. However, more insight should be gain into studying young consumer behaviors in the light of their self-control capacities.

References

Baumeister R.F., 2004. Wyczerpywanie się ego i funkcja wykonawcza Ja, [in:] A. Tesser, R.B. Felson, J.M. Suls (red.), Ja i tożsamość. Perspektywa psychologiczna. Gdańsk: GWP.

Baumeister R.F., Bratslavsky E., Muraven M., Tice D.M., 1998. Ego-depletion: Is the active self a limited resource? Journal of Personality and Social Psychology, 74, 1252–1265.

Baumeister R.F., Heatherton T.F., Tice D.M., 2000. Utrata kontroli. Jak i dlaczego tracimy zdolność samoregulacji. PARPA, Warszawa.

Besser A., Priel B., 2010. Grandiose narcissism versus vulnerable narcissism in threatening situations: Emotional reactions to achievement failure and interpersonal rejection. Journal of Social and Clinical Psychology, 874–902.

Bruin de G.J., Brug J., and Lente F.J., 2009. Neuroticism, conscientiousness and fruit consumption: Exploring mediator and moderator effects in the theory of planned behaviour. Psychology and Health, 9, 1051–1069.

Diagnostic and Statistical Manual, 2000. Fourth Edition, Text Revision: DSM-IV-TR. American Psychiatric Association. Washington, DC.

Faber R.J., Vohs K.D., 2004. To buy or not to buy? Self-control and self-regulatory failure in purchase behaviour. [in:] Handbook of self-regulation. New York, The Guilford Press, 509–524.

Freud S., 1920/2000. Poza zasadą przyjemności. Warszawa.

Gailliot M.T., Baumeister R.F., DeWall N.C., Maner J.K., Plant A.E., Tice D.M., 2007. Self-control relies on glucose as a limited energy source: Willpower is more than a metaphor. Journal of Personality and Social Psychology, 92, 325–336.

Tesser A., Felson R.B., Suls J.M., 2004 (red.), Ja i tożsamość. Perspektywa psychologiczna. Gdańsk, GWP.

Gailliot M.T., Hildebrandt T., Eckel L.A., and Baumeister R.F., 2010. A theory of limited metabolic energy and premenstrual syndrome symptoms: Increased metabolic demands during the luteal phase divert metabolic resources from and impair self-control. Review of General Psychology, 3, 269–282.

Gearhardt A.N., and Corbin W.R., 2010. Body mass index and alcoholconsumption: Family history of alcoholism as a moderator. Psychology of Addictive Behaviors, 2, 216–225.

Levitan R.D., and Davis C., 2010. Emotions and eating behaviour: Implications for the current obesity epidemic. University of Toronto Quarterly, 2, 783–799.

Hofmann W., and Friese M., 2008. Impulses got the better of me: Alcohol moderates the influence of the impulsive vs. reflective system on eating behavior. Journal of Abnormal Psychology, 117, 420–427.

Houben K., 2011. Overcoming the urge to splurge: Influencing eating behavior by manipulating inhibitory control. Journal of Behavior Therapy and Experimental Psychiatry, 3, 384–388.

Hoyle R.H., 2006. Personality and self-regulation: Trait and information-processing perspectives. Journal of Personality, 74, 1507–1525.

Kofta M. i Doliński D., 2003. Poznawcze podejście do osobowości. [in:] (red.), J. Strelau. Psychologia. Podręcznik akademicki. Psychologia ogólna. Gdańsk.

Millon T., Davis R., 2005. Zaburzenia osobowości we współczesnym świecie. Warszawa, Instytut Psychologii Zdrowia PTP.

Patrick M.A., Schulenberg J.E., O'Malley P.M., Maggs J.L., Kloska D.D., Johnston L.D., Bachman J.G., 2011. Age-related changes in reasons for using alcohol and marijuana from ages 18 to 30 in a national sample. Psychology of Addictive Behaviors, 2, 330–339.

Pervin L.A. 2002. Psychologia osobowości. Gdańsk, GWP.

Sieri S., Krogh V., Saieva C., Grobbee D.E., Bergmann M., Rohrmann S., Tjonneland A., Ferrari P., Chloptosis Y., Dilis V, Jenab M., Linseisen J., Wallstrom P., Johansson I., Chirlaque M.D., Sanchez M.J., Niravong M., Clavel-Chapelon F., Welch A.A., Allen N.E., Bueno-de-Mesquita H.B., van der Schouw Y.T., Sacerdote C., Panico S., Parr C., Braaten, T., Olsen, A., Jensen, M.D., Bingham, S.A., Riboli, E. and Slimani, N., 2009. Alcohol consumption patterns, diet and body weight in 10 European countries. European Journal of Clinical Nutrition, 63, 81–100.

Skeel R.L., Pilarski C., Pytlak K., Neudecker J., 2008. Personality and performance-based measures in the prediction of alcohol use. Psychology of Addictive Behaviors, 3, 402–409.

Steinberg S.A., Yalch R.F., 1978. When eating begets buying: The effects of food samples on obese and nonobese shoppers. The Journal of Consumer Research, 243–246.

Strelau J., 2003. Temperament.W:J. Strelau (red.), Psychologia. Podręcznik akademicki. Psychologia ogólna. Gdańsk: GWP, 683–719.

Stutts M.A., Zank G.M., Smith K.H., Williams S.A., 2011. Nutrition information and children's fast food menu choices. Journal of Consumer Affairs, 1, 52–86.

Sugarman D.E., DeMartini K.S., Carey K.B., 2009. Are women at greater risk? An examination of alcohol-related consequences and gender. The American Journal of Addictions, 18, 194–197.

Vaughn M.G., DeLisi M., Beaver K.M., Wright J.P., Howard M.O., 2007. Toward a psychopathology of self-control theory: the importance of narcissistic traits. Behavioral Sciences and the Law, 25, 803–821.

Yates W.R., Fulton A.I., Gabel J.M., Brass C.T., 1989. Personality risk factors for cocaine abuse. American Journal of Public Health, 79, 891–892.

2

ANALYSIS OF CONSUMER PREFERENCES FOR FOOD PRODUCTS AVAILABLE ON THE LOCAL MARKET

Introduction

Food products and they consumption are fundamental aspects of humanity development. Consumption needs are base of consumer behavior and determine demand for commodities and services.

Studies on the impact of different variables on the choice of food products showed that the most important factors for 74% of respondents were freshness and price (43%), sensory quality (38%), health (32%), and habits (29%). Increasingly, the respondents shall care for the safety and nutritive value of products, characterized by varying calorific value so that they could compose a diet according to their own wishes and habits. Also consumers looking for products available, convenient to prepare and easy to storage, suitable for freezing and temporary chill storage or durable at ambient temperature [Makała, Olkiewicz 2004, Wielewska 2004, Bartnikowska, Zawadzka 2002, Babicz-Zielińska 2000]. The potential customer before buying assesses the packaging form of foodstuff, its features, including the availability and usefulness, and on the basis of these characteristics forming own perception about a particular item. Unless the characteristics connected with form of product may decide, when making a purchase, once when the product is consumed its main palatability picks up strongly role in shaping the overall assessment. Among the sensory characteristics of taste and smell will serve a key role in the acceptance of the product in question and the evolution of consumer preferences [Suwała 2000].

Analysis of consumers behavior on food market should take into consideration necessity of satisfy them physiological needs as well as other impulses influenced on decision process. Consumer's preferences had a great impact on making decision of purchase food products. Preferences were determined as a system of estimation and priorities, after which some products are estimating higher than others. They also illustrated relation between attitudes towards products from the same category. Knowledge about consumer preferences with reference to food products provide estimation of feeding habits and is useful in feeding education process. In addition, enables producers of food products to adjust the profile of production to consumer expectations, and thereby strengthen their market position [Górska-Warsewicz 2006, Jeżewska-Zychowicz 2004, Falkowski, Tyszka 2002, Babicz-Zielińska 2000, Rudnicki 2000, Urban 1999].

Changeability of factors which influenced on satisfaction and consumer preferences cause that the consumer has no fixed scale of preferences in relation to a particular range of goods. Some preferences are constant in time, other changed under the influence of mood or

environment. The evolution of preferences may impact other factors such as socioeconomic status, age, gender, environment cultural, family, religion, the patterns learned from childhood, the impact of fashion and advertising, and many others [Nieżurawska 2002, Gawęcki, 2000]. On the choice decision of food products in addition to the factors listed below also had an effect a context (situation resulted from location and time), customs and coincidences in which product is consumed. Physiological determinants are important features in shaping consumer preferences [Babicz-Zielińska 2000].

Food companies are obligated to carry out appropriate market analyses to recognize and meet with continually rising consumer requirements. Food market is a very specific subject of marketing researches and requires selection of appropriate marketing tools to obtain complete information about it.

Market analyses are based on marketing researches which are related to making accurate decision by companies. Marketing researches were determined by Kotler [2005] as methodical planning, collecting, analyzing and passing on data and information essential to marketing situation of companies. Through collected information these researches put together needs and expectations of consumer, public opinion and marketing manager operations. Marketing researches including following operations: the analysis of information necessities, selection and collection of variables, revising, analyzing and drawing conclusions which are useful to take right marketing decisions [Michalski 2009, Kędzior 2005, Mazurek-Łopacińska 2005, Gutkowska 2002, Churchill 2002]. The result of proper conducted marketing researches should be satisfaction and fulfillment of consumer expectations.

The dynamic development of marketing analyses is related to introducing more and more complicated research procedures and in these analyses we can observe a drift to connection they qualitative and quantitative aspects [Churchill 2002, Kędzior, Karcz 2001]. Currently most of food companies had individual division responsible for market analyses.

The objective of the study was to collect data related to consumer preferences in respect of food products available on the local market. Undertaken analysis provided knowledge about most popular groups of foodstuff, places, costs and frequency of purchase.

Material and methods

The research was conducted with the method of questionnaire. To identify any drawbacks that might have occurred while it elaborating the pilot study on 20 respondents was conducted. The survey was composed of three parts: first part included title and short instruction for respondents, essential part with 7 closed-ended questions and third part with questions about personal details of questioned (gender, age, education, social status, income, place of living, size of household). On the surveyed population contributed 302 residents of Lower Silesia more than 17 years old (164 women and 138 men). It was possible to mark several answers for some questions from this is follow the total number of given answers is higher than number of respondents.

Collected data were analyzed statistically using the chi square test (χ^2 test) and software Statistica v. 8.0.

Table 1

The profile of population

Gender	**Number of replies**	**[%]**
female	164	54.30
male	138	45.70
Age		
18–29	65	21.52
30–44	66	21.85
45–59	79	26.16
>59	92	30.46
Education		
elementary	8	2.65
occupational	56	18.54
secondary	131	43.38
higher	107	35.43
Social status		
student	26	8.61
blue-collar worker	56	18.54
white-collar worker	134	44.37
unemployed	19	6.29
retired	67	22.19
Average net income of household		
0–1 300,00 [zł]	75	24.83
1 300.01–2 500.00 [zł]	112	37.09
2 500.01–5 000.00 [zł]	90	29.80
>5 000.01 zł.	25	8.8
Place of residence		
city with up to 1000 inhabitants	49	16.23
city with 1001–15 000 inhabitants	64	21.19
city with 15 001–50 000 inhabitants	117	38.74
city with 50 001–100 000 inhabitants	15	4.97
city with more than 100 000 inhabitants	57	18.87
Size of household		
1–2	64	21.19
3	99	32.78
4	95	31.46
>4	44	14.57

Results and discussion

The profile of the population was presented in Tab. 1.

Majority of questioned was under 45 years old (43.47%), more than 60 years old was 30.46% of respondents and in age group from 45 to 59 years old was only 26.16%.

In respect of gender 54.30% from surveyed were women and 45.70% men (Tab. 2). Among women 63.04% was more than 59 years old. Men's under investigation represented all age groups in similar number (33 men of age from 18 to 29 and the same number of age from 30–44, and 34 more than 59 years old, respectively), with the exception of age group from 45 to 59 (38 men).

The conducted survey covered 43% respondents with secondary education, 35% with higher education, 19% of all respondents had occupational and 3% elementary education.

Among 302 respondents almost 44% were white-collar workers, 22% were retired, 19% were blue-collar workers and 9% were students. Only 6% of population was represented by unemployed people.

For most of surveyed average monthly net incomes were in range from 1300,01 zł. to 2500 zł. (37%), 30% earned monthly more than 2500 zł. and only 8% more than 5000 zł.

Decidedly most of questioned resided in locality with more than 15 000 and less than 50 000 inhabitants. Also most of them had a household consisted of 3 or 4 people (33% and 31%, respectively).

Table 2

Division on age groups

Age/gender	18–29		30–44		45–59		>60	
	no.	%	no.	%	no.	%	no.	%
Women	32	49.23	33	50.00	41	51.90	58	63.04
Men	33	50.77	33	50.00	38	48.10	34	36.96
Total	65	100.00	66	100.00	79	100.00	92	100.00

Table 3

Analysis of dependences by testing with chi square test

Dependence	χ^2 counted	df	critical χ^2 ($p \leq 0,05$)
children x age	175.71	3	7.81
children x education	15.12	3	7.81
children x income	10.80	3	7.81
children x place of living	64.7	4	9.49
age of children x gender	10.73	3	7.81

Analyses of data enclosed in Tab. 3. demonstrated that age, education, income and place of living were influenced on the size of family. Together with age increasing number of respondents with children. Also group of population with secondary and higher education had children. Most rarely had they respondents, which declared the highest monthly incomes. Similar situation was observed in group of surveyed resided in big city (more than 100 000 residents).

Table 4

Analysis of dependences by testing with chi square test

Dependence	χ^2 counted	df	critical χ^2 ($p \leq 0,05$)
frequency of purchase x gender	18.77	3	7.81
frequency of purchase x education	23.28	9	16.92
groups of food products x age	54.38	21	32.77
place of purchase x gender	10.17	4	9.49
place of purchase x age	40.51	12	21.03
sweets purchase x age	29.19	18	28.87

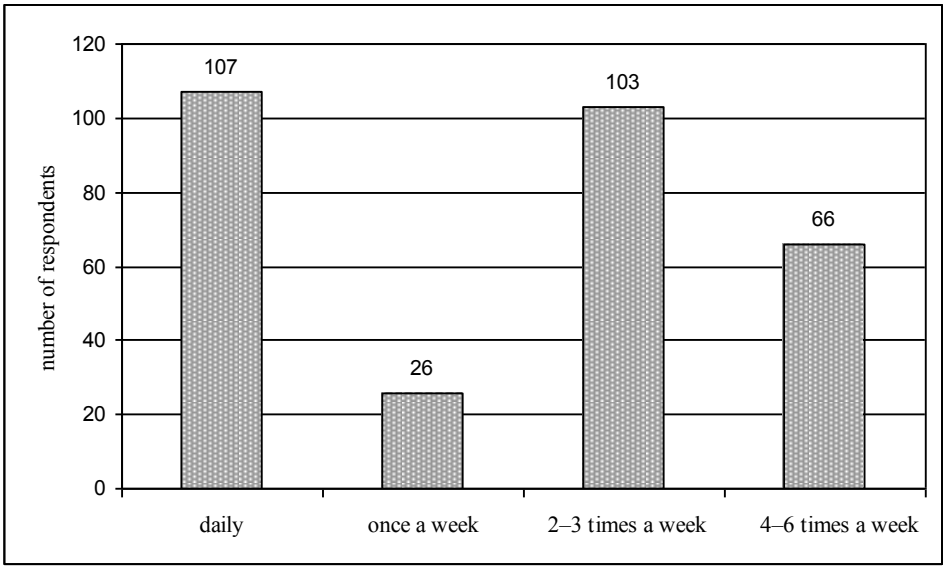


Fig.1. Frequency of purchase food products

In conducted survey an essential part consisted of 7 closed-ended questions related to consumer's purchase habits, i.e. frequency, place of purchase and usually buying groups of food products.

The aim of the first question included in questionnaire was to eliminate respondents who had never purchased food products. Most of interviewee appeared to buy foodstuff daily (this answer marked 35.43% of them) or 2–3 times a week (34.11%). Only ever twelfth asked person declared to do shopping once a week (Fig. 1). In this study gender was the main factor affected frequency of purchase (Tab. 4). This relationship was observed also in researches conducted in 2008 by CBOS (Polish Public Opinion Research Center). In accordance with that report women definitely more frequently doing shopping. At the same time men three times more often declared that they never purchased food products (http://www.cbos.pl).

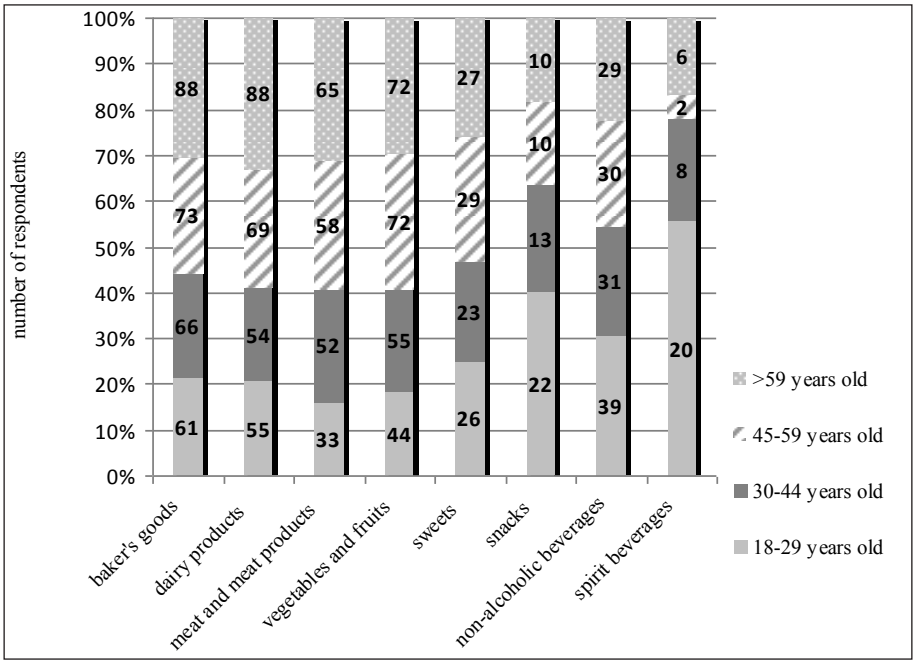


Fig. 2. Frequency of purchase a particular groups of food products

The frequency of purchase particular groups of food products was presented on Fig. 2. The most frequently purchased group of food products were baker's goods. Among 302 respondents 288 people indicated this group as purchased every time when they doing shopping. Apart from bread the most popular groups of products were: dairy, vegetables and fruits also processed meat products. Respectively 88.08%, 80.46% and 68.78% of questioned declared to buy these products. Snacks and spirit beverages were purchased most rarely. The level of spirit beverages consumption is similar to data collected by IPSOS. These beverages are often drinking between meals what confirmed researches conducted in Canada and USA. Proportion in purchased groups of food products are related in some degree to feeding habits of consumers. In most of Polish households bread is very popular product. Baker's goods are buying every day cause of their short shelf live and taste, which is the best when bread is fresh. The high retail of dairy products is probably connected with increased milk production and low prices of milk in Poland and on global market. Strong position of vegetables and especially fruits was confirmed in conducted studies. In according to analysis of answers given in the survey fruits are willingly buying and consuming between meals as a light snacks. Researches carried out by agency IPSOS in last three years pointed that 97% of Polish people eat meat and according to data collected by GUS 20% of meat was purchased as processed meat products (http://www.ipsos.pl, http://www.stat.gov.pl). In relation to these data meat and meat products were included in list of most frequently purchased groups of products by respondents under investigation. According to data placed in Concise Statistical Yearbook of Poland [2010] average monthly consumption of selected foodstuffs in households presented quite different. Related to this data the highest consumption in 2009 was observed in case

of dairy products and vegetables (13 kg and 10.28 kg per capita, respectively). The amount of consumed meat, dairy products and baker's goods was on similar level (5.55 kg, 5.17 kg, 4.85 kg per capita, respectively).

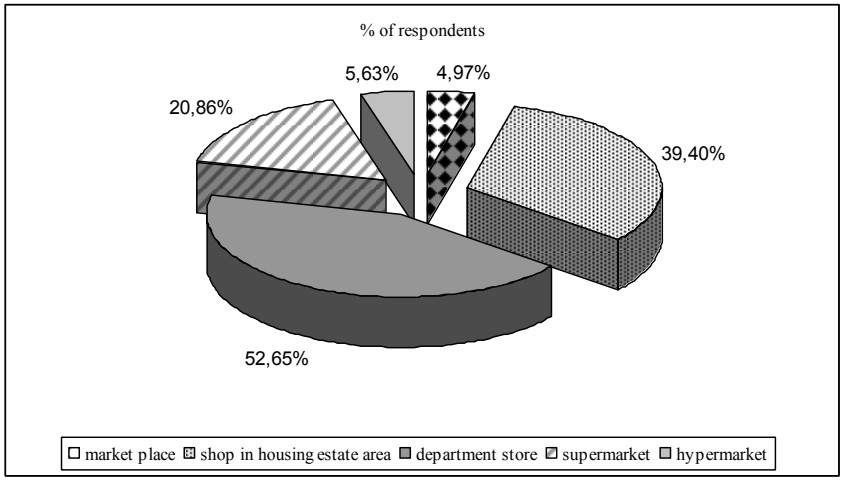


Fig. 3. Place of purchase

Analysis results of collected data testing with chi square test (Tab. 4) showed that selection and purchase of particular food products were strictly related to consumer's age. In example the youngest group of respondents (18–29 years old) definitely more often than other age groups purchased snacks and beverages. The oldies group of questioned consumed more frequently baker's goods, dairy products also meat and processed meat products. Surprisingly sweets were most popular group of purchased food products among respondents at the age of 45–59 years.

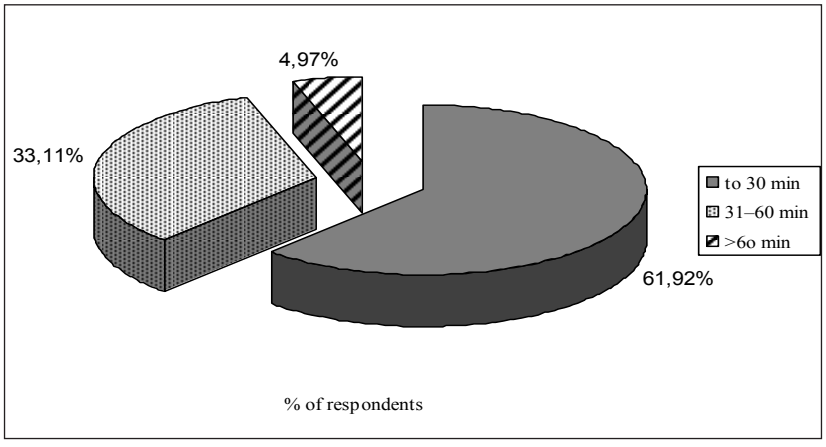


Fig. 4. Time intended by consumers for purchases

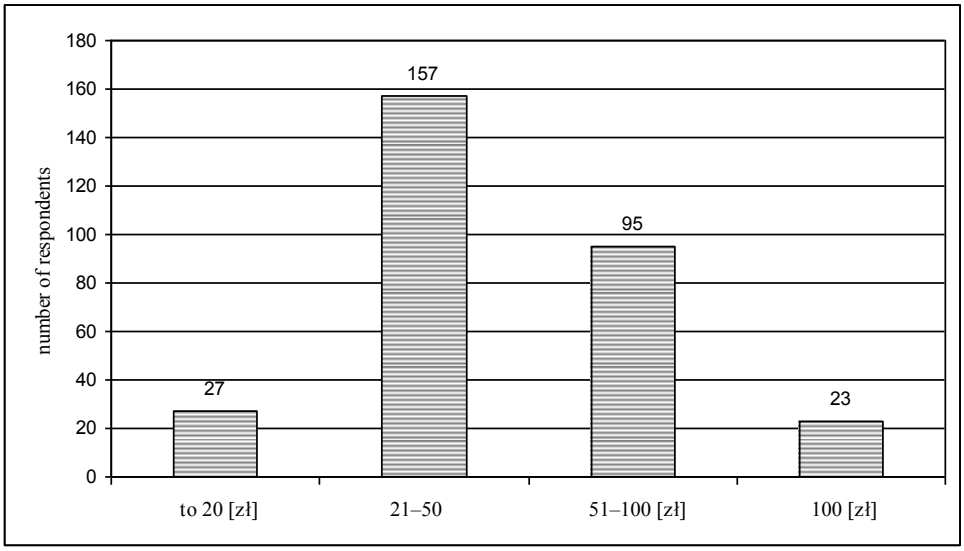


Fig. 5. Average once expenditures on food products

On the making purchase decision process by consumers the strong influence had a place of products distribution [Rudnicki 2002]. In recently years have changed popularity of places where Polish people supplied with food products. Significantly increased importance of supermarkets, although consumers still willingly visiting small shops especially situated near place of living [Babicz-Zielińska et al. 2000, http://www.cbos.pl]. Consumers have some reflection about particular retail places that's way some products willingly purchased in supermarket and others prefer to buy on market places [Rudnicki, 2002]. In conducted survey respondents marked department store (52.65%) and shops in housing estate area (39.40%) as most frequent places of buying groceries. Most rarely place of purchase were market place (4.97%) and hypermarket (5.63%) (Fig. 3). In Poland traditional retail trade is still the most popular place of purchase cause of its localization near consumer's place of living [Rudnicki 2002, Richterova 2002, Plichta 2002]. According to data collected by CBOS in 2008 54% of questioned going shopping to supermarket, in compare 11 years ago did the same only 19% of community. In conducted survey gender and age had influenced on decision about place of shopping. Men more frequently than women did shopping in hypermarket. Most of women prefer purchases in small shops situated near place of living. Hypermarkets were more often visited by young people in age 18 to 29 years.

The time intended by consumers for purchases is usually depending on the frequency of doing shopping. Most of respondents supplied with food products daily or 4 to 6 times a week (all 50%). Consumers which buying groceries every day intended the least time for them than these which go shopping once a week. Almost 69% of respondents spent to 30 min daily doing shopping, only 5% doing them longer than one hour (Fig. 4).

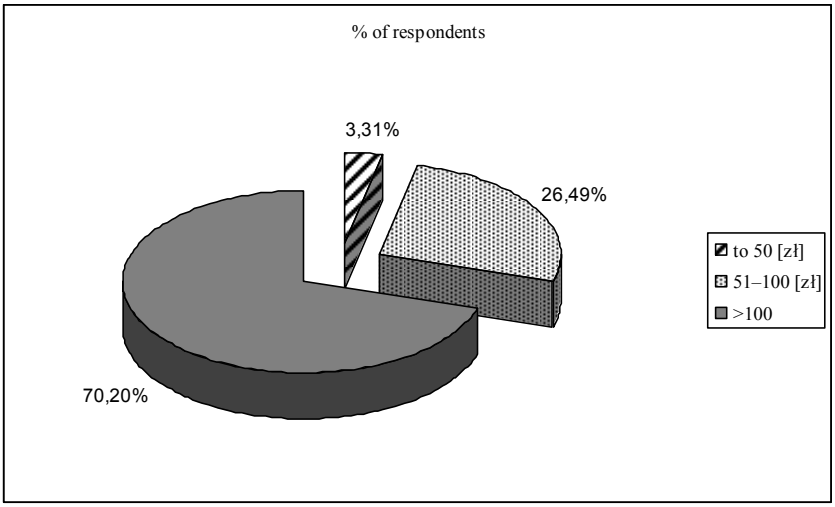


Fig. 6. Average weekly expenditures on food products

When asked about expenses most of respondents (52%) declared to intended once for food average from 21 to 50 zł., purely 8.95% tried to not expend more than 20 zł. for them. More than 70% of questioned intended for buying foodstuff more than 100 zł. a week (Fig. 5, 6). According to data presented by GUS [Concise Statistical Yearbook of Poland 2010] average household in 2009 expended monthly 25.1% of income (per capita) on food and non-alcoholic beverages. On the second place in households budgets situated expenses on hose, water, electricity, gas and other fuels (19.7%). And on the third place were transport (9%) and recreation counted with culture (8.0%).

Conclusions

1. The conducted survey enabled to collect valuable data and essential knowledge about consumer's preferences for food products available on local market.

2. According to studies, gender and age, determine consumer preferences – purchase frequency and place of their making.

3. Most of respondents under investigation appeared to buy food products daily or 2–3 times a week, only ever twelfth asked person declared to do shopping once a week.

4. Analysis of replies proved that gender was the main factor affected frequency of purchase.

5. The most frequently purchased group of food products were baker's goods. Apart from bread the most popular groups of products were: dairy, vegetables and fruits also processed meat products. Snacks and spirit beverages were purchased most rarely.

6. Analysis of collected data showed that selection and purchase of particular food products were strictly related to consumer's age.

7. The conducted research confirmed that the most popular place of purchase is still traditional retail trade for example department stores and small shops situated in housing estate area.

8. Most of respondents supplied with food products daily or 4 to 6 times a week and most of questioned spent to 30 min daily doing shopping. Average weekly expenditures for most of asked people came to more than 100 zł.

References

Babicz-Zielińska E., 2000. Konsument żywności i jego zachowania rynkowe. Wyd. SGGW, Warszawa.

Bartnikowska E., Zawadzka K., 2002. Nowe produkty mięsne. Cz. I. Opracowanie i wprowadzenie na rynek. Przem. Spoż., 8, 62–92.

Churchill A.G., 2002. Badania marketingowe Podstawy metodologiczne. Wyd. Nauk. PWN, Warszawa.

Concise Statistical Yearbook of Poland 2010. Mały Rocznik Statystyczny Polski 2010. Główny Urząd Statystyczny, Warszawa, Rok LIII.

Falkowski A., Tyszka T., 2002. Psychologia zachowań konsumenckich. Gdańskie Wyd. Psychologiczne, Gdańsk.

Gawęcki J., 2000. Wybrane fizjologiczne uwarunkowania zachowania konsumentów żywności, Konsument żywności i jego zachowania rynkowe. Ogólnopol. Konf. Nauk. 12–13. 10. 2000, Warszawa 2000, 300–306.

Górska-Warsewicz H., 2006. Strategie marek mleczarskich. Przegl. Mlecz., 4, 34–35.

Gutkowska K., 2002. Badania marketingowe na rynku żywności. Wyd. SGGW, Warszawa.

Jeżewska-Zychowicz Z., 2004. Wpływ preferencji na konsumpcję mleka i przetworów mlecznych wśród młodzieży. Acta Technologia Alimentaria, 3, 171–182.

Kędzior Z., 2005. Badania rynku, metody zastosowania. PWE, Warszawa.

Kędzior Z., Karcz K., 2001. Badania marketingowe w praktyce. PWE, Warszawa, 61–134.

Kotler P., 2005. Marketing. Dom Wydawniczy Rebis, Poznań, 160–186.

Mazurek-Łopacińska K., 2005. Badania marketingowe: teoria i praktyka. Wyd. Nauk. PWN, Warszawa.

Makała H., Olkiewicz M., 2004. Zasady opracowywania nowych produktów z uwzględnieniem oczekiwań konsumentów, na przykładzie mięsa i jego przetworów. Żywność. Nauka. Technologia. Jakość., 1 (38), 11, 120–134.

Michalski E., 2009. Marketing. Podręcznik Akademicki. Wyd. Nauk. PWN, Warszawa.

Nieżurawska M., 2002. Jakość żywności a preferencje konsumentów. Przegl. Piek. Cuk., 7, 8–9.

Plichta G., 2002. Czynniki wpływające na wybór wielko powierzchniowych obiektów handlowych na miejsce zakupów. Zeszyty Naukowe AE w Krakowie, 605, 135–151.

Richterova K., 2002. Badanie zachowania nabywców w punkcie sprzedaży detalicznej. Zaszyty Naukowe AE w Krakowie, 581, 73–80.

Rudnicki L., 2000. Zachowania konsumentów na rynku. Wyd. AE, Kraków, 21–32.

Rudnicki L., 2002. Miejsce sprzedaży jako czynnik kształtujący zachowania konsumentów. Zeszyty Naukowe AE w Krakowie, 579, 49–57.

Suwała G., 2000. Analiza czynników determinujących konsumenckie decyzje zakupu na przykładzie soków owocowych. Konsument żywności i jego zachowania rynkowe. Ogólnopol. Konf. Nauk. 12–13.10.2000, Warszawa, 454–459.

Wielewska I., 2004. Wymagania jakościowe konsumentów żywności w świetle badań. Rocz. Nauk. SERiA, t. VI z. 2, Warszawa Poznań Puławy, 330–334.

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3

THE ROLE OF FOOD PRODUCT LABELING IN SHAPING CONSUMER CHOICES AND NUTRITIONAL KNOWLEDGE

Introduction

Although health considerations play an important role in shaping consumer attitudes and behaviors, the efforts to demonstrate the correlation between diet and health and the attempts to improve consumers' nutritional habits often fail to bring the desired results. The consumers' eating habits are difficult to change even with the help of educational programs, nonetheless, continued exposure to various forms of nutritional education over long periods of time could significantly raise the level of consumer awareness [Ares et al. 2008].

Packaging labels are among the most important tools that convey nutritional information to consumers. From the point of view of consumer education, nutrition facts are a vital source of information about product type, a product's attributes, list of ingredients, best before/durable life date, nutritional value, etc. Label information enables consumers to make well-informed choices by comparing similar products. It also assists shoppers in choosing optimum products that will contribute to a well-balanced diet. Label reading skills and the ability to interpret nutritional information and symbols are becoming increasingly important on the contemporary market. Educational campaigns, preceded by an evaluation of the consumers' existing level of knowledge, are needed to enable consumers to optimize their nutritional habits with the help of label information [Wansink et al. 2004].

The objective of this paper was to determine the extent to which the information printed on food packaging is appealing and comprehensible to consumers, and whether and which types of information affect the consumers' nutritional awareness.

The study consisted of focus group interviews, a method that is increasingly often used in qualitative research. Interviews are conducted in small respondent groups, and they focus on a specific topic. The aim of the study was to elicit a controlled discussion between group members. The discussion was led by a moderator who had a sound knowledge of the object and purpose of the study.

Group interviews may account for the entire body of the study or they may support the interpretation of survey results. Analyses of the type often take place before survey research to develop questionnaires and interpret the results of statistical surveys. In this study, focused group interviews were also carried out prior to quantitative surveys, and their findings supported questionnaire development and result analyses.

Materials and Methods

Qualitative consumer research was carried out in the first half of 2010[1]. The research cycle comprised the following phases: sample selection, development of the script for group interviews and other research instruments, interviews, analysis and interpretation of the results.The described study was a focus group interview. Group members attended an hourly interview in the conference room of the Faculty of Food Sciences at the University of Warmia and Mazury in Olsztyn. Interviews were recorded on a digital sound recording device at the participants' consent. A total of three group interviews were held with the involvement of Olsztyn residents. The respondents were recruited through advertisements placed in all student dormitories in Olsztyn as well as in several randomly-chosen companies in Olsztyn. The candidates contacted the researchers by telephone. The persons who took part in the survey were consumers responsible for household food shopping, aged 18 and over. The candidates had to give their informed consent to participate in the survey.

The interview script featured the following sections:

1. Introduction to the subject of the survey;
2. An implicit association test involving various types of food and nutritional information important for consumers;
3. A test evaluating the participants' perception of product packaging as a carrier of information intended for consumers;
4. A test evaluating the participants' perception of nutritional information, nutrition and health claims on food packaging as features supporting consumer education.

Respondent profiles

The first interview was carried out in a group of six women aged 18 to 24. They were students who have chosen the following majors at the University of Warmia and Mazury in Olsztyn: management, administration, education, environmental protection, international relations and biology. The second group comprised six men aged 18 to 24. They were students who have chosen the following majors at the University of Warmia and Mazury in Olsztyn: veterinary medicine, agriculture, animal bioengineering, mathematics and computer science, technical sciences and geodesy. The third group involved ten respondents: five men and five women aged 24 to 55. This group was inclusive of: bank employees, graduate students, a penitentiary employee, a veterinary inspection employee, self-employed persons and power company employees. This group was most differentiated as regards the respondents' financial status and education.

The majority of respondents were open persons characterized by a high level of interpersonal communication skills and the ease of articulating their thoughts. Difficult respondents were not encountered in any of the surveyed groups. Two gender-specific groups and one mixed group were used in the experiment to determine how the gender factor affects group integration and interactions between group members.

1 This study was financed from a research grant of the Ministry of Science and Higher Education covering 2008–2012.

It should be noted that qualitative surveys involving focus group interviews cannot be analyzed in terms of a statistically significant sample. Interview results support the development of questionnaires for quantitative surveys, and they enable researchers to evaluate differences in opinion within groups and to identify extreme opinions.

Results and Discussion

Perception of various types of nutritional messages

Contemporary consumers can look to various sources of information on food and nutrition. The content and the comprehensibility of the conveyed information varies. The respondents in each of the three groups were asked to list the sources of health and nutritional information that they were familiar with. Most respondents pointed to: television and radio advertisements, topical television and radio programs, the Internet, print media, advertising leaflets, advice from family and friends, and food product packaging. The members of the male student group also suggested the advice of nutritional experts, while the respondents in the mixed group pointed to nutrition books and guides. The majority of female students claimed to search for nutritional information in the Internet, print media and television. For the male students, the Internet was the main source of information on healthy nutrition and food products. According to all respondents, food packaging was the most comprehensive and the most accessible source of information for consumers.

The results of our qualitative study cannot be used to draw valid conclusions for the general population, nonetheless, they are similar to the findings of a quantitative survey carried out by the European Consumers' Organization (BEUC) in 2005 across five European countries: Germany, Denmark, Spain, Hungary and Poland. According to the BEUC study, the main sources of food and nutritional information for consumers in the surveyed countries were: television, print media, advice of family and friends, product labels and packaging [Report of European… 2005]. In 1996, the Institute of European Food Studies carried out a pan-European survey of consumer attitudes to determine that television, radio, print media, health professional. food packaging, family and friends are considered to be the prime sources of nutritional information. In all EU Member States, the above sources were used equally often, although the hierarchy of their importance for consumers was difficult to determine. In Belgium, France, Greece and Portugal, consumers were most likely to rely on the information provided by health professional. while the key source of food information in the remaining countries was TV and radio. In Italy and Spain, the list was topped by both electronic media and health professionals (www.eufic.org).

In the opinion of female students and members of the mixed group, product packaging was the most reliable source of information, while TV advertisements were seen as the least reliable source. The male student group vested less trust in the information printed on product packaging. Some members of that group claimed that the presence of organic food symbols, health and nutritional claims and the recommendations of health institutions on product packaging increased their trust in this information source. The surveyed students pointed to physicians, nutrition professional. friends and relatives as the most reliable sources of nutritional information.

Some members of the society have no interest in information on the nutritional value of products and the health benefits of a balanced diet, while others expect such information for reasons of health [Jeżewska-Zychowicz 1997, McIntosh 2008]. As demonstrated by the results of our study, consumers search for nutritional information for a variety of reasons. Members of the first and the second student group argued that many consumers needed nutritional knowledge for health reasons. Members of the mixed group, in particular women, claimed that consumers searched for food information for reasons of personal and family health and to maintain healthy body weight. Mixed group participants were in agreement that women made most food purchase decisions in the household, therefore, their needs were very important in the choice-making process. A well-balanced diet for the consumer and the entire family was suggested as the main choice criterion.

Research results confirm that consumers begin to take greater interest in nutrition when they are forced to change their eating habits due to health problems [Jarosz et al. 2003, Williams 2005]. A similar opinion was voiced by the participants in our study who claimed that people suffering from health problems, such as food allergies or intolerances, were more likely to search for information about the product's composition and its potential allergenic effects, in particular on the packaging.

Product packaging as a carrier of information for consumers

Packaging is a special carrier of information intended for consumers. It supports product identification and distinction, and it contains instructions and recommendations for use. Packaging is often the only source of product information, therefore the displayed data have to clearly inform consumers about the product's composition, nutritional value or health risks [Czarnecka-Skubina, Janicki 2009].

When asked to indicate all known types of information displayed on product packaging and food labels, the respondents listed nearly all obligatory data, i.e. the product's name, the manufacturer, list of ingredients, brand name, best before/durable life date, net weight and nutritional value. Members of the mixed group also pointed to the terms of storage, instructions for use, organic food symbols and quality marks. Although price is not an integral part of packaging and it is not a food labeling requirement, it was mentioned by respondents from both student groups. Price was not a factor enumerated by the members of the mixed group.

Female students declared that from among all indicated types of information, they were most likely to pay attention to the product's best before/durable life date, followed by the brand name, list of ingredients, nutritional value and the price. According male students, in addition to the product's best before/durable life date, list of ingredients, nutritional value and price, they also checked the information on the product's weight and the manufacturer. Similar responses were obtained during an interview with the mixed group, except for the information about the product's price. The noted difference can be probably attributed to students' lower financial standing in comparison with the respondents who were part of the workforce. In most cases, students have limited budgets, therefore they pay more attention to the price of the products they buy. The above observation has been validated by a TNS OBOP (Center for Public Opinion Research) survey of 2003 which showed that the higher the respondents' financial standing, the less attention they paid to the price of daily purchases [TNS OBOP 2003].

The results of a quantitative survey commissioned in 2005 by the BEUC to investigate consumer perceptions of foodstuffs labeling suggest that similarly to European consum-

ers, Polish shoppers pay most attention to the product's price, best before/durable life date, net weight and brand name [Report of European… 2005]. Similar results were reported in a survey carried out by the Department of Dairy Science and Quality Management, Faculty of Food Sciences at the University of Warmia and Mazury in Olsztyn which demonstrated that consumers had the greatest interest in the following information displayed on the packaging: best before/durable life date, brand name, the product's composition and nutritional value [Staniewska et al. 2008].

When inquired about the circumstances in which they read the information displayed on the packaging of food products, the respondents from every interviewed group claimed to read it in the shop and at home when preparing a meal or consuming the purchased product. The place and circumstances in which the respondents read label information were determined by the type of product and the type of information. The members of all three groups declared that they always paid attention to the product's best before/durable life date in the shop, and most respondents claimed to examine the list of the product's ingredients and nutrition facts at home after making the purchase. The respondents from the male student group also noted that they read most of the information displayed on the packaging when buying a given product for the first time. As regards familiar and regularly purchased products, they focused solely on the item's best before/durable life date.

The respondents were asked to write down the types of labeling information that they considered to be important on packaging prepared especially for the needs of the survey. They were also asked to arrange the listed factors in a descending order from the most to the least important factors. A comparison of the lists compiled by the members of all three groups indicates that the packaging labeled by female students was most deficient in information, whereas male students and mixed-group respondents listed a variety of factors that they considered to be important for consumers. All respondents placed the product's name and net weight on the front of the package. The members of the mixed group and the male student group also marked the front of the packaging with the manufacturer's logo or the brand name and, in some cases, a graphic logo. Two members of the male student group displayed promotional slogans, while one member of that group indicated the price on the packaging. The majority of respondents placed the best before/durable life date in the top part of the package near the opening end. Two respondents from the mixed group displayed the above information on the front of the packaging, whereas three male students placed it on the side wall of the package. Nearly all surveyed respondents placed the list of ingredients on the side of the package. Nutrition fact tables were included on the package by all members of the second group, but they were not accounted for by one female student and three members of the mixed group. Nutrition fact tables were displayed on the side wall of the package. In six product packages designed by respondents from all groups, nutritional information and the list of ingredients were displayed in the same field of vision. The manufacturer's details were not present on three packs designed by one member of each respondent group. The above information was also placed on the side of the pack. Three male students also displayed bar codes on the side wall of the packaging. Product quality marks were placed on three packs designed by mixed group members and two packs developed by male students.

The respondents then arranged the selected types information in a descending order from the most to the least important data for consumers (Table 1). Both student groups focused on the price, whereas members of the mixed group pointed to the product's name as the most important attribute. According to groups 1 and 3, the best before/durable life date was

the second most important type of label information, but it was regarded as only the fourth most significant factor in the second group of respondents who paid more attention to the product's nutritional value, list of ingredients and the manufacturer's details. In the group of female students, the brand name, the product's net weight and list of ingredients constituted more important label information that nutrition facts. Similarly to the members of the male student group, the respondents from the mixed group were of the opinion that the list of ingredients was an important attribute, and nutritional value was given only the fifth place. The product's net weight and quality marks were regarded as less important types of information, although their significance was recognized by some participants.

Table 1

Hierarchy of information displayed on the packaging of food products
from the most to the least important types of information intended for consumers

No.	Group I Female students	Group II Male students	Group III Mixed group
1	Price	Price	Product's name
2	Best before/ durable life date	Nutritional value	Best before/durable life date
3	Brand name	List of ingredients	List of ingredients
4	Net weight	Manufacturer	Manufacturer
5	List of ingredients	Best before/durable life date	Nutritional value
6	Nutritional value	Quality marks	Net weight
7	Other information	Other information	Other information

The significance of various types of label information in the process of shaping consumer perceptions of food products

In the last part of the survey, the respondents were asked to formulate their opinions about the commercial packaging of fruit juice, fruit nectars and drinks of different flavors, brands and shapes, etc., with special emphasis on the displayed label information. The respondents' first choice were popular and renowned brands, i.e. higher priced products.

The respondents from all three groups agreed that the font size of the displayed information was too smal. making the labels difficult to read despite the large size of the package. According to all surveyed subjects, some packages were characterized by overstated graphic design which effectively captured the consumers' attention but detracted from the legibility of the presented information. Group 1 respondents observed that selected fruit juice packs featured excessive information, such as the manufacturer's details in several languages, which reduced the space available to information that was more vital from the consumer's point of view. Female students and members of the mixed group negatively reviewed the packaging of products with sophisticated names that did not suggest the type of product they contained. According to mixed group respondents, fruit juice packaging should feature a graphic representation of the fruit from which the juice was made, indicating the product's flavor. Male students attached the greatest importance to simple labels, legible information, clear ingredient lists and nutrition fact tables. In their opinion, juice packaging should have attractive design that captures the consumer's attention.

The respondents' expectations toward the packaging of food products are taken into account in the process of developing food and nutrition legislation. The legislators emphasize the need for clear label information that is comprehensible to consumers. Product labeling

norms list the requirements relating to font size, font type and color contrast [Regulstion… Journal of Laws No. 171, item 1225, www.pfpz.pl]. The above particularly applies to products in small unit packaging which is often labeled in several languages and features small font size that decreases the legibility of label information. The best before/durable life date is often difficult to decipher as it is printed on the heat-sealed edge of the package or in a poorly visible location. Manufacturers should account for those difficulties when designing the packaging of the supplied products [Wierzejska 2006].

Conclusions

The results of this study suggest that consumers rely on the following sources of food and nutritional information: food advertisements, television, the Internet, printed media, advertising leaflets, friends and family. According to the majority of respondents from all three surveyed groups, packaging labels are the most comprehensive and the most reliable source of nutritional information for consumers. Health problems are an important motivator which encourages consumers to read nutritional information and make well-informed purchase choices. According to the polled subjects, product packaging is a highly effective carrier of vital nutritional information. In addition to the price, the respondents attached the greatest importance to the product's best before/durable life date, brand name, list of ingredients and nutritional value. All survey participants were of the opinion that label information was presented in font size that was too small and illegible for many consumers.

The findings of this study were consistent with the results of a quantitative statistical survey [Panfil-Kuncewicz 2010] in more than 90%.

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References

Ares G., Giménez A., Gámbaro A., 2008. Influence of nutritional knowledge on perceived healthiness and willingness to try functional foods. Appetite, nr 51, 663–668.

Brug J., Debie, S., van Assema P., Weijts W., 1994. Psychosocial determinants of fruit and vegetable consumption among adults: results of focus group interviews. Food Qual. Prefer., nr 6, 99–107.

Czarniecka-Skubina S., Janicki A., 2009. Znakowanie produktów żywnościowych. Informacje żywieniowe i zdrowotne. Przem. Spoż., nr 1, 34–37.

Dransfield E., Morrot G., Martin J.-F., Ngapo T. M., 2004. The application of a text clustering statiscal analysis to aid the interpretation of focus group interviews. Food Qual. Prefer., nr 15, 477–488.

Jarosz A., Kozłowska-Wojciechowska M., Uramowska-Żyto B., 2003. Oczekiwania konsumentów wobec informacji umieszczonej na opakowaniach produktów spożywczych. Rocz. PZH , nr 54 (2), 23 –239.

Jeżewska-Zychowicz M., 1997. Źródła wiedzy żywieniowej w opinii wybranej grupy kobiet. Żywienie Człowieka i Metabolizm, nr 24 (3), 293–303.
Jędruszek B., 2010. Zogniskowane wywiady grupowe jako metoda badania satysfakcji klienta. [w:] Wybrane aspekty zarządzania jakością II. Red. Salerno-Kochana M. Wydawnictwo AGH Kraków.
Kaczmarczyk S., 2002. Badania marketingowe. Metody i techniki. Polskie Wydawnictwo Ekonomiczne Warszawa.
Macintosh H., 2008. Marketing uwzględniający różnice w zwyczajach żywieniowych kobiet i mężczyzn. Przem. Spoż., nr 1, 30–31.
Polish Federation of Food Industry (PFPZ), 2010. http://www.pfpz.pl.
Report of European Consumers Perseption of Foodstuffs Labelling. 2005. Results of Consumer Research conducted on behalf of BEUC.
Panfil-Kuncewicz H., 2010. Badania nad znakowaniem produktów spożywczych w aspekcie bezpieczeństwa konsumentów oraz kształtowania ich wiedzy o odżywianiu. Nr N 312306135.
Staniewska K., Panfil-Kuncewicz, H., Staniewski B., 2008. Information and promotion function of unit packages of dairy products in consumers opinion. Pol. J. of Natural Sci., nr 23(3), 718–728.
The Europen Food Information Council (EUFOC), 2010. http://www.eufic.org/article/pl/artid/consumer-attitudes-food-nutrition-health/03.
TNS OBOP, 2003. Zakupy po polsku 1. Co wpływa na wybór klienta?
Ustawa z dnia 25 sierpnia 2006 r. o bezpieczeństwie żywności i żywienia, Dz. U. Nr 171, poz. 1225.
Wansink B., Sonka S.T., Hasler C.M., 2004. Front – label health claims: when less is more. Food Policy, nr 29, 659–667
Wierzejska R., 2006. Nowe wymagania w znakowaniu żywności. Przem. Spoż., 2, 34–37, 44.
Williams P., 2005. Consumer understanding and use of health claims for foods. Nutr. Rev., nr 63 (7) 256–264.

4

VALIDATION OF THE LABELING OF MEAT AND MEAT PRODUCTS DISTRIBUTED BY A NETWORK OF WHOLESALERS

Food Labelling

All food products introduced to the market in unit- and collective packaging, as well as without any packaging whatsoever, must be properly labelled. This should be the task either for the product's manufacturer or the person introducing the product to the market – e.g. the marketer.

Information included on the product's label specifies its durability and storage conditions, helping the marketer in managing the product and allowing the proper identification of both the product and its manufacturer.

Aside from satisfying the requirements of the law, the main aim of the food labelling process is to simplify the decision-making process for the customer, so that he/she may buy the product which suits his/her needs. Proper labelling – i.e. the one, which does not mislead the consumer – constitutes the basis of the consumer information, which in turn is a vital factor in food quality assurance.

The provisions of the Act on General Product Safety of 12 December 2003 [Dziennik Ustaw no. 229, item 2275] stipulate that the responsibility for the product shall be borne by either the manufacturer or the person introducing the product to the market, as a part of his/her business activities, in addition to providing the consumers with the information concerning the product. As for the marketer, he/she shall participate, in the scope of his/her business activities, in the monitoring of the safety of the products introduced to the market. In accordance with the provisions of the Act, the product safety includes also the get-up and labelling of the product. This means that both the manufacturer and the marketer are responsible for the proper labelling of the product.

In case of violation of the Polish and European Food Law, the Inspectors of the Food Authority are entitled to impose a fine, or even the penalty of restriction of liberty or the penalty of deprivation of liberty, on both the manufacturer and the marketer. Depending on the proven non-compliance, the manufacturers and marketers of food products may be obliged to pay a fine, amounting from PLN 200 to 100 000.

The labelling process is governed in detail by the following legal documents: Directive 2000/13/EC of the European Parliament and of the Council of 20 March 2000 on the approximation relating to the labelling, presentation and advertising of foodstuffs [Official Journal of Laws no. L109 of 6 May 2002], Act on Food and Nutrition Safety of 25 August 2006 [Dziennik Ustaw no. 171 of 2006 *item* 1225], Act on the Commercial Quality of the Agricultural and Food Products of 21 December 2000 [Dziennik Ustaw no. 187, *item* 1577],

Ordinance of the Minister of Agriculture and Rural Development on Marking of Foods and Allowed Additions [Dziennik Ustaw no. 135 *item* 966 of 10 July 2007], Act on General Product Safety of 12 December 2003 [Dziennik Ustaw 229 item 2275] et. al.

Aim and Scope of the Research

Aim of the Reserch

The aim of the following evaluation was to assess the labelling procedures applied with regards to the products distributed via a nationwide network of meat warehouses. The evaluation process was designed to assess whether these procedures meet the standards specified in provisions regarding labelling, applicable both in Poland and on the territory of European Union.

The following questions were asked:

- Whether the vendors of the warehouse network label their products in accordance with the binding provisions of law?
- What information is missing on the product labels?
- Will the marketer and the consumer be able to obtain information necessary in order to use the product safely by studying the label?
- Is there any difference in the correctness of labelling between different vendor groups?
- Are all offered products properly labelled?

Scope of the Studies

The assessment included all vendors supplying the warehouse network with the following product groups: cold meats, meat, frozen food, ready-to-cook foods, canned foods, etc. The labels of 6 randomly chosen products were verified with regard to the correctness of legally required information. The correctness of additional information was also verified.

Vendors were immediately informed about any non-compliances via written notice.

Materials and Methods

Test Samples

Test samples consisted of labels from products distributed by the warehouse network and delivered by vendors. The sampling was conducted on the basis of random selection. The total number of 646 products was assessed on the basis of this research. These products belonged to the following groups: red meat, poultry meat, frozen food, cold meats (incl. smoked meats, coarse- and fine-minced sausages, homogenized sausages, formed meats, pork jellies), canned foods, ready-to-cook foods, etc. al. The aim of the research was to assess 6 different products of each company; however the companies tended to provide the researchers with a smaller number of products. In some cases, the number of different products available in a given warehouse was smaller than 6. As a result, the number of assessed products was smaller than it was initially established. On average, 4 product labels of each company participating in the evaluation were assessed.

Research Methods

The following check-list, designed to assess the conformity of labelling applied to the products distributed by the warehouse network, was drawn on the basis of information presented in the Polish and European legal acts, regarding the labelling of food products. Labels were assessed on the basis of 16 different criteria. For each criterion, a number of points ranging from 0 (incorrect labelling) to 5 (correct labelling) was awarded. Every non-compliance with the binding law resulted in the loss of points. Table 1 illustrates in detail the rules, according to which the points were granted.

Table 1

Rules regarding the product check-list

No.	Check-list Criterion	Information Regarding the Grade Scale
1	2	3
1.	Product Name	full name (5 pts.), partial name (3/1 pts.), depending on the clarity of provided information), no name (0 pts.)
2.	Actual Presence of the Label	Yes/No – in cases where the label was missing, a note on the infringement of provisions concerning the labelling of food products was made
3.	Nutrient Contents	full content, no abbreviations, full names of ingredients, in case of functional contents – information on their kind, e. g. stabilizers, preservatives, pigments, antioxidants, etc. (5 pts.), use of abbreviations and/or lack of information on the kind of functional ingredients (3 pts.), use of abbreviations, lack of information about the functional ingredients (1 pt.) lack of any information (0 pts.)
4.	Use-by Date	full date – i.e. day, month, year (5 pts.), impartial date – month, year/ month, day (1 pt./such format is correct in case of tinned products, which means that 5 pts. were awarded), lack of use-by date (0 pts.)
5.	Net Weight	accurate weight of the product, including decimal. preceded by the phrase "net weight", or the number of pieces, if the product is sold by the piece (5 pts.), accurate weight (5 pts.), accurate weight not preceded by the phrase "net weight" (3 pts.), lack of any information about weight (0 pts.)
6.	Information Identifying the Manufacturer	manufacturer's name (5 pkt.), no information about the manufacturer (0 pts.)
7.	Storage Conditions	storage temperature is preceded by the phrase "best keep in the temperature of" or any similar phrase (5 pts.), storage temperature is not preceded by the phrase "best keep in the temperature of" or any similar phrase (3 pts.), lack of any information about storage temperature (0 pts.)
8.	Place or Source of Origin	exact address (5 pkt.), partial address, e. g. the name or the number of the street is missing (3 pts.), lack of any information regarding address
9.	Batch Number	if included (5 pts.), if lacking (0 pkt.)
10.	Trade Quality Class	if included (5 pts.), if lacking (0 pkt.), this information is treated as additional.
11.	Allergens	list of allergens preceded by the information that the product in question contains allergens (5 pts.), list of allergens without any information that these substances are allergens (3 pts.), lack of any information (0 pts.)

Table 1 cont.

1	2	3
12.	Veterinary Sign	proper veterinary sign included on the label consisting of the following annotations: PL, eight digits, EC (in case of regional/domestic goods, this annotations should not be included) (5 pts.), sign included, but not entirely correct (1 pts.), lack of any signs (0 pts.)
13.	Nutritional Value	information on the energy content (kcal/100 g), protein (g/kcal per 100 g), fats (g/kcal per 100 g), carbohydrates (g/kcal per 100 g) is included on the label (5 pts.), only the information about the energy content per 100 g is included on the label (1 pt.), lack of any information regarding nutritional value (0 pts.), the information mentioned above is not legally required, however can be very useful for the customer, therefore its inclusion was awarded with additional points
14.	Other Information	information concerning packaging methods (5 pts.), lack of any additional information (1pt.). No 0 points were awarded, since lack of additional information is not contrary to the regulations in force
15.	State of Packaging	whole, clean, undamaged, legible and undamaged label (5 pts.); damaged, dirty, legible and undamaged label (1 pt.); damaged, dirty, illegible and/or damaged label (0 pts.)
16.	Notes	All non-compliances in labelling of a given product were entered in this area. The same applies to all particularly favourable remarks regarding given product

(Source: own work)

Each product could receive up to 70 points. Scoring was accompanied by descriptive assessment, dependent on the percentage degree in which labelling met the requirements. The details concerning the grade scale are illustrated by the means of table 2.

Table 2

Grade scale used to assess labels

Range of Points	**Degree in which the Requirements Were Met**	**Descriptive Assessment**
70–63 pts.	100–91%	EXEMPLARY
62–56 pts.	90–81%	VERY GOOD
55–49 pkt.	80–71%	GOOD
48–42 pts.	70–61%	AVERAGE
41–35 pts.	60–51%	POOR
<34 pts.	<50%	VERY POOR

(Source: own work)

The following results were devised on the basis of popular statistical methods, by using Microsoft Excel 2007 worksheet. For the total number of assessed labels, as well as for the manufacturer groups created on the basis on the basis of product categories and the size of deliveries, both the average value and the percentage were calculated.

Results and Discussion

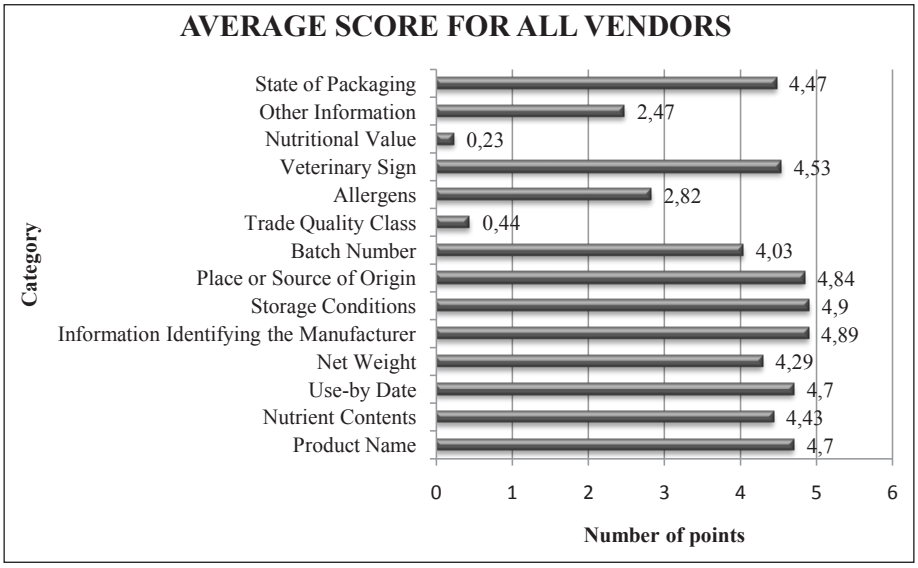
The total number of 188 companies was qualified to participate in the evaluation. This amount consisted of all vendors who during the three-month preceding period delivered goods at least once to at least one warehouse. Evaluation of labelling was conducted on the total number of 150 companies, which makes up about 80% of the network's associates. The researchers failed to evaluate the labelling in case of 20% of vendors (i.e. 39 companies). The reason behind this is the fact that at the time of the evaluation, no products supplied by these companies were available in warehouses.

The labelling of products distributed by the warehouse network was assessed by the employees of Quality Assurance and trained apprentices. The total number of people involved in the assessment process equalled 9.

The last stage of research had the researchers informing the vendors of the research results, in order to initiate changes in labelling procedures, so that their products may fulfil legal requirements regarding labelling and provide the consumer with information facilitating the decision-making process, as well as so that the vendors may avoid fines for improper labelling levied by the Official Food Control. A notice form was created and filled on the basis of check-list.

Evaluation of Labels

Labels were assessed on the basis of a previously prepared check-list. A total number of points ranging from 0 to 5 were awarded to each criterion. The criteria and the average score for all assessed products were described by the means of the graph presented below.



Graph.1. Average score for all vendors *Source: Own work*

As shown on the graph, the highest number of points, i.e. 4.9 out of 5, was awarded for information about storage conditions. The information about storage temperature, units in which the temperature was measured, as well as a statement about the temperature range being part of information about storage conditions were all properly included on the label. Non-compliances concerned mostly the lack of information about the temperature range suitable for storing the product.

Another category, for which a significant number of points was awarded – meaning that information were properly included on the label – were **Information Identifying the Manufacturer**. The average number of points awarded for this criterion was 4.98. The information, i.e. name of the manufacturer or the full name of the company, as well as its exact address, including postal number and the number of the street, were properly included on the majority of inspected labels.

The third categoy for which a considerable number of points was awarded (4.84), was the information regarding **place or source of origin**, present on almost every assessed label.

For the correct inclusion of the product name, an average number of 4.7 points was awarded. Points were subtracted for the use of abbreviations (e.g. "K-holenderska z serem P" – "Dutch s. with m. cheese", instead of "Dutch sausage with mouldy cheese").

One of the non-compliances that appeared repeatedly were inaccuracies in the **Use-by Date**, which should be preceded by the phrase "Należy spożyć do:" ("Use by:"). This phrase was often replaced by similar phrases, such us: "Najlepiej spożyć do" ("Best use by"), "Spożyć do" ("Use before") or "Należy spożyć przed" ("Best use until"). In case of frozen foods, an expiry date, preceded by the phrase "Najlepiej spożyć przed" ("Best – before") or "Najlepiej spożyć przed końcem" ("Best before end"). The average number of awarded for this information was 4.96.

It is obligatory to include the **manufacturer's identifying veterinary number (Veterinary Sign)** on all animal food products, as well as those products whose main ingredients are products of animal origin. Such facilities should be supervised by the Veterinary Inspectorate. Each facility should also have its own veterinary number. The average number of points awarded for this information was 4.52. In some cases, companies did not include the veterinary sign on their products' labels, even though they own such sign. Another common non-compliance was the incorrect form of the sign. One of the companies manufacturing ready-to-cook foods deserves a special mention here, for including two separate veterinary signs – each of them of different shape and with different number – on the label of their product named "Galareta drobiowa" ("Chicken Jelly").

For the **state of packaging,** the average number of 4.47 points was awarded. The scope of this category included tightness of packaging, how the label was attached, as well as the label's legibility.

Non-compliances regarding information on **nutrient contents** were in most cases limited to the use of abbreviations, such as "wp" ("p.") instead of "wieprzowe" ("pork") and/or lack of information about the percentage of meat ingredients. Additionally, some of the labels did not contain the information on nutrient contents at all. The average number of points awarded for the inclusion of this information was 4.43.

In case of **net weight**, one of the most common non-compliances was the inclusion of the information regarding the weight preceded by the word "Weight" instead of "Net Weight". Lack of information about the units in which the actual weight was measured was another

non-compliance that occurred frequently. The average number of points awarded for this information was 4.29.

Some of the labels did not include **the batch number**. In some cases, the actual number was not preceded by any statement identifying it as being the batch number. The average number of points awarded for this information was 4.02.

The low number of points was also awarded in case of **information on allergens** (2.81 points) and **other information** (2.47 points). Most non-compliances consisted in the fact that the allergens included the product were named in the list of its contents, however the label did not include the phrase "this product contains allergens". In some cases, the label contained information that the product contains trace amounts of different substances that can cause an allergy, however no information that these substances are allergens was included. Therefore, most of the manufacturers were awarded with 3 points for information on allergens. Additional information consisted mostly of information on the packaging methods: dry packing, modified atmosphere packaging, information on the methods of preparing the product for consumption (which are vital in case of raw and frozen products), such as "spożyć po obróbce termicznej" ("to be consumed after cooking"). In case of frozen foods, it is vital to inform the consumer that "the product should not be re-frozen after defrosting" and that it is the "deep-freeze product".

The lowest amount of points was awarded for the information on the **trade quality class** (0.44 points) and **nutritional value** (0.23 points). Non-compliances related to the nutritional value were in most cases connected with the fact that the manufacturer included only product's energy value, with the exclusion of information on the protein, fat, hydrocarbons and monosaccharide content, or the information on the calorific value per 100 g of product's weight, which is non-compliant with the Ordinance on Marking Foods with Nutritional Value. The low number of points awarded in this category may also be the result of these information being treated as additional, i.e. there is no provision of law stating that these information should be included on the label, the only exception being meat. In this case, the label should at least contain the information on the trade quality class.

Evaluation of the Suppliers

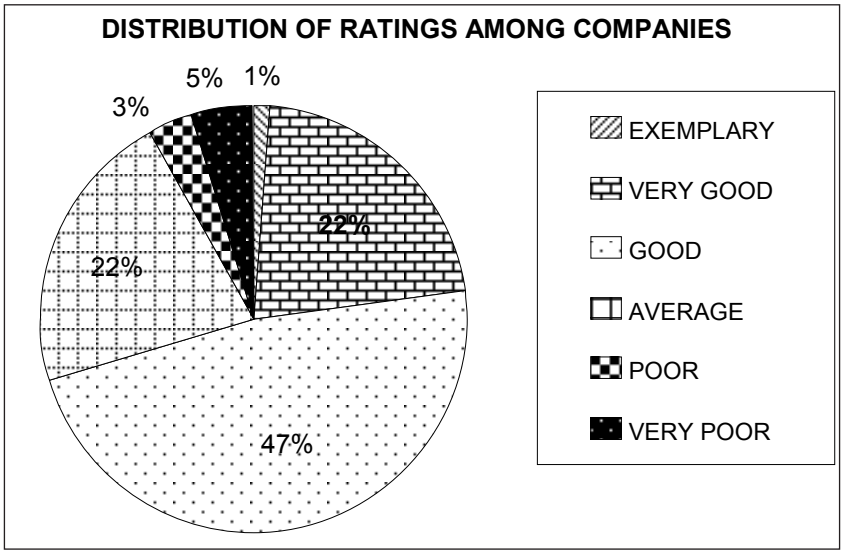
According to the research methodology established by the Quality Assurance, the majority of companies whose products are distributed by the warehouse network mark their products in a proper fashion and in accordance with the provisions of the Food Law. On the basis of the points awarded for each assessed product, an average score for each vendor was calculated. The maximum number of points for each assessed label was 70, while the minimum number was equal 0 points. On the basis of the score, a descriptive assessment was drawn.

General Evaluation

During the research, only two companies were awarded with the maximum number of points, meaning that the labelling of their products was assessed as "exemplary". The products of these companies constitute 1.35% of all evaluated products. The research results described below show that in most cases, the companies which participated in the research mark their products correctly. The total percentage of 68.91% of companies (i.e. 102 manu-

facturers) received either "good" or "very good" ratings, meaning that their labelling procedures are compatible with the Polish and European law on labelling.

The percentage distribution of particular ratings among the companies, whose labelling procedures were evaluated, is presented by the means of graph 2.



Graph. 2. Percentage distribution of ratings among companies *Source: Own work*

About 22% of the companies (i.e. 30 manufacturers) fits in the "average" category, which means that the labelling of their products contains some non-compliances, in addition to the included information being not always correct or complete, e.g. using the word "Weight" instead of "Net Weight" or supplying information about the net weight of the product without any information on the units in which the weight was measured. However, no drastic non-compliances or violations of law were noted.

About 8% of the companies (i.e. 13 manufacturers) received either "poor" or "very poor" ratings, as a result of many non-compliances noted on the labels. The product labels of these companies contain numerous non-compliances and often lack many basic information. The vendors of the red meat are the ones that have been noted to label their products most incorrectly. In case of four manufacturers, a drastic violation of provisions concerning the labelling of products was noted, meaning that there were no labels on the products.

Evaluation on the Basis of Delivery Size

The vendors were also divided into groups, basing on the size of their deliveries. Three groups – large vendors, medium vendors and small vendors – were created, according to size of deliveries in the three-month period preceding the research. The classification of vendors according to the size of their deliveries, established by the Quality Assurance, does not refer to the size of the company, but to the size of its deliveries. Group 1 (large vendors) consists of companies, which in the period preceding the research have delivered the largest amounts of products (the size of deliveries was measured in kilograms). Group 2 consists of

companies delivering average amounts of products, while Group 3 consists of vendors, who delivered the smallest amounts of products to the warehouse network. Based on this division, there were no explicit differences between the separate groups. The results are shown via the means of table 3.

Table 3

Average number of points and median with the division on the basis of delivery size

	Large	Medium	Small	Total
Average Label Score	**53.62** / [56,6]	**50.33** / [52,4]	**50.06** / [48,6]	**51.34** / [52,64]

(Source: Own work)

On the basis of the average score of large, medium and small vendors, as presented in Table 3, the highest number of points was awarded to large vendors (53.62 points), then medium vendors (50.33 points) and finally, small vendors (50.06 points). In case of nation-wide vendors, the opposite tendency was noted: small companies were awarded with the highest number of points (54 points), then the medium vendors (53.36) and finally, large vendors (50.81 points).

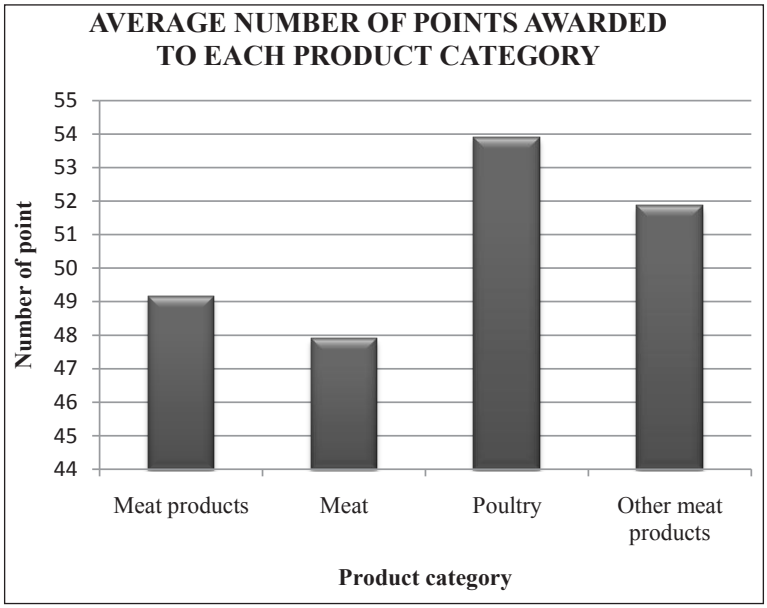
Evaluation on the Basis of Product Categories

The labelling of specific product categories by their vendors was also assessed during the research.

Lists of companies, whose product range includes cold meats, were drawn for the purposes of calculations. The total number of points available for the cold meats vendors was established by adding up average scores of the companies mentioned above and then calculating the average value on the basis of the results. In case of other products, i.e. meat, poultry, as well as "other meat products" category, the same method was applied. Thus, the following results were obtained: the food product categories where the labelling standards were highest, were poultry – the average number of points awarded in this category is 53.88 – and other meat products – 51.83 points. Meat products were on the third position, with the average number of points being 49.14. The labelling standards in these three categories were rated as "good". Meat was the product category where the lowest average number of points was awarded – 47.88, average rating. The average number of points awarded on the basis of check-lists to specific product categories was presented by the means of graph 3.

A notice about the research, detected non-compliances and possible legal actions on the part of the Official Food Control was send to the manufacturers of incorrectly labelled products. In order to avoid possible fines, the Quality Assessment division of the warehouse network recommended correcting the non-compliances on labels and adjusting the product marking to the requirements of the food law, in addition to declaring the will to clarify any doubts.

Responses from vendors served as a basis for the lists of remedial actions, which the vendors declared to undertake. Majority of vendors who responded to said notices agreed with their contents and declared adjusting the labelling of their products, so that it conforms to the requirements of the Food Law.



Graph 3. Average number of points awarded to each product category (*Source: Own work)*

After receiving the responses, another evaluation of labelling was carried out, in order to assess whether the labels were corrected according to the suggestions of the warehouse network's Quality division.

Table 4

The number of notices send to vendors and the number of responses received

Vendors	Number of notices send	Number of responses received	Number of companies that introduced changes in labelling	Number of companies that did not	Percentage of companies that introduced changes in labelling
Total	145	51	35	67	24.14%

(Source: Own work)

On the basis of responses received from vendors, it can be deduced that the vendors were heavily interested in labelling evaluation, which can be proven by a number critical responses, suggesting that the hints send by the Quality Assurance have been analysed. The majority of vendors declared that they will take received notices into account and introduce changes in the labelling system, so that it is in accordance with the requirements of the food law.

Conclusions

On the basis of the research, the following conclusions have been reached:

- The majority of the warehouse network vendors label their products in accordance with the binding provisions of Food Law.
- The information that was included on the lowest number of assessed labels was the product's nutritional value, as well as other additional information.
- Both the consumer and the marketer will be able to find information necessary to use the product safely – i.e. storage conditions, information regarding the product's manufacturer, product's name and use-by date – on the majority of assessed products.
- There are no discernable differences between large, medium and small vendors in the labelling correctness.
- There are distinct differences in the labelling of different product groups. Poultry products are labelled in the most correct manner, followed by other products and cold meats. Red meat labelling was found to be most incorrect.

References

Directive 2000/13/EC of the European Parliament and of the Council of 20 March 2000 on the approximation relating to the labelling, presentation and advertising of foodstuffs (Official Journal of Laws no. L109 of 6 May 2002).

Gawęcki J., Wagner W., 1984. Podstawy metodologii badań doświadczalnych w nauce o żywieniu i żywności, PWN, Poznań.

Łomnicki A., 2005. Wprowadzenie do statystyki dla przyrodników. Polskie Wydawnictwo Naukowe PWN, Warsaw.

Evaluation of the Sanitary Conditions in the Mazowieckie Province. Provincial Sanitary and Epidemiological Station in Warsaw.

Evaluation of the Sanitary and Hygienic Conditions and Epidemiological Situation in the Capital City of Warsaw in the Year 2006, June 2007. Regional Sanitary and Epidemiological Station in Warsaw, Warsaw.

Ozimek I., 2006. Bezpieczeństwo żywności w aspekcie ochrony konsumenta w Polsce. Wydawnictwo SGGW, Warsaw.

The Consumer's Situation on the Food Market, Basing on the Inspection of Diary, Meat, Fish and Honey Products. Warsaw, December 2009

Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin. OJ L 139, 30.04.2004.

Regulation (EC) No 1760/2000 of the European Parliament and of the Council of 17 July 2000 establishing a system for the identification and registration of bovine animals and regarding the labelling of beef and beef products and repealing Council Regulation (EC) No 820/97. OJ L 204, 11.08.2000.

Commission Regulation (EC) No 543/2008 of 16 June 2008 laying down detailed rules for the application of Council Regulation (EC) No 1234/2007 as regards the marketing standards for poultrymeat. OJ L 157, 17.06.2008.

Ordinance of the Minister of Agriculture and Rural Development on Marking of Foods and Allowed Additions. Dziennik Ustaw no. 137, *item* 966 of 10 July 2007.

Ordinance of the Minister of Agriculture and Rural Development on Marking of Foods with Nutritional Value. Dziennik Ustaw no. 137, *item* 967 of 25 July 2007.
Ordinance of the Minister of Agriculture and Rural Development on the Amount of Fines Levied for the Violation of the Provisions of Law Regarding the Products of Animal Origin, Dziennik Ustaw no. 93, *item* 600 of 26 May 2010.
Sanitary Conditions in the Śląskie Province Regarding the Hygiene of Food, Nutrition and Items of Use. Provincial Sanitary and Epidemiological Station in Katowice.
Act on Food and Nutrition Safety of 25 August 2006. Dziennik Ustaw no. 171, *item* 1225.
Act on General Product Safety of 12 December 2003. Dziennik Ustaw no. 229, *item* 2275.
Act on the Commercial Quality of the Agricultural and Food Products of 21 December 2000. Dziennik Ustaw no. 187, *item* 1577.
Wieczorkowska G., Wierzbiński J., 2007. Statystyka. Analiza badań społecznych. Wydawnictwo Naukowe Scholar, Warsaw.

CHAPTER 2

QUALITY AND SENSORY PROPERTIES OF FOOD

1

QUALITY FUNCTION DEPLOYMENT AS A TOOL TO DEVELOP NEW PRODUCTS

Introduction

Quality Function Deployment is a tool used to plan the quality [Kleniewski 1995]. The key element in the development of QFD is the role of customer in product development [Hamrol 2008]. The main aim of this method is to translate clients' expectations into technical language. The method includes: market research, development study, invention, new concepts' design, testing of a prototype and final product, as well as after sale service [Kowalska 1995]. All of the above mentioned elements ensure the creation of high quality product in agreement with clients' expectations.

Quality Function Deployment enables to assess the general technical parameters of newly designed products or processes aiming to produce the individual elements of the product. Such an approach has a positive impact on product quality, which is very important especially for large companies with mass production of advanced technical products and limited direct contact with customer [Hamrol 2008].

The basic tool used in QFD method is a matrix called "the House of Quality". The success of this method depends on matrix construction.

QFD provides an opportunity to develop goods which are well adjusted to customers' needs. It assigns a platform of communication between product engineers and the clients. The customers determine the product attributes according to individual criteria and the constructors define the possibilities for product modification using a technical language. QFD aims to improve an understanding between the consumers and the engineers, which in practice is not so easy [Krzemień and Wodniak 2001].

QFD can be applied to develop new product as well as to improve an existing one [Karaszewski, 1999].

QFD method has been applied with great success in many industries such as: motor industry, ship industry, building engineering, but also in development of new services, software and computer systems.

The method is also a useful tool in developing food products. The application of QFD brings several advantages: increases chances of product success, helps to produce high quality products and decreases the cost and time of development phase [Benner et al. 2003]. All phases of product life cycle starting from concept phase to product liquidation has an impact on its quality [Borkowski, Kaczorowski 2005], however, an application of quality function deployment method for food products is very limited [Benner et. al. 2003].

A weak knowledge about QFD among food industry representatives results in small interest of its use. QFD is a complementary tool for other traditional techniques used in market research, such as survey which focuses only on identification of consumers' expectations

[Maleszka, Gałka 2005]. Use of ISO 9000:2000 standard which follows current trend and carefulness of marketing reputation results in low popularity of QFD method among Polish companies. Moreover, such an approach contributes to omission of many problems related to quality improvement. It happens because the companies use only the tools which are imposed by the stanards. An additional issue in application of QFD method together with ISO 9000 standard before 2000 was the design of the norm in which very little attention was paid to clients, their needs and means to satisfy the needs. The revision of the standard brought considerable changes; many attention was paid to attain the customers' satisfaction and the necessity to permanently monitor their changing expectations [Wolniak, Brzeszcz 2004].

The aim of this work was to specify the consumers' preferences and the factors affecting the process of decision making when purchasing tvarog, and to determine the possibility of QFD application to modify the traditional food product such as tvarog.

Methods

The study consisted of two stages:

1. Direct interview based on a survey questionnaire was conducted among 100 customers (76 women and 24 men) of one of the supermarkets in Olsztyn. Trial selection was random, based on typical customer image [Gutkowska, Ozimek 2002], which means that only tvarog consumers took part in a survey. The anonymous questionnaire included 12 questions related to the factors influencing consumers' choice when purchasing tvarog.
2. Construction of the House of Quality: based on the results obtained in first stage the detailed consumers' requirements and their preferences related to tvarog were determined. The construction of House of Quality proceeded according to the following phases:

I. Identification of consumers' requirements.
II. Determination of requirements importance
III. Translation of consumers' requirements into technical parameters of the product.
IV. Determination of correlation between requirements and technical parameters.
V. Evaluation of technical parameters importance.
VI. Determination of relationship between technical parameters (conflict analysis).
V.II Development of target values for technical parameters.
VIII. Difficulty rating.

Results and discussion

The tvarog cheeses' market is very diversified. The study helped to specify the consumers' expectations and how the producers can fulfill them.

Identification of consumers' requirements

The survey was targeted to the regular consumers of tvarog. It is very likely that people who know the product can easily specify their requirements toward it.

The demographic characteristic of the group was the following: 76 women and 24 men took part in the survey, as women are more often responsible for selection, purchase and

preparation of food products in a household. Most of the respondents were at the age of 45–65 for women (33% of women) and 25–34 for men (33% of men) (Table 1).

Table 1

Participation (%) of the respondents in the survey in respect to gender and age

Gender	**Age** below 18	**Age** 18–24	**Age** 25–34	**Age** 35–44	**Age** 45–65	**Age** over 65
Women	1	28	25	13	33	0
Men	0	29	33	13	21	4
Total	1	28	27	13	30	1

The majority of the respondents had secondary or higher education, 51 and 44% of the respondents, respectively (data not shown).

The attributes of the product, such as taste, price, availability, fat content, net weight of the product, best before date, and type of package were evaluated by the consumers using 7-point scal. where 1 meant least important and 7 most important (Fig. 1). 46% of the respondents claimed that taste was the most important parameter in decision making process during purchase of tvarog cheeses. Among others, best before date (24%), fat content (13%) and price (12%) were classified as factors influencing the selection of the product. Type of package had the least importance (41% of respondents gave note 1). In general, one can conclude that organoleptic features of food products are the most important parameters influencing decision during purchase process.

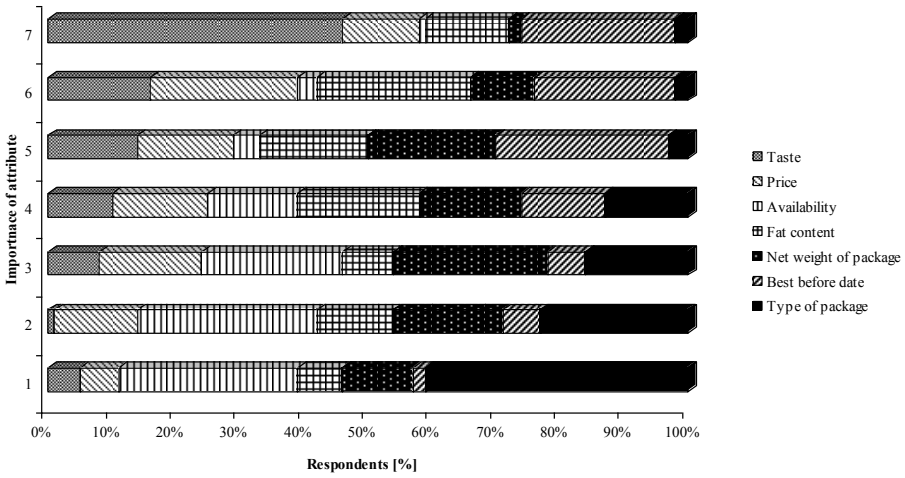


Fig. 1. The importance of tvarog cheese attributes for consumers
*7 – the most important attribute, 1 – the least important attribute

After identification of the most important product attributes the study was conducted so to determine the preferences of the consumers related to individual product features.

When asked about the taste the most preferable (29%) was slightly acid (Fig. 2), followed by natural taste (21%) and not acid (15%). Quite diversification of the answers resulted from an open character of this question. The answers with high degree of similarity (i.e. sweet and sweetish) were linked in one group. For tvarog cheeses slightly acid taste was mentioned as the best option, and according to the Polish standard PN-A-86300:1991 [Polish Standard, PN – A – 86300:1991] tvarog should have delicate, slightly acid taste with pasteurization flavour.

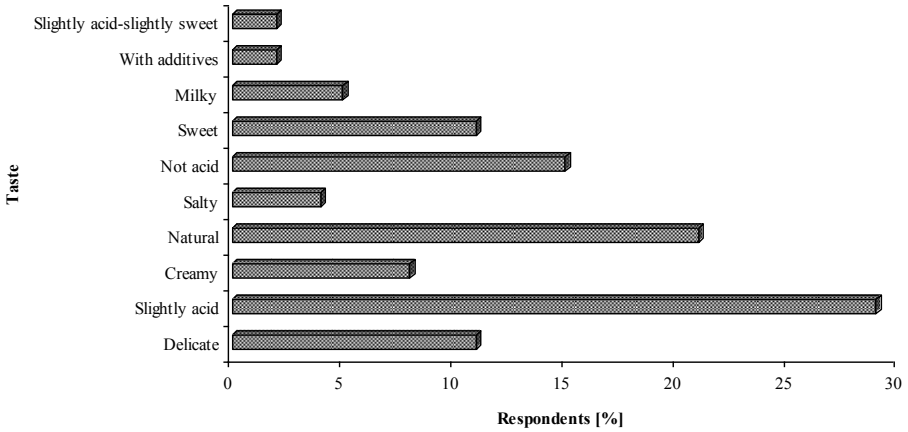


Fig. 2. Preferences of the consumers for taste.

Considering fat content, significantly higher number of respondents (82%) prefers semi-fat tvarog cheeses when compared to skim (11%) and fat (7%) products (Fig. 3). In terms of form in which tvarog is sold, 49% of respondents chose tvarog cut into cubes (so called "krajanka") (Fig. 3). Moreover, almost one third of this group (32%) was people at age in range 45–64. Traditional tvarog manufactured by small and medium dairies sold on local market was in form of "krajanka", probably old habits of 45–64-years-old consumers influenced their decision. Moulded tvarogs (‘wedge’ (so called klinek) and round shape) were preferred by 38% of consumers who took part in the survey, and milled tvarog (cheese cake type) by 13%. The retail of the later usually increases at holiday time (i.e. Christmas and Easter).

Price is a very important factor that has an impact on selection of food products. In current study, the consumers more often chose tvarog in smaller packages and at lower price. The acceptable price for the consumers was below 3 zł. and 3.50 to 4.50 zł. for 200 g tvarogs, 12 and 13% of respondents indicated these price ranges, respectively (Fig. 4). For 250 g products the preferred price was in range 3.50 to 4.50 zł., 34% of respondents was willing to pay such price (Fig. 4).

Also, the net weight of the product is one of the attributes that can influence the decision making process during purchase of tvarog. Most of the consumers (50%) indicated products with net weight of 250 g (Fig. 4). Small interest was toward bigger products (400 g and more). Due to relatively short best before date the consumers prefered to buy product in smaller package as the need arises. According to Central Statistical Office [2007] there is majority of 1-, 2- and 3-person households in Poland, and as the forecast shows this trend will

continue. The demand of smaller numerically households are much smaller than the bigger one, which can explain the preferences of the consumers toward smaller packages.

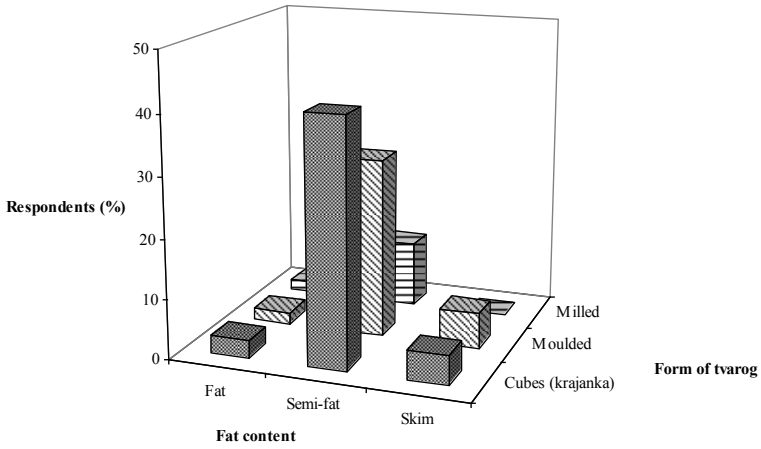


Fig. 3. Choice of tvarog according to fat content and form in which tvarog is sold

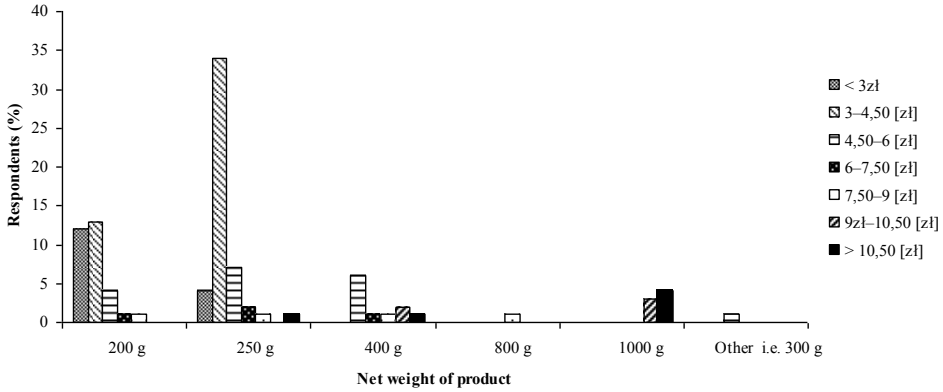


Fig. 4. Choice of tvarog according to net weight of the product and price

The material that the tvarog package is made of also plays a role in selection of the product. The consumers most often chose tvarogs in foil package (33%), then wrapped in parchment with additional foil (25%) and only in parchment (21%) (Fig. 5). Other types of packages, such as bucket or package equipped with plastic tray had less interest. The most popular foil packages have several advantages: can be easily open, are hermetic which guarantee freshness and are cheaper than other packages. However, additional features of the package can increase the price of the packed product.

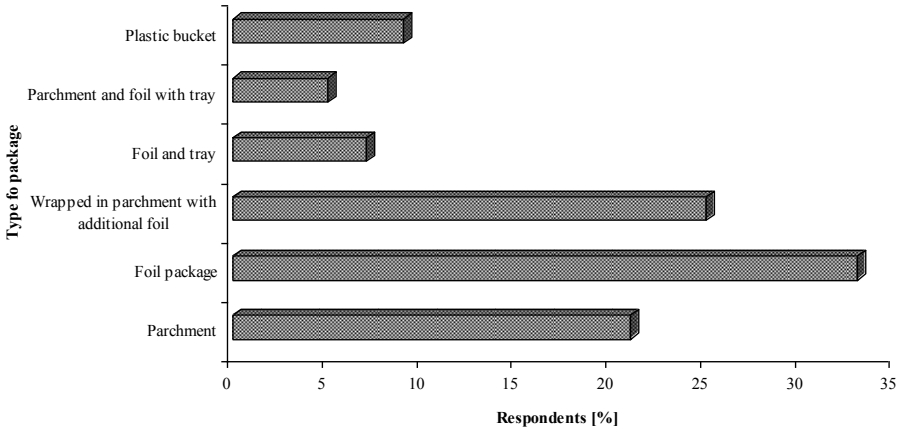


Fig. 5. Choice of tvarog according to type of package

One of the goal of this study was to determine the functions of the packages that could attract the product to the consumers. Among the most important the respondents indicated freshness assurance (57%) and facility to open (40%) (Fig. 6). The possibility of multiple opening and closing as well as environmentally friendly package were selected by 27 and 23% of consumers, respectively (Fig. 6). We can assume that the consumers want to consume fresh product in a package that don't cause any problems when opening. In general, comfort while using the product is more important than concern about an environment.

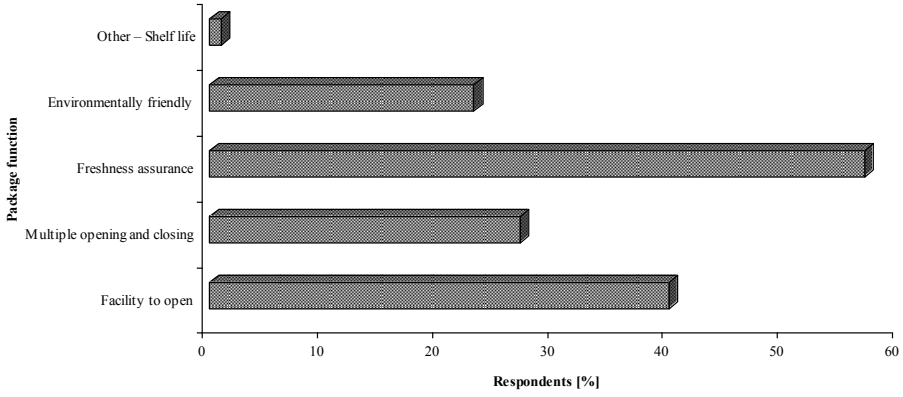


Fig. 6. Choice of package function

The most important element on the package was defined as the information (79%) (Fig. 7). Color, shape of the package and the graphics design were less important, 17, 12 and 10% of respondents chose these options, respectively.

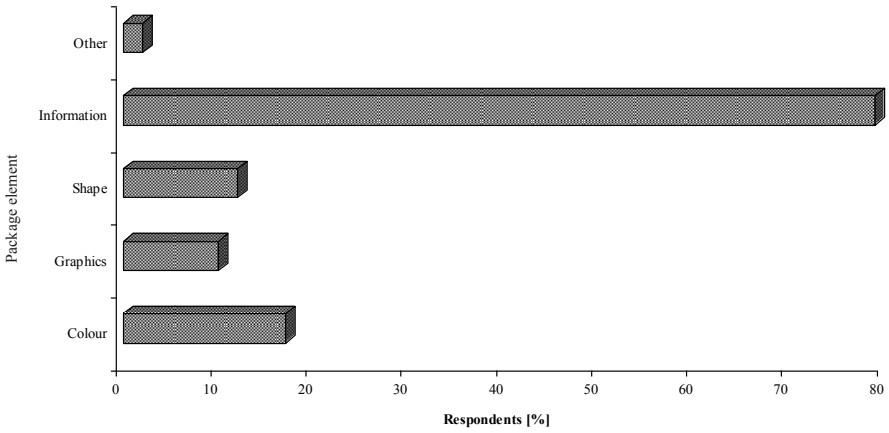


Fig. 7. Choice of the most important element on the package

By determination of fundamental product features which play the most important role in product choice on the market shelf, we wanted to improve the product, however, a majority of consumers (90%) did not wanted any changes in the product itself as well as in the package (84%). Only small number of respondents mentioned more friendly to environment package (3%) and facility to open (2%) as a way to upgrade the product. Huge competitiveness on the market force dairy companies to launch new products which should be more attractive than competitors' products. As the market offer is very broad it is very likely that the consumers are not even aware of a particular need (unconscious need), and only when a new modified product is introduced to the market they are willing to accept it and take advantage of a new feature. Taking the above into consideration the company wanting its products to be competitive on the market has to anticipate the other and create a need for a product or its particular attribute instead of answering only to the market needs.

Construction of House of Quality for tvarog cheeses

Based on the results of the survey it was possible to create a profile of the typical consumer of tvarog and to determine the key factors that influence purchase of this product. These factors were incorporated into House of Quality.

As stated earlier in this work the most important product attributes that can influence consumer purchase decision are taste, than fat content, price, best before date, net weight of the product and availability. Type of the package had least influence. Based on such analysis it was possible to determine the importance of technical parameters for the product in the later stage of this study.

In the first phase of designing of House of Quality we identify consumers' requirements toward the product. In order to avoid mistakes, the original answers of the consumers were used to formulate the requirements. The requirements were as following (Table 2): slightly acid taste, semi-fat tvarog, cut into cube ("krajanka"), net weight of the product 250 g, reasonable price, foil package, facility to open, guarantee of freshness, legible information on the package and attractive package encouraging purchasing the product.

Table 2

The consumers requirements toward the product and its importance

Requirements	Importance
Taste, slightly acid	5
Semi-fat tvarog	5
Cut into cube ("krajanka")	3
Net weight 250 g	4
Reasonable price	4
Foil package	2
Facility to open	4
Guarantee of freshness	4
Legible information on the package	3
Attractive package encouraging to purchase the product	4

Then, the importance was ascribed to each of the requirement. The results of the survey allowed to perform this task; in one of the question the respondents were asked to range (from 1 to 7, where 1 is the most important and 7 least important) given attributes of the product. Based on the consumers notes the importance of the requirements was determined (Table 2). Taste and fat content were given 5 points on 5-point scal. where 5 mean highest importance, 1 least. The requirements such as net weight of the product (250 g), price, facility to open, guarantee of freshness and attractive package were estimated as 4. Shape of the tvarog – cubes and legible information on the package were characterized as less important with the note 3. The requirement with the least importance was the material of the package – foil that was given 2 points.

Third phase focused on translation of consumers' requirements into technical parameters of the product. Each requirement was translated at least to one technical parameter and nature of each parameter was ascribed (Table 3). The nature of technical parameter can be characterized as nominal value, maximal or minimal. In terms of minimal: lower value of the parameter better satisfy consumers' need. Maximal value indicates that higher value of the parameter better meets consumers' preferences. Nominal value means the value of parameter that has to be at certain level and in order to provide for consumers' needs the company has to approach it in a maximal way [Konarzewska-Gubała 2003]. In current study most of the technical parameters were described as nominal value. Among them were acidity that has a direct influence on taste of tvarog, fat content, pressing and moulding processes during production, application of foil to pack the final product, new package design, vacuum package and information on the label.

The next step in the construction process of House of Quality was the determination of correlation between consumers' requirements and technical parameters. The matrix of relationship is shown in Figure 8. The relationship is usually described using 1–3–9 progressive scale. Strong relationship is indicated with "9", in current study the relationship between following requirements and technical parameters was identified as strong: taste of tvarog and acidity, shape of tvarog and moulding, reasonable price and production cost, facility to open and new package design. For relationships with medium strength numerical value of "3" was ascribe, i.e. by developing new better package or application of foil to pack the product one can better guarantee freshness of the product. An example of weak correlation (value of "1"), however, influencing to some extent the quality of the product was facility to open and appli-

cation of foil during packing process. With lack of correlation when consumers' requirement and technical parameter do not depend on each other, the fields of matrix remained empty i.e. taste of tvarog and information on the package label.

The values in the matrix of correlation present a very important source of information on possible product improvements. Interpretation of the data from the matrix allows claiming if the requirements of the consumers are reflected by product concept [Hamrol 2008].

Table 3

Determination of technical parameters and their nature

Technical parameter	Nature of the parameter
Acidity	●
Fat content	●
Pressing	●
Moulding	●
Production cost	↓
Application of foil for packaging	●
New package design	●
Vacuum package	●
Hygiene of production, packaging, storage	↑
Information on the label	●
Graphical design of the package	●

● – nominal value ↑ – maximal value ↓ – minimal value

The determination of the importance of the consumers' requirements and relationship between requirements and technical parameters allowed performing the next phase of construction of House of Quality which was evaluation of importance of each technical parameter. The following formula was used to calculate the importance [Hamrol 2008]:

$$\mathbf{Tj}=\sum_{i=1}^{t} \mathbf{Wi\ Zij}$$

where:
Tj – parameter importance *j*;
Wi – requirement importance *i*;
Zij – relationship between requirement *i* and technical parametr *j*.

By calculating the importance for each technical parameter it was possible to identify these parameters that had the greatest influence on meeting the consumers' requirements and succeeding to produce product with improved characteristics (having the highest Tj value) [Zymonik, Wąsińska 2007].

New package design (89 points), acidity (49 points), fat content (45 points) and vacuum package (42 ponits) were the key parameters for tvarog (Table 4), so in the product improvement process a special attention has to be paid to these characteristics if the product market success want to be achieved.

Determination of relationship between technical parameters (conflict analysis) was conducted by construction of the roof of house of quality (Fig. 9). In a special matrix, on the cross-cut area for particular two parameters the strength with which the two parameters affect

each other was marked. If there is a positive influence between the two parameters, meaning that improving one parameter we can improve also the other, there is a positive correlation (+). When the improvement of one of the parameters causes deterioration of the second one, there is a negative correlation (–). For the successful product development it is better to have more positive correlations than negative between technical parameters. If there is more negative values one can expect a lot of troubles during product development [Jazdon 2002, Liśniecka, Pater 1997]. In current study there were more positive relations. For example, there was positive correlation between the application of foil to pack tvarog and vacuum package, as foil does not transmit an air which is very important in case of vaccum package. The new package design is also positively correlated with new graphic design. There was a negative correlation between the cost of production and new package design as well as graphic design. Any improvement of the package caused an increase in production cost which should be kept low in order to keep the price of the final product at reasonable level. Large number of neutral correlations (empty fields), i.e. acidity and information on the label, moulding and graphical design of the package, together with number of positive correlations present a good perspective for the future to improve the characteristics of tvarog.

Matrix of correlation between requirements and technical parameters →	**IMPORTANCE OF REQUIREMENT**	Acidity	Fat content	Pressing	Moulding	Production cost	Application of foil for packaging	New package design	Vacuum package	Hygiene of production, packaging, storage	Information on the label	Graphical design of the package
		●	●	●	●	↓	●	●	●	↑	●	●
Taste, slightly acid	**5**	9										
Semi-fat tvarog	**5**		9									
Cut into cube	**3**			1	9							
Net weight 250 g	**4**			1	3							
Reasonable price	**4**					9						
Foil package	**2**						9	1	3			
Facility to open	**4**						1	9				
Guarantee of freshness	**4**	1					3	3	9	9		
Legible information	**3**							1			9	1
Attractive package	**4**							9				9
Target value*		a	b	c	d	e	f	g	h	i	j	k
Importance of techical parameters		49	45	7	39	36	34	89	42	36	27	39
Importance of techical parameters (%)		11,1	10,2	1,6	8,8	8,1	7,7	20,1	9,5	8,1	6,1	8,8
Key attributes		II	III					I	IV			

Fig. 8. House of Quality for tvarog
* Specific information on target value are presented in Table 5

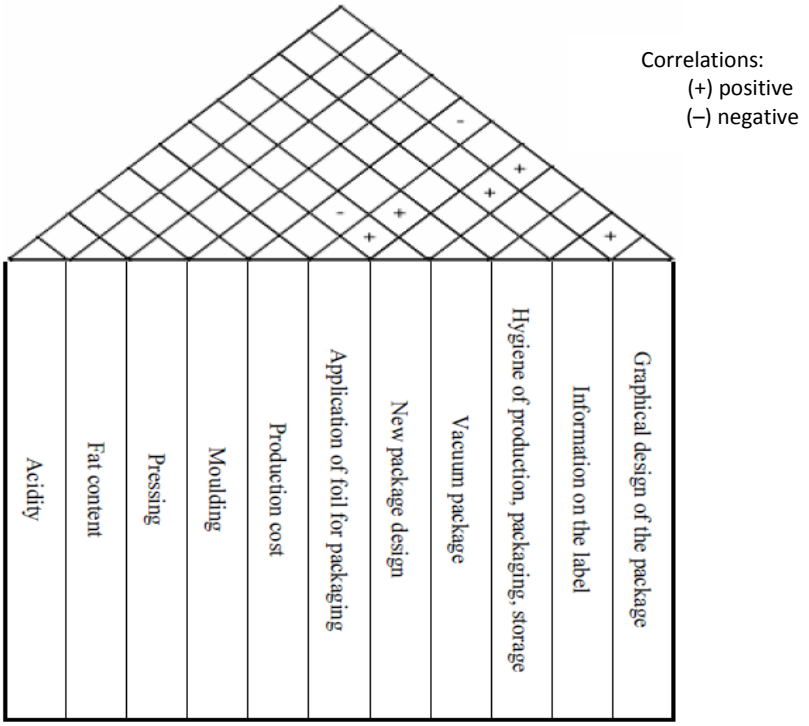


Fig. 9. The roof of House of Quality: Relationships between technical parameters

Table 4

The importance of technical parameters

Technical parameter	Importance
Acidity	49
Fat content	45
Pressing	7
Moulding	39
Production cost	36
Application of foil for packaging	34
New package design	89
Vacuum package	42
Hygiene of production, packaging, storage	36
Information on the label	27
Graphical design of the package	39

Originally the 7th phase in the construction of the House of Quality is an analysis of competitiveness, where the new product is compared to the products with high level of substitution offered by other companies. Such analysis can be performed by the customers and

product designers. The purpose of this study was to indicate the most important from the consumers' perspective tvarog attributes as well as the technical parameters which should be improved in order to meet the consumers' requirements for a traditional dairy product – tvarog. This study referred to a product category not any particular brand. For this reason the analysis of competitiveness was not done.

In our case, the seventh stage in the construction of the House of Quality was the development of target values for technical parameters. All parameters should be specified by numerical values and written in the technical documentation for verification (at later stages of product development) if the consumers' requirements were met. If it is not possible to determine the target value numerically one should do it in a descriptive way [Jazdon 2002]. These values must be achievable and measurable. Such an assignment results in new product design that is closer to reality (Table 5).

Table 5

Target values for technical parameters.

Parametr	Target value
Acidity (a)	[ph]
Fat content (b)	[%]
Pressing (c)	According to Internal Standard
Moulding (d)	According to Internal Standard
Production cost (e)	[mln złoty]
Application of foil for packaging (f)	According to PZH* permission
New package design (g)	According to PZH* permission
Vacuum package (h)	According to Polish Standard
Hygiene of production, packaging, storage (i)	GMP, GHP, HACCP
Information on the label (j)	According to actual decree of MZiOS
Graphical design of the package (k)	According to Polish Standard

* PZH – National Institute of Hygiene (Państwowy Zakład Higieny)
*MZiOS – Polish Ministry of Health and Social Care (Ministerstwo Zdrowia i Opieki Społecznej

The last phase was the difficulty rating for tvarog production according to the developed model while achieving the target values.

The difficulty was rated with index number as points on 5-point scale. The highest number (5) indicates significant problems and a special care that must be paid to a particular parameter by more detailed control and accurate determination of production parameters [Hamrol 2008]. After thorough analysis the technical parameters were rated depending on the difficulty in achieving each of them. Based on the obtained results (Fig. 10) among the key parameters (with highest importance value) the design of a new package was the most difficult in achieving followed by vacuum package. The other two key parameters: acidity and fat content showed rather low degree of difficulty meaning that the achievement of optimal value for these parameters should not present problems.

Matrix of correlation between requirements and technical parameters ↘	IMPORTANCE OF REQUIREMENT	Acidity	Fat content	Pressing	Moulding	Production cost	Application of foil for packaging	New package design	Vacuum package	Hygiene of production, packaging, storage	Information on the label	Graphical design of the package
		●	●	●	●	↓	●	●	●	↑	●	●
Taste, slightly acid	**5**	9										
Semi-fat tvarog	**5**		9									
Cut into cube	**3**			1	9							
Net weight 250 g	**4**			1	3							
Reasonable price	**4**					9						
Foil package	**2**						9	1	3			
Facility to open	**4**						1	9				
Guarantee of freshness	**4**	1					3	3	9	9		
Legible information	**3**							1			9	1
Attractive package	**4**							9				9
Target value*		a	b	c	d	e	f	g	h	i	j	k
Importance of techical parameters		49	45	7	39	36	34	89	42	36	27	39
Importance of techical parameters (%)		11,1	10,2	1,6	8,8	8,1	7,7	20,1	9,5	8,1	6,1	8,8
Key attributes		II	III					I	IV			
Difficulty rating		2	2	1	1	5	2	4	3	2	1	3

Fig. 10. House of Quality for tvarog
* Specific information on target value are presented in Table 5

QFD is a very time-consuming method, and needs to be very well plan. It helps improving the product development process by focusing on consumers, which results in higher acceptance of purchased products. QFD contributes to lower production cost and enables modifications of product attributes during development process. The results of current study have clearly demonstrated that QFD can be successfully applied to improve the parameters of traditional food products such as tvarog. Using QFD it was possible in a legible way to demonstrate the key parameters influencing product improvement.

References

Benner M., Linnemann A.R., Jongen W.M.F., Folstar P., 2003. Food Quality and Preferencje 14, 327–339.

Central Statistical Office (Główny Urząd Statystyczny), 2007. Rocznik demograficzny, Zakład Wydawnictw Statystycznych, Warszawa.

Gutkowska K., Ozimek I., 2002. Dobór próby. [in:] Badania marketingowe na rynku żywności. Wydawnictwo SGGW. Warszawa, 107–112.

Hamrol A., 2008. Metody wspomagające zarządzanie jakością. [w:] Zarządzanie jakością z przykładami. Wydawnictwo naukowe PWN, wydanie drugie, zmienione. Warszawa, 362–376.

Jazdon A., 2002. Metoda QFD – Quality Function Deployment (Sterowanie Jakością przez klienta). [in:] Doskonalenie zarządzania jakością, Bydgoszcz,129–142.

Karaszewski R., 1999. Quality Function Deployment (QFD) – metoda zaawansowanego planowania jakości. [in:] Total Quality Management. Zarządzanie przez jakość, wybrane zagadnienia, Toruń, 147–158.

Kleniewski A., 1995. Badania i analiza potrzeb klienta – QFD. Problemy jakości, 5, 12–17.

Konarzewska-Gubała E., 2003. Metoda QFD i dom jakości. [in:] Zarządzanie przez jakość. Koncepcje, metody, studia przypadków. Wyd. Akademii Ekonomicznej we Wrocławiu, 152–168.

Kowalska D., 1995. QFD – metoda umiejscowienia funkcji jakości. Problemy Jakości, 3, 13–16.

Krzemień E., Wolniak R., 2001. Zastosowanie komputerowego wspomagania w metodzie QFD. Problemy jakości, 7, 31–34.

Liśniecka K., Pater S., 1997. QFD narzędziem strategicznego planowania jakości produktu. Problemy jakości, 3, 2–13.

Maleszka A., Gałka K., 2005. Zastosowanie metody QFD do wspomagania zarządzania w przemyśle mleczarskim. [in:] Towaroznawcze problemy jakości, 3, 29–37.

Polish Standard, PN – A – 86300:1991. Mleko i przetwory mleczarskie – Sery twarogowe niedojrzewające.

Stankiewicz J. (red), 2005. Kapitał – Informacja – Jakość, 131–137.

Wolniak R., Brzeszcz S., 2004. Analiza możliwości wykorzystania metody QFD w organizacjach stosujących normę iso 9001:2000. [in:] Zeszyty naukowe Politechniki Śląskiej. Organizacja i zarządzanie z. 19, 1–20.

Zymonik Z., Wąsińska A., 2007. Zastosowanie QFD na przykładzie wyrobu sektora maszynowego. Problemy jakości, 3, 14–18.

2

QUALITATIVE EVALUATION OF THE POPULAR MEAT PRODUCTS OFFERED ON THE RETAIL TRADE

Introduction

In Poland, almost 60% of meat is consumed as a meat products, which quality is determined by the composition of raw material. manufacturing technology and conditions of the supply and retail. Consumers expect these products to satisfy themnot only in sensory appeal and utility, but also in nutritional value and health safety. According to the current food law producers are responsible for compliance of these requirements, however, other participants in the distribution chain are also responsible for quality and durability of final food products.

There are none obligatory norms that strictly define the composition of raw materials input in processed meat products. This may raise concerns about the repeatability of food production [Kłossowska 2003]. Currently, valid definition of meat in the EU forces on producers of meat products necessity of using meat with appropriate fat content and connective tissue (in the total protein content) to a level no higher than 30% and 25% in pork, 25% in other mammals meat except rabbits and 15%, 10% in case of poultry and rabbits [Directive 2001/101/EU]. In this legislation with regarding to food labelling there is obligation to indicate the percentage of a particular kind of meat, while mechanically deboned meat was excluded from mentioned definition and must be declared as a separate component of the meat products. In addition, on the label of meat products, information about content of connective tissue must be contained, when its amount exceeds 12% of the total protein. All of these and other compulsory elements of foodstaff marking should help the consumer make the right choice of product according to their expectations [Dz. U. 2006, Dz. U. 2007]. Products safety is also guaranteed by the necessity to measure and declare amount of food additives or allergenic substances used in food production [Dz. U. 2010].

Amongpopular processed meat products which are produced from fine-comminuted raw material. it can be expected a high variability in the quality caused by raw materials which are used. Thereby assurance of stable quality of these products may not be realized. The aim of this study was to characterize the selected qualitative features of popular assortments of meat products.

Materials and Methods

The experimental material was the range of three meat products available on local market in the city of Wroclaw: pork frankfurters in unit packages, sterilized poultry pates in aluminium cans, and sterilized pork luncheon meat in metal tins. The meat products from

several producers were evaluated and in each case an assessment was repeated in four batches. From each production batch at least 3 pieces of evaluated products were taken.

The evaluation of selected meat products was carried out on the following parameters: the accuracy of labelling and packaging quality, basic chemical composition (water content [ISO 1442:2000], proteins [PN-75/A-04018], fat [ISO 1444:2000], collagen [ISO 3496:2000], NaCl [ISO 1841–1:2002] and nitrates III) [PN-EN-12014–3: 2006]. In addition, colour measurement in L*a*b* system using a Minolta camera CR-200B and sensory assessment were evaluated [ISO 4121:1998].

The data obtained from the examination were submitted to a one-way analysis of variance with repetitions in ANOVA module and Duncan test was applied to determine significant differences between averages of groups. All data analysis was performed using Statistica version 8.0. PL.

Results and Discussion

Tested frankfurters were packed in a convenient way for the customer. The net mass of the product in the package was between 240–300 g. This is the amount that the client is able to consume in a short period of time without risk of his health.

Frankfurters were aesthetically packed in a thermoshrinkable foil. All packages have a clear, durable, and distinctive veterinary symbol on the unit package label. The signs were placed in a way that it was not possible to remove them without damaging the label. All producers' packages include the information which allows to identify the production batches, date of production and expiration date. In addition, all evaluated packages include the product name, the identity of the country and producer, and the net mass. Moreover, the labels placed on packages contain information written in Polish. There was some manufacturer (company C) which have not applied the obligation to include the information about the conditions in which the meat products should be stored.

Food labelling has an informational function for the consumer and helps them to make decision about purchase. Furthermore, it may also have an educational function. The consumer expectsunderstandable information because of different reasons, but the most important is the ability to:

- compare with other products, to facilitate the purchase decision,
- compare the quality of the product with the price,
- avoid ingredients or products that are not desirable or which may cause adverse reactions (e.g. allergic) [Urban 2007].

Requirements for the chemical composition of this group of meat products (frankfurters), according to standards PN-A/82007:1996 (currently not applicable), specify that the protein content should not be less than 9%, fat content no more than 40%, water content no more than 69%, and salt no more than 3%. In this work, the studies of chemical composition showed that all four producers of frankfurters comply with these recommendation, in addition these assessments are the basic elements of the commodity evaluation controls.

Protein content in frankfurters was in the range of 12,75–13,67% (Table 1). From the nutritional point of view, products contained higher level of protein are more preferable, because they have a greater nutritional value. Another indicators of this attribute is the amount of collagen in total protein marked as not complete protein. Collagen content was noted

on the level 12–13%, this is the amount that does not require the manufacturer (in case of pork meat products) to determine the origin of this connective protein. Though one of the producers declared the amount of collagen protein in the formula of products composition. The highest protein content was noted in case of products manufactured by the producer D. Moreover the lowest amount of collagen protein additionally indicate the best nutritional value of these products.

Table 1

Physicochemical features of frankfurters

Producer / Feature		A	B	C	D
1		2	3	4	5
Water [%]	run I	46.65a*)	45.44a	47.29a	42.92c
	run II	46.77a	47.64a	48.12a	47.13a
	run III	46.09a	46.79a	47.60a	48.15a
	run IV	48.23a	46.23a	45.71a	45.47b
	average	46.94A**)	46.53A	47.18A	45.92A
Protein [%]	run I	12.59b	12.19b	13.39ab	12.75b
	run II	12.87ab	13.30a	13.49ab	14.15a
	run III	12.61b	13.28a	14.17a	14.25a
	run IV	13.05a	12.22b	12.89b	13.53ab
	average	12.78B	12.75B	13.48AB	13.67A
Fat [%]	run I	35.46a	36.74a	33.76a	35.01a
	run II	32.88b	33.66b	33.45a	31.63c
	run III	32.97b	34.85ab	32.91a	34.18ab
	run IV	32.17b	30.74c	33.39a	32.79bc
	average	33.37A	34.00A	33.20A	33.40A
Collagen [%]	run I	1.83a	2.19a	2.11a	1.61a
	run II	1.88a	2.14a	2.11a	1.68a
	run III	1.83a	2.09a	2.24a	1.71a
	run IV	1.84a	2.13a	2.14a	1.66a
	average	1.84B	2.14A	2.15A	1.67C
Collagen [% total protein]		14.40B	16.78A	15.95A	12.22C
NaCl [%]	run I	3.01a	2.63a	2.92a	2.87a
	run II	3.01a	2.54a	3.00a	2.76a
	run III	2.87a	2.67a	2.92a	2.99a
	run IV	2.79a	2.70a	2.91a	2.86a
	average	2.92A	2.63B	2.94A	2.87A
$NaNO_2$ [ppm]	run I	41.54a	8.31a	55.71a	65.70a
	run II	44.40a	9.03a	56.17a	65.72a
	run III	29.93b	7.22a	55.39a	68.86a
	run IV	38.62ab	8.20a	55.75a	66.73a
	average	38.62C	8.19D	55.76B	66.75A

Table 1 cont.

1	2	3	4	5	6
Colour L*	run I	69.74b	68.68b	70.71c	70.81c
	run II	68.68c	70.15a	71.39b	71.40b
	run III	69.68b	67.60c	72.18a	73.14a
	run IV	70.71a	68.72b	71.40b	71.22b
	average	69.70B	68.81C	71.43A	71.64A
Colour a*	run I	9.11b	8.91b	9.94b	9.72b
	run II	9.34a	9.24a	10.14b	10.83a
	run III	8.29c	8.29c	11.05a	8.47c
	run IV	8.81b	8.81b	10.36b	9.65b
	average	8.89C	8.82C	10.37A	9.67B
Colour b*	run I	10.83a	8.47c	9.51a	10.83a
	run II	11.09a	9.47a	9.23a	11.04a
	run III	11.08a	8.83b	9.57a	11.00a
	run IV	10.99a	8.90b	9.45a	10.79a
	average	11.00A	8.92C	9.44B	10.92A

*)a, b, c – different small letters in column indicate significant differences in values within each parameter between runs at $p \leq 0.05$

**)A, B, C – different big letters in verse indicate significant differences in average values, at $p \leq 0,05$

In all batches of meat products from all producers similar fat content was evaluated (more than 33%).

In tested products the content of NaCl ranged from 2.63% to 2.94%, while producer B used a significantly lower amount of this ingredient.

The content of nitrates (III) varied widely among the investigated products. The amount of sodium nitrate (III) ranged from 8.19 to 66.75 mg $NaNO_2$/kg of product and was significantly different in the products from different producers. However, all measured values are in compliance with requirements of acceptable amounts of nitrates in processed meat products [Dz. U. 2010].

The results of data statistical analysis indicated that all producers have a problem with maintaining the repeatability of production and the content of ingredients frequently differs in different production batches (Table 1). Colour measurement also confirmed the variation of all of its parameters, that also shows diversity of ingredients used in the production (Table 1). Frankfurters are the products that give producers a possibility to use cheaper raw material. and it may explain higher variability in its composition.

Except for assessment of the chemical composition, the essential qualitative criterion is the sensory analysis. The results of this evaluation are presented in Table 2. These assessment confirmed the diversity of products quality from different producers, however all of them were assessed at a good level. The highest score obtained frankfurters from the B producer, which showed the least variation in the investigated features in different production batches.

Physicochemical and sensory parameters of evaluated, commercially available frankfurters are in compliance with the criteria included in Norms for these kind of products. Moreover, in connection with their popularity among consumers these meat products should be possibly valuable meal with acceptable protein content, low content of fat, salt and ni-

trates (III). In presented study these criteria were kept. The results of Tyburcy et al [2005b] also confirmed, that there is compliance of polish producers with qualitative criteria and law requirements concerning the quality and proper labelling of these meat products.

Table 2

Sensory evaluation of frankfurters.

Producer Feature	A	B	C	D
Colour	4.2B*)	4.7A	4.2B	4.1B
Cohesiveness	4.0AB	4.3A	3.6BC	3.2C
Aroma	4.0B	4.7A	3.8BC	2.6C
Flavour	3.6AB	4.2A	3.4AB	3.1B
Juiciness	3.3A	3.5A	3.0AB	2.9AB
General evaluation	3.7AB	4.2A	3.9A	3.4B

*) A, B, C, – different letters in the verse indicate statistically significant differences at $p \leq 0.05$

Subsequent assortments of processed meat products under investigation were sterilized poultry pates. Among analyzed pates, three products (from producers E, G and H) are called "poultry pates", and information about the composition of the product declared the content of poultry ingredients in the range of 16–60%. The F producer named his product as "chicken pates" and declared percentage content of chicken on the level 39% in raw material. Furthermore, the information on the packages include the producer data, net mass, storage conditions, production batch, connected with the expiry date, the veterinary approval number. In addition, date and net mass were properly placed in the same view. There was also information about the presence of gluten (considered as a hypoallergenic ingredient). In the composition there were mentioned additives with their technological functions and with the symbol E. The labelling of these products was clear, durable and in polish language. Investigated products of all producers (E, F, G, H) can be considered as correctly labelled. The greater amount of deviations was found between declared and real net mass. For all processed meat products of producer H was demonstrated mass deficiency in the range from 0.1% to 2.8%. In case of producer's F products mass deficiency occurred in ⅓ of his products, from 0.35 g to 2.05 g (from 0.23% to 1.32%), and in 16% of products belonged to manufacturer E were found out an understate of weight at the maximum level 0,74%. There were no underweight products within assortments of producer G.

The results of the physicochemical analyses of the pates were presented in table 3.

Investigated poultry pates were characterized by a water content on the level over 52%, except of meat products from producer G (39.7%). Water is one of the most important factors which have a significant effect on the structure of batter. Water causes irrigation and dissolution or swelling of proteins released from muscle fibres. Also it can affect on production yield. Products with excessive water content have a decreased nutritional and sensory value and also lower stability [Olkiewicz et al. 2007].

The level of fat in the processed meat product substantially affects on their juiciness, flavour and texture [Dolata 2001]. The results of fat content evaluation were more varied between products from different manufacturers and between production batches in the products of producers E and F. According to PN-A-86525:1996 fat content of poultry conserve should not be greater than 35%. None of the producers exceeded this value. Pates are fairly

high calorie products, but there was observed a tendency to reduce fat content in poultry pates incomparison to meat pates [Kolanowski 2002]. Tyburcy et. al. [2005a], analyzed goose pate available on the Polish market in which the level of fat was determined at 10%.

In the pates of each producers were observed significant differences in protein content in production batches. Within the products of manufacturers E and F indicated significantly lower level of this component (about 7,3–7,7%). Meat protein is an important factor of the nutritional value of meat, but in the popular, low-cost products the cheaper protein substitutes such a soy preparation were used very often in order to improve the nutritional value of this kind of products [Słowiński, Mroczek 2000].

Table 3

Physicochemical features of pates

Producer / Feature		E	F	G	H
1		2	3	4	5
Water [%]	run I	52.45a*)	52.39a	39.95a	52.07a
	run II	52.52a	52.50a	39.67a	52.09a
	run III	52.49a	51.86b	39.34a	52.17a
	run IV	52.32a	51.45a	39.80a	52.49a
	average	52.45A	52.05A	39.69B	52.21A
Protein [%]	run I	7.50b	7.03b	10.31b	10.99a
	run II	7.27b	7.50a	10.72a	10.90a
	run III	7.93a	7.01b	10.35b	10.50b
	run IV	7.92a	7.76a	10.48b	10.36b
	average	7.66B	7.33B	10.47A	10.69A
Fat [%]	run I	14.98a	13.83b	23.01a	12.92a
	run II	14.56b	13.98b	23.43a	12.65a
	run III	14.97a	14.79a	23.22a	12.68a
	run IV	14.07c	13.59b	23.01a	12.52a
	average	14.65B	14.05B	23.17A	12.69C
Collagen [%]	run I	0.76b	0.76a	1.36a	1.12a
	run II	0.76b	0.71a	1.22b	1.13a
	run III	0.89a	0.53b	1.05d	1.19a
	run IV	0.88a	0.71a	1.16bcd	1.10a
	average	0.82B	0.68B	1.20A	1.14A
Collagen [% total protein]		10.7B	9.2C	11.46A	10.66B
NaCl [%]	run I	2.73a	2.49a	2.87b	3.10a
	run II	2.82a	2.40a	2.90b	2.88a
	run III	2.27b	2.54a	3.26a	3.19a
	run IV	2.61a	2.35a	2.76b	3.00a
	average	2.61B	2.45B	2.95A	3.04A
$NaNO_2$ [ppm]	run I	16.95a	8.67a	29.91a	9.08a
	run II	18.27a	7.76a	28.64a	10.41a
	run III	17.05a	7.48a	29.73a	9.59a
	run IV	17.09a	8.19a	30.76a	10.08a
	average	17.34B	8.03C	29.76A	9.79C

Table 3 cont.

1		2	3	4	5
Colour L*	run I	59.43a	56.92c	61.05a	54.98c
	run II	59.55a	59.00a	61.59a	55.77b
	run III	59.19a	58.58a	59.69b	56.30a
	run IV	58.15b	57.84bc	61.03a	55.01b
	average	59.08B	58.09B	60.82A	55.52C
Colour a*	run I	5.11c	6.94a	7.00a	9.62a
	run II	6.16b	4.86b	6.34b	7.40c
	run III	6.12b	4.85b	6.36b	7.86c
	run IV	6.42a	4.48c	6.51b	8.21b
	average	5.95BC	5.17C	6.55B	8.27A
Colour b*	run I	12.46a	10.22b	10.37b	12.11b
	run II	12.29a	12.11a	11.74a	13.18a
	run III	12.42a	12.57a	10.36b	12.47b
	run IV	11.17b	12.75a	11.30a	12.34b
	average	12.09A	11.91A	10.94B	12.53A

*) footnotes see table 1

The content of collagen in the protein of these meat products was the greatest in the producer's G products, where the most significant differences between production batches were also noticed. However only the products of manufacturer F did not exceed the amount of collagen accepted as typical for poultry – 10% of total protein. In the other products, the higher content of this protein was a result of the skins additive that have been mentioned in the raw material composition on the packaging. Whereas the addition of the plant protein decreased the ratio of collagen to total protein.

Sodium chloride is a commonly used substance in the production process of meat. It shapes an appropriate flavour and has antimicrobial activities.Already out of date norm PN-A-86525:1996 limited a salt content in poultry conserves to 2.3%, furthermore recommendations of nutritionists also suggest the necessity to reduce its consumption in processed food. The investigated pates, unfortunately, contained much more sodium chloride, even more than 3% (manufacturer H). Tyburcy et al. [2005a], showed that the chloride content in poultry, livestock and game pates is in the range of 2–2.5%.

Pates of all manufacturers contained a similar amount of nitrates (III) residues in following production batches, but the differences were found between the tested products (Table 3). Nevertheless, the content of nitrates (III) was at the level accepted by the food low, and it was determined from about 8 ppm to 30 ppm.

The pates assessment also includes determination of physical parameters of colour by reflection method in CIE L*a*b* system (Table 3).

The highest values of lightness (L*) was determined in the products of manufacturer G, that may be result of significantly higher fat content in these products. Whereas the lowest value of L* parameters characterized the products with the lowest fat content (manufacturer H). Values of parameter a* (chromaticity within red-green spectrum range) were the highest for products with the greater content of protein. Animal origin protein is the carrier of hem pigments, which determine the value of this parameter.

The significant impact on colour of sterilized pates have not only the type of basic raw materials but also non-meat additives, spices, the amount of mechanically de-boned meat, curing factors or the color stabilizers. Tyburcy et al. [2005a] compared the poultry pates and from meat of large slaughter animals and found out that the results obtained in the studies did not confirm the expected dependence that products from the meat of large slaughter animals are darker and "more red" than the poultry products.

Summary of the pates sensory evaluation results are presented in Table 4.

Table 4

Sensory evaluation of pates

Producer Feature [point]	E	F	G	H
Colour	3.7A*)	3.9A	4.1A	3.4B
Aroma	3.5A	3.5A	3.2A	3.4A
Lubricity	4.5A	3.6B	3.1B	4.4A
Consistence	4.5A	3.6B	2.8C	4.7A
Salinity	3.5B	3.6B	3.7B	4.3A
Flavour	3.7A	3.8A	3.4A	3.6A
General evaluation	4.1A	3.9A	3.5B	4.0A

*) footnotes see table 2.

In the sensory evaluation the highest average scores of all parameters obtained the pate of producer E – 3.9 points (in 5-point scale). The pates of manufacturers F and H gained slightly less points, respectively 3.8 and 3.7. Statistical analysis of results did not confirm the assessments to differ significantly. The lowest score (3.5) received a pate of manufacturer G.

The highest score was given to the pate, which was produced specifically for one of the grocery chains and simultaneously among all the evaluated pates it had the lowest price. As the worst it has been evaluated a product with the highest price. This fact contradicts the establishment of a large group of consumers that the cheaper products manufactured specifically for grocery chains have lower quality. Currently there is observed a growing group of consumers for whom the hypermarkets, supermarkets and large grocery stores are the main place to purchase meat and meat products [Górska-Warsewicz 2006].

Another popular range of products, sterilized pork luncheon meat produced by three different manufacturers (I, J, K), were evaluated.

These products widely differed in raw materials composition declared on the packaging. Preserves produced by the manufacturer I contained only 4% of pork, from the company J – 93%, and from company K – 45%.

The evaluation of the quality and packaging integrity showed that there was no leak and none deformation of a double cover and a bottom of the tins in any of the products. Labelling of the packages, their readability and aesthetic appearance also aroused no objections.

The study of the net mass of conserves showed that within 77% of all was underweight. The content of the jelly or meat juice according to norm PN-A-82022:1998 should be at a level no greater than 28% and this value was not exceeded in any of the tested products.

The assessment of chemical composition of products from different production batches confirmed the repeatability in case of all three manufacturers (Table 5).

Table 5

Physicochemical features of pork luncheon meat

Producer / Feature		I	J	K
1		2	3	4
Water [%]	run I	61.15a*)	62.23a	63.81a
	run II	61.14a	64.79a	64.39a
	run III	61.48a	64.10a	65.18a
	run IV	61.24a	65.35a	64.09a
	average	61.25B	64.12A	64.37A
Protein [%]	run I	11.79a	16.65a	10.29b
	run II	11.07b	17.30a	10.82b
	run III	11.50a	17.04a	11.80a
	run IV	11.64a	17.02a	10.95ab
	average	11.50B	17.00A	10.97C
Fat [%]	run I	11.59b	11.55a	13.29a
	run II	15.55a	11.21a	15.44b
	run III	14.77a	10.43a	12.25a
	run IV	17.18a	13.10a	13.63a
	average	14.77A	11.57B	13.65AB
Collage [%]	run I	2.47a	0.84a	1.58c
	run II	2.22a	0.73b	1.79b
	run III	2.35a	0.89a	2.82a
	run IV	1.83b	0.93a	2.05a
	average	2.22A	0.85B	2.06A
Collagen [% total protein]		19.30A	5.00B	18.78A
NaCl [%]	run I	2.64a	2.30b	1.96b
	run II	2.32a	2.46a	2.09b
	run III	2.19b	2.47a	2.15b
	run IV	2.13b	2.40a	2.41a
	average	2.32AB	2.41B	2.15B
$NaNO_2$ [ppm]	run I	6.75a	10.62a	11.47a
	run II	7.92a	11.00a	11.49a
	run III	6.31a	11.22a	6.16b
	run IV	6.10a	11.99a	7.05b
	average	6.77B	11.21A	9.04AB
Colour L*	run I	58.10a	63.80a	64.18c
	run II	58.00a	63.89a	60.79b
	run III	58.21a	64.09a	61.04
	run IV	58.10a	63.78a	58.00a
	average	58.10C	63.89A	61.00B

Table 5 cont.

1	2	3	4	5
Colour a*	run I	10.68a	10.88a	8.67b
	run II	9.99a	9.14b	7.50b
	run III	9.54a	10.71a	12.48a
	run IV	8.03b	10.25a	5.97c
	average	9.54AB	10.24A	8.66B
Colour b*	run I	12.97b	10.45b	10.85a
	run II	14.76a	11.31a	10.82a
	run III	15.16a	10.48b	9.21b
	run IV	15.88a	9.97b	10.29a
	average	14.78A	10.48B	10.29B

*) footnotes see table 1.

The repeatability of the batches is very important from the both consumer and producer point of view. Every time the consumer wants to buy the product of the same quality which corresponds to hisexpectations.

The levels of the basic ingredients of tested products differed: significantly less amount of water was determined in conserves of producer I, they contained the most fat (14.8%), and 11.5% of protein, while the collagen protein constituted around 19.3% of the total protein. The conserves of producer J were characterized by the highest amount of protein and the lowest level of connective proteins (5% of total protein). Furthermore, these products had the lowest lipid content among the investigated products (11.6%). However, it should be noted, that the conserves contained relatively not much fat. The content of this component has a direct impact on the product flavour and shapes of texture, while the proteins determine their nutritional value.

Evaluation of the curing agents amount - sodium chloride and nitrates (III) – despite the statistical differences that were found between the products – generally were at the correct levels. The amount of NaCl was determined within 2.4% – 2.15%, and $NaNO_2$ in the range of 6.8–11.2 ppm. The largest quantities of these preservatives were determined in the products, where the manufacturer declared 95% content of the pork in production and these components were used in the curing process of raw material.

Another feature of the qualitative assessment was the colour. In the case of K manufacturer's products the greatest variability in the measured parameters in different production batches was determined, that indicated the variability of raw material. The values of parameters L* and a* in products of manufacturer J, were at the highest level, which may be due to the highest water content in the products and the significantly largest content of meat (a carrier of the dyes). High fat content in products of I manufacturer contributed to a significantly higher proportion of yellow colour in the reflectance spectrum (b*=14.8) but it did not affect on the increasing the lightness. The level of fat, as an ingredient in a formula, with high lightness and high values of the parameter b*, has a crucial impact on the chromatic parameters of the final products [Acton, Dawson 1994, Pietrasik 1998].

The sensory evaluation (Table 6) indicated irrelevant differences in all evaluated products features. Thus, despite significant differences in formula, the products were investigated

similarly. One insignificant tendency was only observed. It was a trend to higher assessments of parameters such as: colour, cohesiveness and juiciness in products of manufacturer J.

Table 6

Sensory evaluation of pork luncheon meat

Producer Feature [point]	I	J	K
Colour	3.8A*)	4.0A	3.5A
Aroma	3.8A	3.8A	3.4A
Consistence	3.8A	3.6A	3.5A
Cohesivness	3.8A	4.0A	3.7A
Juiciness	3.7A	3.8A	3.5A
Salinity	3.7A	3.6A	3.4A
Flavour	3.6A	3.6A	3.2A
General evaluation	3.7A	3.7A	3.5A

*) footnotes see table 2.

The quality of food products is checked by the State Trade Inspection bodies. The results of research showed that the most common failures concerning labelling of meat products were:

- lack of meat component percentage or information about storage conditions,
- lack of inclusion a technological function of additives, the names of animal species from which the meat uses in the production is originated, net mass,
- lack of all the substances use in production in the list of ingredients, including additives.

However, in order to identify the raw materials used in production such a multicomponent meat products as these under investigation, often the modern methods of research are used, such as polymerase chain reaction – PCR. Control investigations conducted by this method have shown its usefulness for detecting the fakes of meat products. Among the sausages declared as pure pork presence of beef was found. Moreover the presence of poultry and protein preparations was discovered, although the producers did not declare these ingredients on the label of products [IJHRS 2010].

References

Acton J.C., Dawson P.L., 1994. Color as a functional property of proteins [in:] Protein functionality in food systems. Ed. by Hettiarachy, N.S., Ziegler, G.R., Marcel Dekker, Inc.

Dolata W., 2001. Wpływ warunków kutrowania surowców mięsnych i tłuszczowych na jakość farszów wędlin. Mięso i Wędliny, 3, 28.

Dyrektywa Komisji 2001/101/WE z dnia 26 listopada 2001 r. zmieniająca dyrektywę 2000/13/WE Parlamentu Europejskiego i Rady w sprawie zbliżenia ustawodawstw Państw Członkowskich odnoszących się do etykietowania, prezentacji i reklamy środków spożywczych.

Dz. U. 2006 r. nr 171, poz. 1225 ze zmianami. Ustawa z dnia 25 sierpnia 2006 r. o bezpieczeństwie żywności i żywienia.

Dz. U. 2007 r. nr 137, poz. 966. Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 10 lipca 2007 r. w sprawie znakowania środków spożywczych.
Dz. U. 2010, nr 232, poz. 1525. Rozporządzenie Ministra Zdrowia z dn. 22 listopada 2010 r. w sprawie dozwolonych substancji dodatkowych.
Górska-Warsewicz H., 2006. Konsument na rynku mięsa i jego przetworów. Przem. Spoż., 3, 41
Kłossowska B., 2003. Przegląd aktualnych norm z zakresu analityki chemicznej mięsa i przetworów mięsnych. Gosp. M., 3, 20–23.
Kolanowski W., 2002. Sława pasztetów nie przemija od stuleci – były, są i będą. Przegl. Gastronom., 4, 10.
Olkiewicz M., Tyszkiewicz S., Wawrzynkiewicz M., 2007. Wpływ podstawowego składu chemicznego i dodatków funkcjonalnych na charakterystykę reologiczną wybranych produktów mięsnych. Acta Agroph., 9 (1), 147–169.
Pietrasik Z., 1998. Wpływ zróżnicowanego udziału białka, tłuszczu i hydrokoloidów na wybrane wyróżniki oceny sensorycznej i barwę kutrowanych kiełbas parzonych. Żywność. Nauka. Technologia. Jakość. 3 (16), 59–71.
PN-75/A-04018. Mięso i przetwory mięsne. Oznaczenie azotu metodą Kjeldahla i przeliczenie na białko.
PN-A-86525:1996. Produkty drobiarskie. Konserwy drobiowe. Wymagania wspólne.
PN-A-82007:1996/A1:1998. Przetwory mięsne. Wędliny.
PN-ISO 1421:1998. Analiza sensoryczna. Metodologia. Ocena Produktów żywnościowych przy użyciu skalowania.
PN-A-82022:1998. Mięso i przetwory mięsne. Konserwy mięsne.
PN-ISO 1442:2000 Mięso i przetwory mięsne. Oznaczenie zawartości wody (metoda odwoławcza).
PN-ISO 1444:2000 Mięso i przetwory mięsne. Oznaczenie zawartości tłuszczu.
PN-ISO 3496:2000 Mięso i przetwory mięsne. Oznaczenie zawartości hydroksyproliny.
PN-ISO 1841-1:2002 Mięso i przetwory mięsne. Oznaczanie zawartości chlorków. Cześć 1. Metoda Volharda
PN-EN-12014-3-2006 Mięso i przetwory mięsne. Oznaczenie zawartości azotynów i azotanów
Raporty IJHAR-S, 2010 (http://www.ijhar-s.gov.pl/news/items/ijhars-walczy-z-falszerzami-wyrobow-miesnych.html)
Słowiński M., Mroczek J., 2000. Czynniki wpływające na jakość wędlin. Mięso i Wędliny, 4, 59.
Tyburcy A., Kosińska A., Cegiełka A., 2005a. Charakterystyka pasztetów sterylizowanych wytwarzanych z różnych surowców. Acta Sci. Pol., Technol. Aliment. 4 (1), 103–110.
Tyburcy A., Toszek E., Cegiełka A., 2005b. Porównanie składu chemicznego i wskaźników parówek drobiowych i wieprzowych oferowanych w sprzedaży detalicznej w Warszawie. Żywność. Nauka. Technologia. Jakość. 3 (44), 105–111.
Urban S., 2007. Marketing bezpośredni produktów mięsnych. Gospodarka Mięsna, 3, 14–16.

3

QUALITY OF BEETROOT SLICES DRIED BY VACUUM-MICROWAVE METHOD AFTER OSMOTIC PRE-TREATMENT IN SUCROSE SOLUTIONS

Introduction

Beetroot (*Beta vulgaris)* is rich in valuable, active compounds such as carotenoids [Dias et al. 2009], glycine betaine, [de Zwart et al. 2003], saponins [Atamanova et al. 2005], betacyanines [Patkai et al. 1997], folates [Jastrebova et al. 2003], betanin, polyphenols and flavonoids [Váli et al. 2007]. Therefore, beetroot intake can be considered a factor in cancer prevention [Kapadia et al. 1996].

Beetroot is characterized by relatively high moisture content, which exposed it to the physicochemical and microbiological changes leading to the spoilage. There are many ways of vegetal preservation. One of them is drying. Drying can be performed in different methods such as hot air drying, freeze drying, vacuum drying or microwave assisted drying. Osmotic dehydration of vegetables is a possible pre-treatment applied for improving the quality of the finish product and reducing the energy consumption [Le Maguer 1988]. During the process of osmotic dehydration, three types of mass transfer occur at different intensity [Raoult-Wack 1994]. The first type is water flux from the raw material to the osmotic solution. The second type is the solids transfer from the solution to the raw material, while the third type consists of natural solutes migration from the raw material to the solution. The intensities of particular types of mass transfer are depended on the temperature, concentration and kind of the osmotic solution. The optimal concentration of sucrose solution assures high osmotic potential and improves the taste of the dried product.

Osmotic dehydration in sucrose solution was applied to many raw materials such as pepper [Falade and Oyedele 2010], strawberries [Piotrowski et al. 2004], apples [Falade et al. 2003] or pumpkin [Zenoozian, Devahastin 2009].

However, osmotically pre-dried raw material involves finish drying in order to reduce the moisture content until the safe level and to ensure the attractive texture of the finish product. Among several methods used for this purpose, vacuum-microwave (VM) drying seems to be appropriate. During VM drying the energy of microwaves is absorbed by water located in the whole volume of the material being dried. This creates a large vapour pressure in the centre of the material, allowing rapid transfer of moisture to the surrounding vacuum and preventing structural collapse [Lin et al. 1998]. As a consequence, the rate of drying is considerably higher than in traditional methods of dehydration [Sharma, Parasad 2004]. The puffing phenomenon, that accompanies the rapid process of dehydration, creates a porous texture of the food and facilitates obtaining a crispy and delicate texture [Sham et al. 2001], and in this way it reduces the product's density as well as shrinkage.

The VM technique has already been satisfactory applied to reduce the moisture content of many plant material. such as carrots [Cui et al. 2004], cranberries [Sunjka et al. 2004],

strawberries [Krulis et al. 2005], peanuts [Delwiche et al. 1986], bananas [Mousa and Farid 2002], apples [Sham et al. 2001], pumpkin [Nawirska et al. 2009] and garlic [Cui et al. 2003]. However, at the beginning of VM dehydration the intensive water evaporation from the material being dried may exceed the vacuum pump capacity. This would require a reduction in the raw material subjected to drying or application of a large vacuum installation. This problem can be overcome by pre-drying of the material using osmotic dehydration in the sucrose solution. As a result of pre-drying the mass loads of a VM equipment can be radically decreased [Hu et al. 2006]. Pre-drying of the material by convective method before VM finish drying reduced the total cost of dehydration and improved the quality of dried tomatoes [Durance, Wang 2002], nutritional value of strawberries [Böhm et al. 2006] and improved the quality of beetroot cubes [Figiel 2010].

No scientific work has yet been reported on the combined drying of beetroots consisted of osmotic pre-drying in sucrose solution and VM finish drying. This method of drying could make a significant contribution to the vegetable processing industry. However, it is not obvious what concentration of sucrose solution should be applied to ensure the best quality of dried product. Therefore the aim of this work was to determine the effect of sucrose concentration on the drying kinetics of beetroot slices dehydrated by the osmotic pre-treatment and VM finish drying as well as quality of the finish product in terms of shrinkage, colour, texture and sensory attributes.

Materials and methods

Sample preparation

Beetroots of "Alto F1" variety were cultivated in a field situated close to Wroclaw (Poland). Slices of the raw material (5 mm thick and 18 mm in diameter) were prepared with the aid of a cutter (Gastrotech, Kraków, Poland) and a steel-made blanking tool, which was cylindrical in shape and pointed on one of the sides. The slices were mixed in a plastic container and then were dried by the combination of osmotic dehydration and vacuum-microwave drying.

Drying

Three osmotic solutions of sucrose 20, 40 and 60% were prepared in separate containers. The solutions were distributed into 70 ml beakers immersed in water bath of temperature 40°C. The ratio of osmotic solution to beetroot was maintained at 3:1. The mass of the samples was measured after 0.5, 1, 2, 4 and 6 hours of the osmotic dehydration. The samples were taken out from the solution by using a tea strainer and the surplus moisture was gently eliminated from their surfaces with a tissue paper just before measuring of their mass.

VM finish drying was carried out in an SM-200 drier (Plazmatronika, Wrocław, Poland). Pre-dried in osmotic solutions samples of a mass corresponded to the initial mass of 60 g were placed in a cylinder rotating at a speed of 6 rev·min^{-1}. The pressure in the cylinder varied from 4 to 6 kPa. Microwave power amounted to 360 W.

The VM drying kinetics was determined on the basis of mass losses of beetroot samples. The moisture ratio *MR* was determined from the equation:

$$MR = \frac{M(t) - M_e}{M_0 - M_e} \quad (1)$$

The moisture content of dehydrated samples was determined in vacuum dryer (SPT-200, ZEAMiL Horyzont, Krakow, Poland) for 24 hours at temperature 60°C.

Temperature measurement

During VM finish drying the vacuum-drum was rotating in order to avoid the local overheating of beetroot samples. Nevertheless, the temperature of individual slices differed despite of the drum rotation. The temperature of beetroot slices was measured with an infrared camera Flir i50 immediately after taking them out of the VM dryer. The external temperature of most heated slices was recorded. It was supposed that the temperature measured with this method reflected the course of mean temperature during drying. A direct internal temperature measurement of the slices in the drying chamber under vacuum is practically not possible because the measuring elements inserted into the dried material are heated by the microwave emission.

Density and shrinkage

Density ρ and shrinkage S of the dried product were determined from the equation (2) and (3) respectively.

$$\rho = \frac{m}{V} \quad (2)$$

$$S = \frac{V_0 - V}{V_0} \quad (3)$$

The mass of the samples m was measured with the use of balance of accuracy 0.001g, while their volume before drying V_0 and after drying V was determined with the use of a gas picnometer HumiPyc-M2 (InstruQuest Inc., USA).

Colour

Colour of dried samples was evaluated by a Minolta Chroma Meter CR-400 (Minolta Co. Ltd., Osaka, Japan). Instrumental colour data were expressed as CIE L^*, a^*, b^* coordinates, which define the colour in a three-dimensional space: L^* (dark – light), a^* (green – red) and b^* (blue – yellow). Samples before measurement were ground using an electric mill.

Texture Profile Analysis (TPA)

The TPA (Texture Profile Analysis) of beetroot slices was determined with an Instron 5566 strength-testing machine (Instron, High Wycombe, UK) equipped with the strain gauge of 1 kN range. In this test the sample was placed between flat plate and the cylindrical probe with diameter 5 mm fixed to the measuring head. While the test the head was moving at a speed of 60 mm·min^{-1}. The sample was subjected to double compression cycles imitating

the double bite of the human jaws. Shifting of the head amounted to 50% of the initial sample height. The maximum force was achieved at first compression. Upward shift of the head caused decreasing of the compressive force and created a gap between the deformed sample and the surface of the probe. The subsequent compression took place at lower deformation of the slightly recovered sample. The test was completed at the initial position of the head. On the basis of a TPA curve, three basic parameters were determined: hardness, cohesiveness and springiness. Hardness was defined as the first force peak on the TPA curve. Cohesiveness was the ratio of the force area during the second compression to that during the first compression. Springiness was understood as the recovered sample deformation in the second compression.

Sensory evaluation

Sensory evaluation with trained panel was used to discriminate the intensities of the main characteristics of dried product in terms of colour, flavour, taste and texture. The samples were tested by a panel of 8 panellists, ages 25 to 33 years (7 female and 1 mal. all members of the Wroclaw University of Environmental and Life Sciences), with sensory evaluation experience and trained in descriptive evaluation of fruits and vegetables.

Measurements were performed in individual booths according with ISO-PN 8586-1:1996 and ISO-PN 8589:1998 standards. The individual samples were scored for the intensity of evaluated attributes on a scale of 0 to 10, where:

- 0=Non perceptible intensity.
- 10=extremely high intensity.

The samples were presented in 100 mL plastic containers, which stood at room temperature for 30 min prior to analyses.

Results and Discussion

Drying kinetics

The changes of beetroot slices weight during osmotic dehydration in sucrose solution were shown in Fig. 1. It was found that the mass of samples during osmotic pre-treatment was decreasing until the equilibrium stage. Eventually, the weight changes of beetroot slices reached 0.8, 5.2 and 6.6 g for the sucrose solutions 20, 40 and 60% respectively. These weight changes resulted from water flux from the raw material to the osmotic solution and solids transfer from the solution to the raw material. However, water loss was higher than the sucrose gain. The experimental points show that the increase in sucrose concentration increased the mass loss of the pre-treated beetroot samples. The final moisture content of all samples was different and amounted to 85.8, 67.5 and 49.0% wet basis for osmotic solution concentrations 20, 40 and 60% respectively.

The vacuum-microwave (VM) drying kinetics of beetroot slices without pre-treatment as well as pre-dried in sucrose solution of concentrations 20, 40 and 60% were shown in Figs 2–5. It was found that the decrease in moisture content of the beetroot slices during VM finish drying could be described with an exponential equation at very high determination coefficient R^2. The drying time of the samples without pre-treatment was 36 min. This drying time decreased until 30 and 24 min after pre-treatment in sucrose solution of concentrations 20, and 40 or 60% respectively.

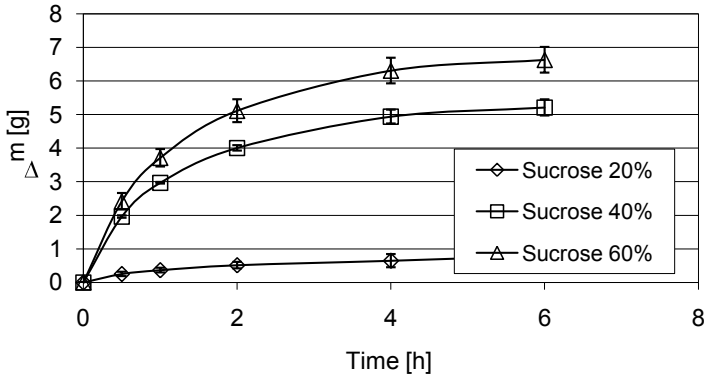


Fig. 1. Changes of weight of beetroot slices during osmotic dehydration in Sucrose solution

It was stated that while VM finish drying the temperature of samples was increasing until the certain moisture content and then was decreasing. The peak temperatures were found for the critical moisture content amounted to 14% wet basis for the sample without pre-treatment The increase in sucrose concentration from 20 to 60% additionally decreased this critical moisture content from 11 to 6%. The highest peak temperature 89°C was found for the pre-treated sample in 60% solution, while for the sample without pre-treatment this peak temperature was 86°C. One can presume, that the course of temperature versus moisture content depends on two phenomena [Figiel 2010]. The first is the generation of heat energy by water dipoles in microwave field [Tang 2005] while the other one is the absorbing of that energy by water evaporating from the surface of the material. The increase in the material temperature until critical moisture content results from the excess of the energy generated over the energy necessary for water evaporation. Naturally, the amounts of water generating the energy and water evaporating are decreasing with decreasing moisture content. Beyond the critical moisture content the energy generated by water dipoles is lower than the sum of the energy necessary for water evaporation and that transferred from the material to the ambient of lower temperature.

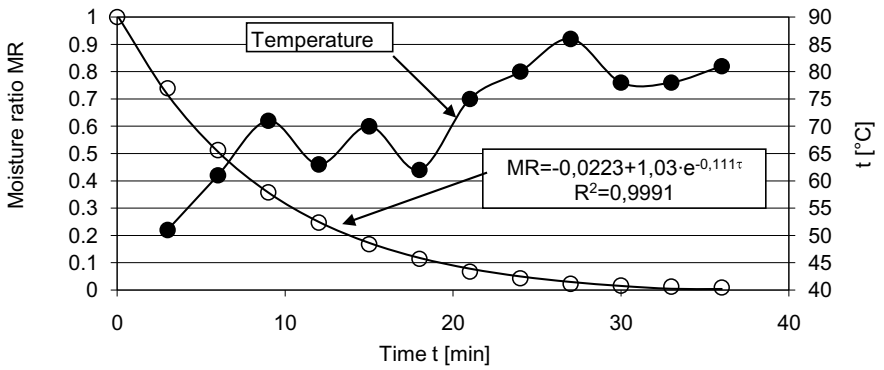


Fig. 2. VM drying kinetics of beetroot slices without pre-drying

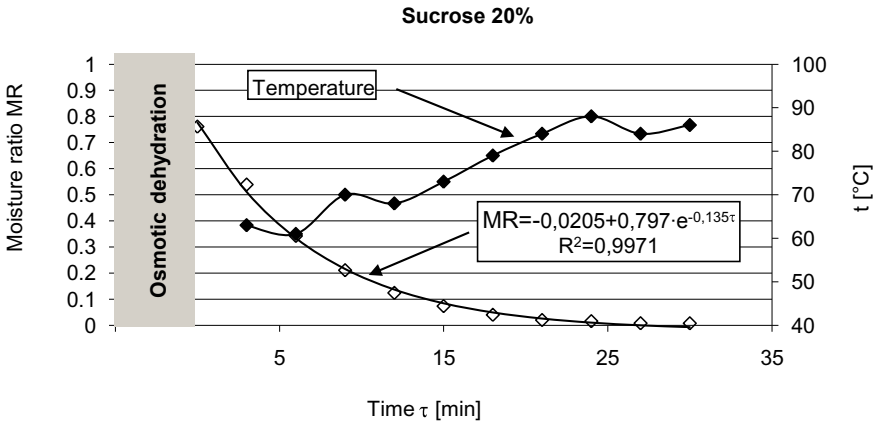


Fig. 3. VM drying kinetics of beetroot slices pre-dried in sucrose solution of concentration 20%

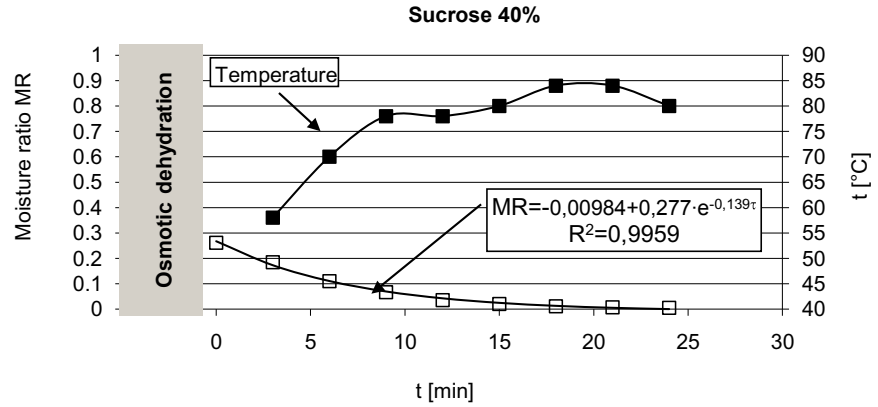


Fig. 4. VM drying kinetics of beetroot slices pre-dried in sucrose solution of concentration 40%

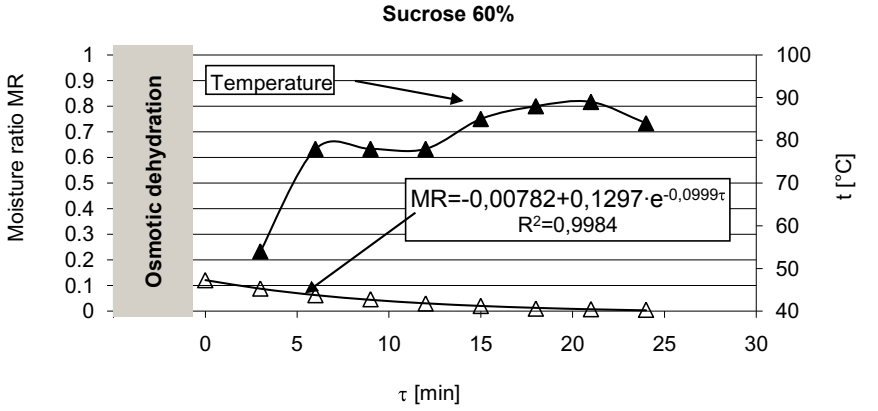


Fig. 5. VM drying kinetics of beetroot slices pre-dried in sucrose solution of concentration 60%

Density and shrinkage

The increase in sucrose concentration of the osmotic solutions decreased density and shrinkage of VM finish dried beetroot slices (Figs 6–7). The highest value of density (1.23 g/cm^3) was found for the sample pre-dried at sucrose concentration 20%, while the highest value of shrinkage (66.25%) was stated for the sample without pre-treatment. The lowest values of density and shrinkage (1.0 g/cm^3 and 52.0% respectively) were determined for the sample pre-dried in the sucrose solution of the highest concentration 60%. Torringa et al. [2001] also reported that the increase in concentration of the osmotic solution decreased the shrinkage of the mushroom samples finish dried by combined microwave-hot-air drying method. The VM method usually ensures lower shrinkage than traditional methods of drying due to the puffing phenomenon [Lin et al. 1998]. This study revealed that optimal addition of sucrose enhances the effect of puffing.

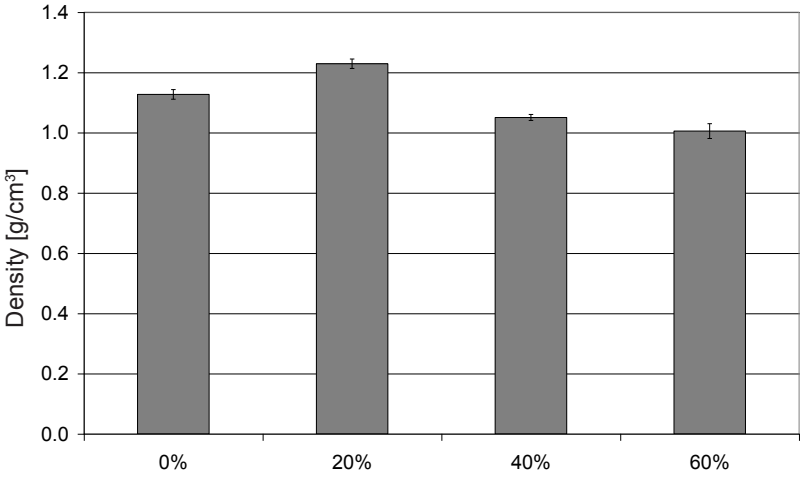


Fig. 6. Effect of sucrose concentration on density of VM finish dried beetroot slices

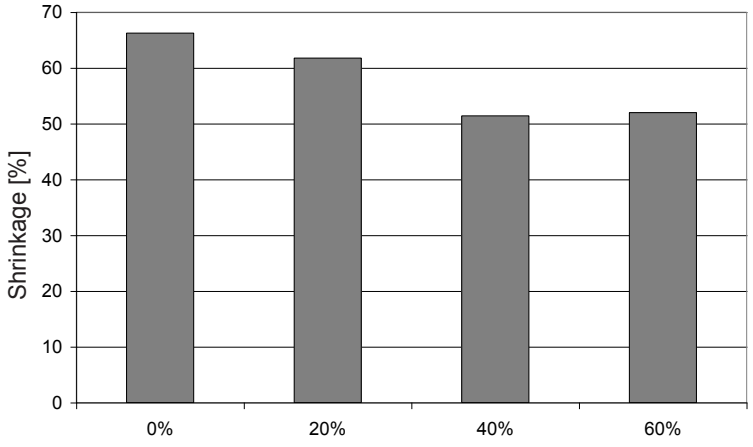


Fig. 7. Effect of sucrose concentration on shrinkage of VM finish dried beetroot slices

Colour

The increase in Sucrose concentration of the osmotic solutions increased colour parameters *L**, *a** and *b** of VM finish dried beetroot slices (Figs 6–7). This means that the colour of the slices was getting lighter shifting towards redness and yellowness. The lowest values of brightness *L**, redness *a** and yellowness *b** determined for the sample without pre-treatment were 34.1, 15.1 and 3.3 respectively while the highest values determined for the sample pre-dried at the sucrose concentration 60% were 39.6, 26.7 and 7.6 respectively. Higher brightness usually makes the colour of the product more attractive for the potential consumers, while red colour is typical for beetroot and thus the increasing of *a** parameter can be considered as the positive alteration.

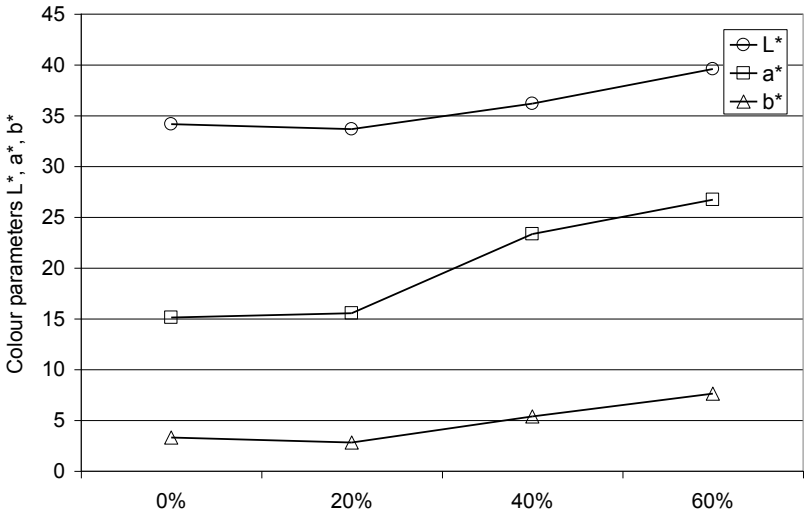


Fig. 8. Effect of sucrose concentration on colour parameters of VM finish dried beetroot slices

TPA parameters

Generally, it can be stated that the increase in sucrose concentration of the osmotic solution increases the hardness of VM finish dried beetroot slices (Fig. 9). However, the highest value of hardness (89.2 N) was found for the sample pre-dried at 40% of sucrose concentration.

On the other hand, the increase in sucrose concentration of the osmotic solution from 0 to 60% decreased the cohesiveness of the VM finish dried product from 0.46 to 0.20 J/J (Fig. 10). The springiness was also decreasing from 1.64 to 1.22 mm when the sucrose concentration was increasing from 20 to 60%. The increased hardness associated with decreased cohesiveness and springiness consequently may invoke the impression of increased crispiness. This is a positive effect increasing the attractiveness for the potential consumers [Szcześniak 1971].

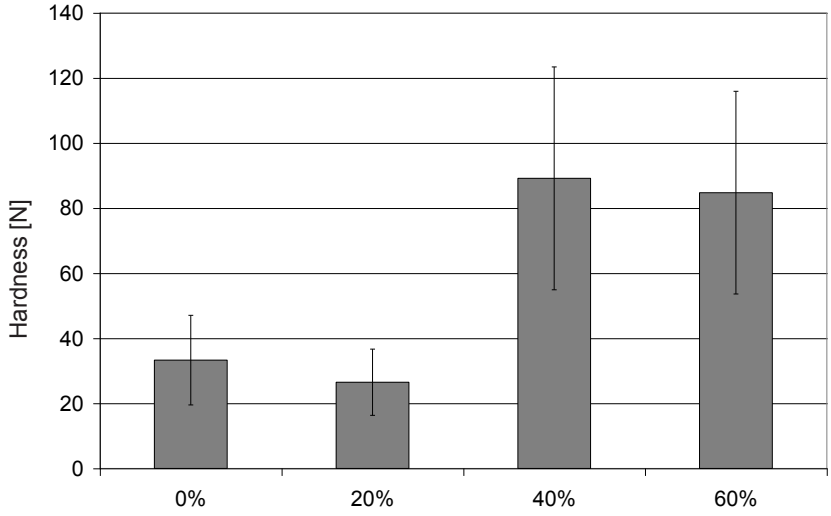


Fig. 9. Effect of sucrose concentration on hardness of VM finish dried beetroot slices

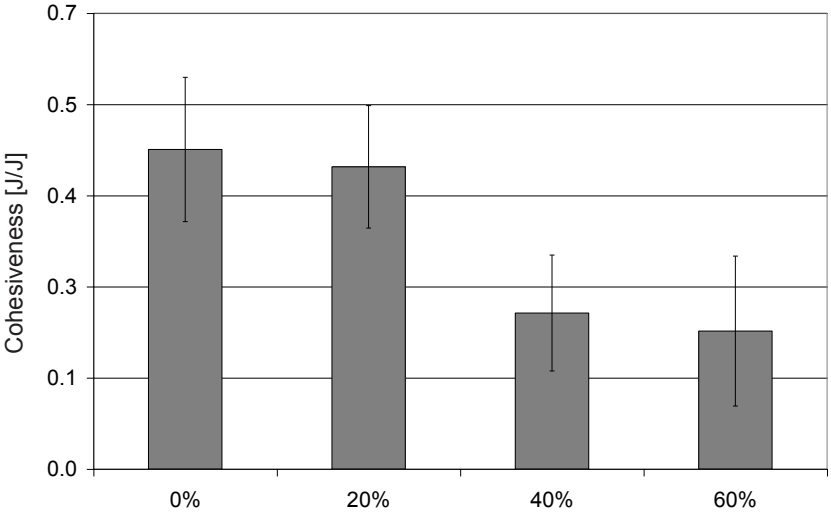


Fig. 10. Effect of sucrose concentration on cohesiveness of VM finish dried beetroot slices

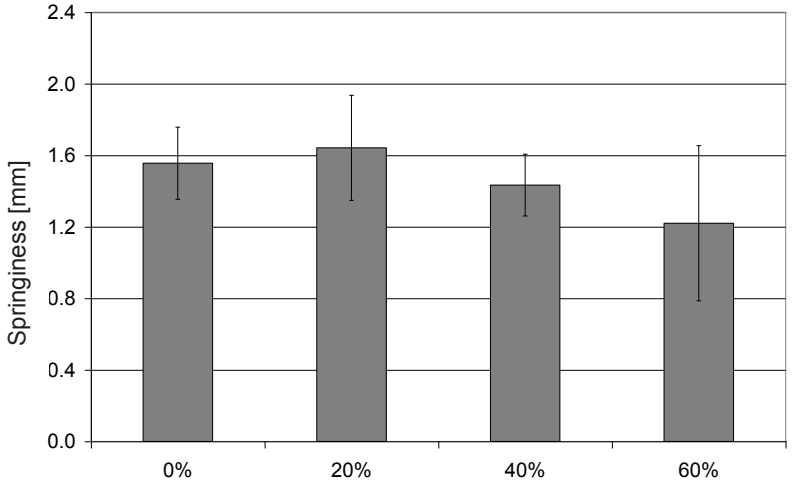


Fig. 11. Effect of sucrose concentration on springiness of VM finish dried beetroot slices

Sensory evaluation

The results of the sensory assessment of appearance, flavour and taste for VM dried beetroot samples osmotically pre-dried at different sucrose concentrations were compiled in Table 1, while the results of the sensory assessment of texture for these samples were shown in Table 2. In most cases the differences between mean values are not significant. However, the test reviled that the beetroot samples without pre-treatment were characterised by the most typical flavour and low hardness, crispiness and tooth packing as well as low attributes of colour and taste. The samples pre-dried at the sucrose concentration 60% exhibited the lowest typical flavour, the lowest gumminess, fibrousity and tooth packing as well as the excellent appearance, taste and crispiness. High crispiness is a positive attribute of the food texture [Szcześniak 1971]. It can be stated that the best product in terms of flavour does not require the pre-treatment in sucrose solution but in terms of appearance, taste and texture involves pre-drying at sucrose concentration amounted to 60%. This increased crispiness evaluated in sensory assessment is associated with decreased cohesiveness and springiness determined in TPA test. The optimal quality of the VM finish dried beetroot slices can be obtained by pre-drying in sucrose solution with concentration between 40 and 60%.

Table 1

Sensory assessment of appearance, flavour and taste for beetroot samples osmotically pre-dried at different sucrose concentrations

Sucrose concentration (%)	Appearance		Flavour	Taste	Taste
	colour	colour uniformity	typical	typical	sweetness
0	6.56±0.79a	5.13±1.10a	7.00±1.28a	7.56±0.63a	5.38±0.73a
20	5.88±1.09a	4.69±0.78a	5.14±0.87a	7.25±0.43a	5.38±0.83ab
40	7.75±0.58a	7.56±0.70a	5.00±0.82a	9.25±0.30ab	6.81±0.62ab
60	7.94±0.57a	6.56±0.90a	4.00±1.31a	8.06±0.58b	7.44±0.59b

Different letters at mean values indicate significant differences (Duncan test, $p<0.05$)

Table 2

Sensory assessment of texture for beetroot samples osmotically pre-dried at different sucrose concentrations

Sucrose concentration (%)	Texture				
	hardness	crispiness	gumminess	fibrousity	tooth packing
0	4.94±0.77ab	3.06±0.93ab	5.63±0.80a	5.06±1.11a	4.56±1.15a
20	4.06±0.38b	2.13±0.60a	6.50±0.71a	5.25±1.44a	5.00±0.96a
40	6.38±0.73a	5.38±0.44bc	6.25±1.15a	4.75±1.22a	5.43±1.15a
60	6.75±0.66a	6.69±1.14c	3.88±1.25a	3.81±1.28a	4.50±1.11a

Different letters at mean values indicate significant differences (Duncan test, $p<0.05$)

Conclusions

1. The mass of samples during osmotic pre-treatment in sucrose solutions was decreasing until the equilibrium stage as the result of water flux from the raw material to the osmotic solution and solids transfer from the solution to the raw material.
2. The increase in sucrose concentration decreased the mass and final moisture content of the pre-treated samples.
3. The decrease in moisture content of the beetroot slices during vacuum-microwave (VM) finish drying could be described with an exponential equation.
4. While VM finish drying the temperature of samples was increasing until the certain moisture content and then was decreasing as the result of the balance of energy generated within the dried material by dipoles of water and the energy necessary for water evaporation.
5. The increase in sucrose concentration decreased density, shrinkage, cohesiveness and springiness but in the same time increased hardness and the colour parameters of the finish-dried product.
6. The best product in terms of flavour does not require the pre-treatment in sucrose solution but in terms of appearance, taste and texture involves pre-drying at sucrose concentration amounted to 60%. The optimal quality of VM finish dried beetroot slices can be obtained by the osmotic pre-drying in sucrose solution with concentration between 40 and 60%.

NOMENCLATURE

a^* Redness
b^* Yellowness
L^* Lightness
m Mass (kg)
MR Moisture ratio
M_e Equilibrium moisture content (kg/kg db)

M_0	Initial moisture content (kg/kg db)
R^2	Coefficient of determination
S	Shrinkage (%)
t	Time (min)
TPA	Texture Profile Analysis
V	Volume (m^3)
V_0	Initial volume (m^3)
VM	Vacuum-microwave
Δm	Change of mass (g)
ρ	Density (g/cm^3)

Acknowledgements

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References

Atamanova A., Brezhneva T.A., Slivkin A.I., Nikolaevskii V.A., Selemenev V.F., Mironenko N.V., 2005. Isolation of saponins from table beetroot and primary evaluation of their pharmacological activity. Pharmaceutical Chemistry Journal, 39(12), 650–652.

Böhm V., Kühnert S., Rohm H., Scholze G., 2006. Improving the nutritional quality of microwave-vacuum dried strawberries: a preliminary study. Food Science and Technology International, 12, 67–75.

Cui Z.W., Xu S.Y., Sun D.W., 2003. Dehydration of garlic slices by combined microwave-vacuum and air drying. Drying Technology, 21 (7), 1173–1184.

Cui Z.W., Xu S.Y., Sun D.W., [2004]. Microwave-vacuum drying kinetics of carrot slices. Journal of Food Engineering, 65, 154–164.

Delwiche S.R., Pearson J.L., Sanders T.H., Wilson D.M., Shupe W.L., 1986. Microwave vacuum drying effect on peanut quality. Peanut Science, 13 (1), 21–27.

de Zwart, F.J., Slow S., Payne R.J., Lever M., George P.M., Gerrard J.A., Chambers S.T., 2003. Glycine betaine and glycine betaine analogues in common foods. Food Chemistry, 83, 197–204.

Dias M.G., Camões M.F.G.F.C, Oliveira L., 2009. Carotenoids in traditional Portuguese fruits and vegetables. Food Chemistry, 113, 808–815.

Durance T.D., Wang, J.H., 2002. Energy consumption, density, and rehydration rate of vacuum-microwave and hot-air convection-dehydrated tomatoes. Journal of Food Science, 67 (6), 2212–2216.

Falade K.O., Akinwale T.O., Adedokun O.O., 2003. Effect of drying methods on osmotically dehydrated cashew apples. European Food Research and Technology, 216, 500–5004.

Falade K.O., Oyedele O.O., 2010. Effect of osmotic pretreatment on air drying characteristics and colour of pepper (Capsicum spp) cultivars. Journal of Food Science and Technology, 47 (5), 488–495.

Figiel A., 2010. Drying kinetics and quality of beetroots dehydrated by combination of convective and vacuum-microwave methods. Journal of Food Engineering, 98, 461–470.

Hu Q.G, Zhang M., Mujumdar A.S, Xiao G.N., Sun J.C., 2006. Drying of edamames by hot air and vacuum microwave combination. Journal of Food Engineering, 77, 977–982.
Jastrebova J., Witthoft C., Grahn A., Svensson U., Jagerstad M., 2003. HPLC determination of folates in raw and processed beetroots. Food Chemistry, 80, 579–588.
Kapadia G.J., Tokuda H., Konoshima T., Nishino H., 1996. Chemoprevention of lung and skin cancer by Beta vulgaris (beet) root extract. Cancer Letters, 100, 211–214.
Krulis M., Kuhnert S., Leiker M., Rohm H., 2005. Influence of energy input and initial moisture on physical properties of microwave–vacuum dried strawberries. European Food Research Technology, 221, 803–808.
Le Maguer M., 1988. Osmotic dehydration: review and future direction. In Proceedings of the International Symposium on Program in Food Preservation Process, CERIA, Brussels, p. 238.
Lin T.M., Durance T.D., Scaman C.H., 1998. Characterization of vacuum microwave, air and freeze dried carrot slices. Food Research International, 31 (2), 111–117.
Mousa N., Farid M., 2002, Microwave vacuum drying of banana slices, Drying Technology, 20, 2055–2066.
Nawirska A., Figiel A., Kucharska A.Z., Sokół-Łętowska A., Biesiada A., 2009. Drying kinetics and quality parameters of pumpkin slices dehydrated using different methods. Journal of Food Engineering, 94, 14–20.
Patkai G., Barta J., Varsanyi I., 1997. Decomposition of anticarcinogens factors of the beetroot during juice and nectar production. Cancer Letters, 114, 105–106.
Piotrowski D., Lenart A., Wardzyński A., 2004. Influence of osmotic dehydration on microwave-convective drying of frozen strawberries. Journal of Food Engineering, 65, 519–525.
Raoult-Wack A.L., 1994. Recent advances in the osmotic dehydration of foods. Trends in Food Science and Technology, 5 (8), 255–260.
Sham P.W.Y., Scaman C.H., Durance T.D., 2001. Texture of vacuum microwave dehydrated apple chips as affected by calcium pretreatment, vacuum level, and apple variety. Journal of Food Science, 66 (9), 1341–1347.
Sharma G.P., Prasad S., 2004. Effective moisture diffusivity of garlic cloves undergoing microwave – convective drying. Journal of Food Engineering, 65, 609–617.
Sunjka P.S., Rennie T.J., Beaudry C., Raghavan G.S.V., 2004. Microwave-convective and microwave-vacuum drying of cranberries: a comparative study. Drying Technology, 22 (5), 1217–1231.
Szczesniak A.S., Kahn E.L., 1971. Consumer awareness of attitudes to food texture: adults. Journal of Texture Studies, 2, 280–295.
Tang J., 2005. Dielectric properties of foods. In H. Schubert, M. Regier (Eds.), The microwave processing of foods (pp. 22–40). CRC Press LLC, Boca Raton, Boston, New York, Washington, DC.
Torringa E., Esveld E., Scheewe I., van den Berg R. Bartels, P., 2001. Osmotic dehydration as a pretreatment before combined microwave-hot-air drying of mushrooms. Journal of Food Engineering, 49, 185–191.
Váli L., Stefanovits-Bányai E., Szentmihályi K., Fébel H., Sárdi E., Lugasi A., Kocsis I., Blázovics A., 2007. Liver-protecting effects of table beet (*Beta vulgaris var. rubra*) during ischemia-reperfusion. Nutrition, 23, 172–178.
Zenoozian M.S., Devahastin S., 2009. Application of wavelet transform coupled with artificial neural network for predicting physicochemical properties of osmotically dehydrated pumpkin. Journal of Food Engineering, 90, 219–227.

4

EVALUATION OF SMOKED MEAT PRODUCTS QUALITY BASED ON THE EXAMPLE OF "SOPOCKA" LOINS

Introduction

Meat market in Poland consists of several thousands of businesses of different profiles and areas of activity. These are small local businesses, operating only in certain regions of our country as well as the large companies of the domestic and foreign capital that operate on the Polish, European and global market. Poland plays a significant role in the international meat trade. Both, exports and imports of Polish meat products are carried out in cooperation with the European Union. The EU countries account for more than 80% of consumers of Polish meat [Ciegiełka, Sałasińska 2010]. Development of local industry has a huge impact on foreign trade in meat products.

The varietyofmeat products is increasingduetogrowingcompetition on the market. It has a big influence on the producersof meat, changes in consumers`trendsandrequirements. Additionally the increase of nutrition awareness is observed. Such consumer behaviours mobilize producers to invest in upgrading facilities to meet the requirements concerning the need of better food safety related to the high product quality. As competition in the meat market is increasing and manufacturers are marketing more and more innovative products. Consumers have wider choice, therefore manufacturers are forced to produce even more attractive goods [Piekut 2008].

To increase the shelf life and improve sensory quality of meat products smoking process is applied in food production. It is an ancient technological action in meat processing, being an integral part of the curing process of many traditional products. It is one of the oldest methods applied in countries of the Centre-North Europe, where environmental conditions do not favour water loss during meat maturation. In cured meat products, smoking, combined with salting and partial dehydration, increases the shelf life, due to surface drying and deposition onto the surface of antioxidant and antimicrobial compounds. Process parameters (temperature, length, distance smoking source-product, relative humidity) and product characteristics markedly influence absorption and penetration of the smoke compounds into the product and, thus, its quality and stability. From a sensory viewpoint, free amino acid patterns influence the taste properties of ripened meat products as they act as precursors of compounds that contribute to sour, sweet and bitter notes [Córdoba et al. 1994]. Some of them could also contribute to the formation of volatile compounds by different pathways (such as the Strecker degradation or the reaction with reducing compounds in the Maillard reaction) or degradate to amines influencing the final quality of the meat ripened products [Ruitz et al. 1999].

The quality of meat products is also considered in the context of sensory appeal, safety and availability. In order to gain consumers acceptance for the product, it must have high quality, especially the sensory one. Because of existing civilization diseases the nutritional

value of the product, is also an important factor of consumers` choices. Recently, sensory quality has become the most important factor in the food products selection by customers, among the various and wide range of products on the market. It has also become an important factor for producers and entrepreneurs. Consumer preferences are often unstable and depend on many different factors. The issue is not so simple due to fact that these factors have different importance and different influence on consumers behaviour. During sensory tests, the behaviour and preferences of the present-day consumers are observed. The knowledge of crucial factors of acceptance or food preferences, increases the effectiveness of the influence on food choice and consumption of specific foodstuffs [Baryłko-Pikielna and Kostyra, 2004].

The quality of food products is also considered in terms of microbiological quality, which determines whether the food placed on the market is suitable for consumption and if there is no negative impact on consumer health. Proper microbiological quality of meat depends on the microbiological quality of raw material. processing procedures, the way of preservation and storage conditions as well as the possibility of secondary infections. Any foods stuffs including meats, must have a suitable microbiological quality, which ensures the health safety of the product [Kołożyn-Krajewska 1998].

The inspection carried out by the appropriate authorities indicated that, in some of the market products some irregularities were observed, which reveal a reduced amount of protein and an excessive fat content. The addition of starch and water was also too high in comparison with the manufacturer's declaration (www.ijhars.gov.pl).The fact may be indicative of attempts to increase the efficiency of the finished product. Lowered protein and higher water content are considered inappropriate for food quality.

Smoked meat products such as Sopocka loins can be produced using the method which guaranties a high yield rate of the final product, ranging from 90 to 130% in relation to raw meat. Smoked meat products characterized by high efficiency are produced with the ingredients which cause the increase of water absorption [Zin 2009].

The aim of the study was to characterize and evaluate the quality of selected Polish pork loins available on the local market.

Materials and Methods

The study was conducted on five samples of Sopocka loins coming from different Polish producers. The samples were purchased in one of Warsaw's whole sale meat company. All tested products were vacuum packed and characterized by comparable shelf life.

Microbiological evaluation

The microbiological analysis consisted of determination total bacteria count (TBC) and total viable count (TVC) using pure plate method (deep inoculating method). The samples were prepared with 5 g of product and 45 ml solution. The samples were collected under sterile conditions. Then the solution 10^{-3}, 10^{-4}, 10^{-5} were prepared. Every sample was prepared in 2 repetitions. The tests were incubated at 30^{o}C for 72 hours. Then the number of microorganisms (L) in a cm^3 or 1 g of sample was calculated and the results were presented as cfu/cm^3 e.g. colony forming units par cm^3 [Burbianka 1983].

Sensory evaluation

The sliced loins samples (25 g) were placed in plastic odourless, disposable boxes covered with lids. For sensory assessment, the sensory QDA method [ISO 13299.2:1998] was applied; an unstructured, linear graphical scale; a 100 mm than converted to numerical values (0–10 conventional units c.u.) Descriptors were chosen, defined and verified in a preliminary session Finally, 13 sensory attributes were measured to quantify the quality of the tested products (5 attributes of odour, 3 attributes of visual quality and texture as well as 5 attributes of flavor). The marks of anchors of the tested attributes were as follows for most of them: no intensity – high intensity, for juiciness (dry – juicy). On the basis of the above mentioned quality characteristics, the assessing sensory panel indicated an overall sensory quality (low – high) for each sample on a separate scale.

All samples were separately coded for assessment with three digit codes and were passed in random order to avoid the carry-over effect (i.e. the impact of a previous sample on the subsequent one).

The trained 10-person panel [ISO 8586–2:1994] assessed the studied material. The panel members were well experienced in meat and meat products evaluation (3–8 years of evaluation practice).

The assessment was conducted in rooms with daylight. Between the subsequent evaluations, the assessors received hot tea without sugar to neutralize the taste. All samples were determined using separate sheets including the instruction of estimation. The estimation was repeated twice so each average result was based on minimum of 18 individual results. The sensory experiment was carried out in the Catering Technology and Food Hygiene, Department of the Faculty of Human Nutrition and Consumer Sciences of Warsaw University of Life Sciences – SGGW. Condition and the assessment mode were determined in accordance with Meilgaard et al. [1999].

Chemical analysis

The chemical analysis was carried out in the Analytical Center at WULS Chemical Laboratory in Warsaw.

Protein content. The examination of protein content was determined by Kjeldahl method. The analysis proceeds was determined in 1 g sample after mineralization in boiling sulfuric acid, which decomposes the organic substance by oxidation to liberate the reduced nitrogen as ammonium sulfate. Based on the amount of 0,1 M HCl solution used to sample titrate the calculated amount of nitrogen was calculated. The result of nitrogen with applying of 6,25 index was expressed as protein content [PN-A-04018:1975/Az3:2002]. Analysis of the samples was performed in triplicate.

Fat content. Fat amounts were obtained by Soxhlet ether extraction methods. The individual sample was about 5 g [ISO 1444:2000]. Freeze-dried samples were placed in a Soxhlet apparatus and refluxed with petroleum ether for approximately 18 h. Fat was removed and placed under a hood to allow ether to evaporate, and placed in a convection oven for approximately 12 h and than was removed and placed in a desiccators until cooled to room temperature. Weights were taken and recorded to determine percentage of fat in each sample. Analysis of the samples was performed in triplicate.

Water content. The water content of the samples (approximately 3 g) was determined by drying at 105±2°C to a constant weight [PN-A-82110:1973]. The individual sample was approximately 5 g. Water content of the samples was expressed as a percentage.

NaCl content. The study was performed NaCl content by Mohr's method. The average individual sample was 10 g. This method consists of salt extraction with hot water, and then titration of chloride standard solution of silver nitrate to the indicator (chromate of potassium). The amount of silver nitrate used in the titration allowed the calculation of salt percentage in the sample [PN-A-82112:1973].

Nitrate and nitrite content. The samples were evaluatedaccording to PN-92/A-75-112. Study of nitrate and nitrite were determined by HPLC method is based on two phases: mobile phase, which is liquid and the stationary phase, which is a solid or liquid. The sample was applied to the apparatus consisting of a chromatography column, where there is a separation of substances and the isolation of nitrate and nitrite. Amount of nitrates and nitrites in the sample in mg/ kg was displayed.

Data analysis

The received results were calculated using the STATISTICA version 9.0. [Stat Soft, Inc. 2009]. Comparison of mean values was performed on the basis of Duncan's multiple range test. The ANOVA test was used for results calculation concerning the sensory analysis. The relationship between the measured attributes in sensory assessment was performed using simple Pearson correlations.

Results and Discussion

The microbiological study. All tested products were vacuum packed which should have a positive influence on microbiological stability of tested products.

This study showed that among the tested five pieces of loin only three samples were characterized by the overall number of bacteria colony below the level of 10^{-5} .The highest total number of microorganisms was detected in loin coded A [3.5 10^6 jtk/cm^3] and in sample coded B [1.88 10^6 jtk/cm^3]. In case of the loins D, E and C the number of colony-forming bacteria were detected below 10^{-5} jtk/cm^3 . The microbiologicalquality was inappropriate in case oftwo tested samples (www.wetgiw.gov.pl).

Microbiological quality is a crucial factor in food production include the products of animal origin, as in most microbiological hazards the ability to multiply the production of micro-organisms or their toxins is significant.

They are the main causes of many health complications; they can lead to permanent health damage. According to the law manufacturers and distributors are responsible for the products safety. Therefore, the producers who take full responsibility for the manufactured product and its health safety, must ensure adequate microbiological quality of the product. The high total number of microorganisms may be caused by poor microbiological quality of raw materials used to produce meat, poor sanitary state of the manufacturing plant, or not maintaining the cold storage chain during distribution [Kołożyn-Krajewska 1998].

The microbiological quality examination is an important stage of research to determine the overall quality of the product. The microbiological contaminations cause also visible

changes in sensory quality of any food products and shorten their shelf life. The obtained results of these studies could be a confirmation of this fact as; the lowest microbiological quality of sample A resulted also in lowest sensory quality. The increase in the degree of microbiological contamination in meat products could change quality parameters which depend also on the temperature during distribution. However, shelf life of meat products, declared by the manufacturers, depend on the type and quality of ingredients (including the ones not containing meat), the type and content of preservatives used, pH, w_a as well as the initial microbiological contamination [Cegielska-Radziejewska et al. 2007].

A storage temperature changes has as a key influence on microbiological grow dynamics. Therefore monitoring the storage conditions and preservation of cold storage chain at all stages of production, storage and distribution, provide a consumer with the product of the acceptable quality [Cegielska-Radziejewska, Pikul 2000].

Extending shelf life, at the meat product can be achieved using modified atmosphere packaging (MAP), packing with protective cultures, other methods of preservation, as well as maintaining appropriate conditions for transport and storage [Czapski et al. 1997, Danyluk et al. 2004]. MAP for meat requires a barrier of either of moisture and gas permeation through packaging materials to maintain a constant package environment during storage. For any type of MAP, it is necessary to remove or change the normal composition of atmospheric air, and encompass both aerobic and anaerobic types of packaging for meat Zhou et al. [2010].

Sensory evaluation. The analysis of the obtained results in this study showed that the studied pork loins differed significantly in overall sensory quality (Fig. 1). The analysis of results obtained by QDA method indicated that the tested material differentiated significantly in smoked odour and flavour, "other" odour and flavour attributes as well as in juiciness. Two of tested five samples (sample E and D) characterized by higher overall sensory quality in comparison to samples A, B and C. The intensity of smoked odour, flavour and juiciness ($r=0,54$; $r=0,59$ and $r=0,63$; $p<0,05$ respectively) increased the overall quality whereas the intensity of colour as well as the intensity of "other" odour and flavour decreased the quality. the calculated correlation coefficient were $r=-0,40$ ($p<0,05$) $r=-0,53$ ($p<0,05$); respectively. The tested samples did not differ in intensity of cured odour and flavour, visible fat as well as salty taste.

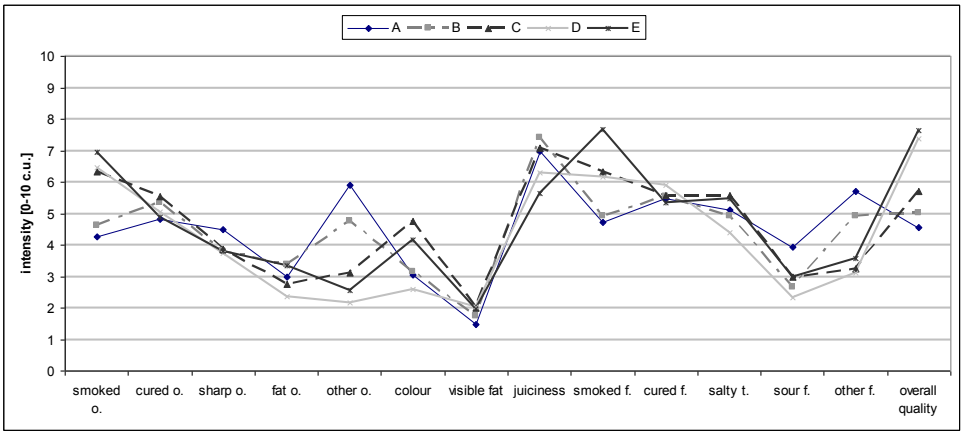


Fig. 1. The intensity of attributes of sensory quality of tested Sopocka loins assessed by QDA method (o.– odour, f.– flavor, t.– taste).

In this study it was shown that other attributes, especially those with a negative sensory influence ("other" odour and flavour as well as sour flavour), determine the overall sensory quality of examined products and are of crucial importance for the overall sensory quality. After exceeding a critical value negative attributes strongly decreased the overall sensory quality of tested products. It is known from literature that even a slight increase of negative attributes intensity, mainly flavour and especially odour is connected with a severe decrease of overall sensory quality of food products. Those relations are not linear in their nature [Meilgaard et al. 1999, Baryłko-Pikielna, Matuszewska 2009].

The flavor of food is a combination of its taste and aroma, which are produced by non-volatile and volatile compounds, respectively. Raw meat is generally characterized as being salty, metallic and bloody tasting with a sweet aroma. During the subsequent processing numerous precursors react to form the characteristic taste and aroma of cured meat products [Ruiz et al. 1999]. A positive effect of smoking on the concentration of some volatile compounds with positive influence on meat product flavor as was observed in presented study. Juiciness also has an important role in overall quality of cured meat products. Juiciness is related to the degree of lubrication of the food during the chewing and the subsequent swallowing. However, the relationship between the subjective sensation and any objective measurement has not been clearly understood. At any rate, the juiciness of meat products is considered to arise from the moisture released by the product during chewing and the moisture from saliva. Intramuscular fat stimulates the saliva secretion and contributes itself to the juiciness by coating on the tongue, teeth and other parts of the mouth. Due to the dehydration that takes place during the processing of cured products, the direct contribution of intramuscular fat itself plays a very important role in their juiciness [Ruiz et al. 1998. Ruiz et al. 2002].

Chemical evaluation. The obtained results regarding protein, fat and water content in tested loins samples are presented in Table 1. The obtained results indicated that the tested samples were significantly different regarding measured traits. The protein content in the studied samples was from 12.5 to 26.1%. According inapplicable PN-A-82007 standard the lowest protein content should have been on the level 12–15%; two of the tested samples (B and C) characterized by protein content around 12%. The tested loins were also characterized by different fat content (from 0.62 to 3.39%) as well as water content (70.7–80.6%). the received results were in acceptable standards for such a meat products. The same samples which were characterized by lowest protein content characterized also by water content above 78% (sample B and C).

Table 1

The protein, fat and water content in the tested Sopocka loins samples

Tested samples	Protein (%)	Fat (%)	Water (%)
A	14.7	1.78	77.2
B	12.8	0.99	80.6
C	12.5	0.62	78.8
D	19.9	1.97	75.7
E	26.1	3.39	70.7

The obtained results indicated that higher sensory quality of the tested products was connected with higher amount of protein. The overall sensory quality was conversely correlated with the water content ($r=-0,71$, $p<0,05$). Water content and fat content correlated with

sensory juiciness of tested samples. The intensity of smoked odour and flavour attributes correlated positively with protein content (from r=0,66 to r=0,78; p<0,05). It could be also pointed that the overall sensory quality was related to the prices of specific products.

Additionally the tested material was examined regarding nitrate and nitrite as well as NaCl content (Table 2).

Table 2

The results of NaCl, nitrate and nitrite content in the tested Sopocka loins

Tested samples	NaCl (%)	Nitrate and Nitrite (mg/kg)
A	2,64	< 0,250
B	2,80	< 0,250
C	3,52	< 0,250
D	1,97	< 0,250
E	2,80	< 0,250

The evaluated NaCl content was connected with the salty taste obtained in the sensory assessment. The excess of salt as well as nitrates and nitrites content, regarding specific regulation [Dyrektywa 2006/52/ WE], was not observed in any samples (Table 2). The excessive amount of sodium chloride, nitrate and nitriteconsumption with food products could have an adverse effect on human body [Jarosz 2006]. In the study of Tietze et al. [2007] it was showed that assessed nitrogen level in animal origin products was within acceptable standards.

Conclusions

The microbiological study showed that among the tested five pieces of loin only three samples were characterized by the overall number of bacteria colony below the level of 10^{-5}jtk/cm^3.

The tested samples were significantly different regarding protein, fat and water content. The obtained protein content in the studied samples was from 12.5 to 26.1%; two of five tested samples characterized by the protein level below 15%. The tested loins were also characterized by different water content (70.7–80.6%) and fat content (from 0.62 to 3.39%). The excess of salt as well as nitrates and nitrites contentwas not observed in any samples

The analysis of the obtained results in this study showed that the studied pork loins differ significantly in overall sensory quality.The intensity of smoked meat odour and flavour and juiciness influenced positively the sensory quality of studied loin samples. In this study it was shown that attributes with a negative sensory influence ("other" odour and sour flavour) decreased the overall sensory quality of examined products.

References

Baryłko-Pikielna N., Kostyra E., 2004. Współczesne trendy wyboru i akceptacji żywności, Przemysł Spożywczy, 58, 12, 3–10.

Baryłko-Pikielna N., Matuszewska I., 2009. Sensoryczne badania żywności, Wyd. Naukowe PTTŻ, Kraków.

Burbianka M., Pliszka A., Burzyńska H., 1983. Mikrobiologia żywności, Wyd. PZWL, Warszawa.

Cegielska-Radziejewska R., Pikul J., 2000. Influence of storage temperature on the quality and shelf-life of sliced poultry sausage packed under modified atmosphere. Food Sciences Technology 4, 17–38.

Cegielska-Radziejewska R., Kijowski J., Nowak E., Zabielski J., 2007. Żywność. Nauka. Technologia. Jakość. „Wpływ temperatury na dynamikę zmian liczby bakterii w wybranych wędlinach przechowywanych w warunkach handlu hurtowego i detalicznego", 76–88.

Cegiełka A., Sałacińska D. Gospodarka Mięsna. www. mieso.com.pl

Cordoba J.J., Antequera T., Ventanas J., Lopez-Bote C., Garcia C., Asensio M.A., 1994. Hydrolysis and loss of extractability of proteins during ripening of Iberian ham. Meat Science, 37, 217–227.

Czapski J., Michniewski J., 1997. Wpływ opakowania na zmiany jakości żywności podczas przechowywania. Przemysł Spożywczy 10 (51), 15–19.

Danyluk B., Gajewska-Szczerbal H., Pyrcz J., Kowalski R., 2004. Trwałość mikrobiologiczna wędlin pakowanych próżniowo. Acta Sciences Polonorum. Technologia Alimentaria, 3, 2, 37–44.

ISO 13299.2:1998. Sensory analysis–methodology–general guidance for establishing a sensory profile.

ISO 1444:2000. Meat and meat products – Determination of free fat content.

ISO 8586–2:1996. Sensory analysis. General guidance for the selection, training and monitoring of assessors part II – Experts.

Jarosz M., 2006. Otyłość, żywienie, aktywność fizyczna, zdrowie Polaków. Wyd. Instytut Żywności i Żywienia, Warszawa

Kołożyn-Krajewska D., 1998. Studium zapewnienia jakości żywności w aspekcie bezpieczeństwa zdrowotnego na przykładzie wybranych produktów mięsnych, Wyd. SGGW, Warszawa.

Meilgaard M, Civille GV and Carr BT, 1999. Sensory evaluation techniques (3rd ed.), London, CRC Press.

Piekut M., 2008. Konsumpcja wędlin – spożycie, preferencje, czynniki wyboru. Gospodarka Mięsna 01/2008.

PN-A-04018:1975/Az3:2002. Produkty rolniczo-żywnościowe Oznaczanie azotu metodą Kjeldahla i przeliczanie na białko.

PN-A-82055–6:1994. Mięso i wędliny. Badania mikrobiologiczne. Oznaczanie ogólnej liczby drobnoustrojów.

PN-A-82110:1973 Mięso i przetwory mięsne. Oznaczanie zawartości wody.

PN-A-82112:1973 Mięso i przetwory mięsne. Oznaczanie zawartości soli kuchennej.

Ruiz J., Garcıa C., Muriel E., Andres A.I., Ventanas J., 2002. Influence of sensory characteristics on the acceptability of dry-cured ham Meat Science, 61, 347–354.

Ruiz, J., Ventanas, J., Cava, R., Andre´ s, A. I., Garcı´a, C., 1999. Volatile compounds of dry-cured Iberian ham as affected by the length of the curing process. Meat Science, 52, 19–27.

StatSoft, Inc. 2009. Statistica (data analysis software system), version 9.0. www.statsoft.com

Tietze, M. Burghardt A., Brągiel, P. Mac J., 2007. Zawartość związków azotowych w produktach spożywczych. Annales Universitas Maria Curie Skłodowska Lublin Polonia, XXV, (1), 71–77.

www.ijhars.gov.pl: z dnia 26.05.2010: Inspektorat Jakości Handlowej Artykułów Rolno-Spożywczych: Informacja zbiorcza o wynikach kontroli w zakresie jakości handlowej przetworów z mięsa czerwonego.

www.wetgiw.gov.pl z dnia 24.06.2010. Wytyczne mikrobiologiczne dla żywności gotowej do spożycia. Maj 2007. Centrum Bezpieczeństwa Żywności. Departament ds. Żywności i Higieny Środowiska.
Zhou G.H., Xu X.L., Liu Y., 2010. Preservation technologies for fresh meat – A review Meat Science 86, 119–128.
Zin M., 2009. Ocena żywności i żywienia, Wyd. Uniwersytetu Rzeszowskiego, Rzeszów.

5

EVALUATION OF SENSORY PROPERTIES OF NEW TYPE AGAR JELLIES

Introduction

Diet rich in fibre and low in sucrose may be important factor in preventing cardiovascular, neoplastic diseases and slowing down the aging processes. The problem of cardiovascular diseases and the related nutritional problems like obesity and overweight have become an important issue in Latvia lately [Kronberga, Karklina 2010, Roberfroid 2005].

Food products introduced as 'new' to the market by food companies can be classified as new form of existing products or reformulation of them. That kind of products can have better colour, improved physical and sensory properties, contain more fibre or less fat. Development of these products may require a longer time, but small changes in the manufacturing process, storage and handling would be performed at minimum costs [Linnemann et. al 2006, Peleg 2006).

Confectionery products are foodstuffs where the emphasis is made on enjoyment. Jellies are high-energy products, meaning that the products are not suitable or acceptable for people who have glycemic problems, obesity, diabetes, and cardiovascular diseases.

Since the principal ingredient of most candies is sugar (sucrose), attempts at reducing the caloric content have been made by reducing the amount of sugar used in their production. Sugar is often used as a bulk chemical, i.e. added in large amounts to food and contributes to sweetness and texture properties [Дубцов et. al 2001, Павлова 2000]. A change in sugar content may therefore both change the perception of sweetness and texture [Bayarri et. al 2004]. From a chemical point of view, there is a large number of sugars and they taste very different from one another [Figuerola 2007]. Sucrose can be replaced by fructose, maltose or different kinds of syrups prepared from certain sugars [Kronberga et al. 2011, Kronberga, Karklina 2011].

Inulin, polysaccharide composed of fructose, is legally classified as food ingredient beloing to the low-calorie sweetener [Frack 2002, Glibowski 2009, Glibowski, Wasko 2008, Kealy 2006, Roberfroid 2005] in all countries where they are used. Jerusalem artichoke (*Helianthus tuberosus* L.) is one of the raw materials what is used for production of high fructose syrups. Jerusalem artichoke is characterized as showing interesting hypoglycemic properties. Its presence in the diet is very useful in controlling the level of blood glucose in diabetic people [Kaur, Gupta 2002, Kronberga, Karklina 2011].

Malt extracts containing disaccharide maltose from starch hydrolysis, is prepared from wort. Malt extract products may improve glycemic control in diabetic population and is used in the production of desserts, soft drinks, ice cream and other foods that are high in carbohydrates as a substitute of sugar.

Sensory and product testing researches are often responsible for new product development and strengthening their position on the market. One of the consumers' demand high-quality products in various innovative forms and for competitive prices [Ekpong et. al 2006]. Product texture could be related to the freshness and excellence of food preparation. Some concerns about health effects could be associated with off textures. Odour can be signal of spoiled food that may be harmful to consumer's health when eaten. People like to be in full control of the food placed in their mouth. Gummy or slimy food, or food, containing unexpected lumps or hard particles, is rejected [Kealy 2006].

Producers are trying to relate consumers' expectations with sensory quality characteristics responsible for product preference. In the contest, food industry carries out different sensory analytical tests [ISO 4121:2003, Blancher et. al 2007, Moskowitz et. al 2006]. Using consumers to measure hedonic acceptability and attribute intensities is a feasible and effective option for product optimisation [Ekpong et. al 2006].

Therefore the aim of the research work to evaluate the effect of inulin syrup and malt extract on the sensory properties of agar-based jellies.

Materials and Methods

The research was carried out in the laboratories of the Faculty of Food Technology in Latvia University of Agriculture.

Materials

The Jerusalem Artichoke Juice Concentrateproduced by Topina, Diät Rohstoff Gmb, (Germany) and malt extract produced by Ilgezeem brewery (Latvia) were used to replace sugar in experimental jellies. Glucose syrup was obtained from the confectionary factory "Laima" (Latvia). Sugar, citric acid and cacao powder were purchased in a local supermarket.

In the preparation of jellies, the gelling substance AgarNordS (E 406) (Estonia) was used. Agar was soaked in cold water, and then heated until agar was dissolved in water [Barrangou et. al 2006, Panouille and Larreta-Garde 2009].

Preparation of jelly samples

The experimental jelly samples were made using recipes and technological scheme presented in Table 1, 2 and Figure 1.

In the research, the replacement of sugar by inulin syrup or malt extract was made in the following ratios 20, 40, 60, 80 and 100% according to the recipes in Table 1 and 2. Figure 1 shows the technological scheme of preparing agar jellies for sensory evaluation by panellists.

Subsequently, the obtained agar/water solution with added sugar, citric acid and other ingredients was hot–filled in 150±10 ml polystyrene (PS) containers, which were sealed with lids and cooled down to temperature 18±2°C.

Table 1

Recipes of experimental jelly samples with inulin syrup

Raw materials [g]	Samples					
	Control (K)	A	B	C	D	E
Agar powder [g]	7.3					
Glucose syrup [g]	226.3					
Sugar [g]	379.6	303.7	227.8	151.8	75.7	-
Inulin syrup [g]	–	75.9	151.8	227.8	303.7	379.9
50% citric acid solution [g]	7.3					
Cacao powder [g]	14.5					
Water [g]	365.0					
Total [g]	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0

Table 2

Recipes of experimental jelly samples with malt extract

Raw materials [g]	Samples					
	Control (K)	F	G	H	I	J
Agar powder [g]	7.3					
Glucose syrup [g]	226.3					
Sugar [g]	379.6	303.7	227.8	151.8	75.7	–
Malt extract [g]	–	75.9	151.8	227.8	303.7	379.9
50% citric acid solution [g]	7.3					
Cacao powder [g]	14.5					
Water [g]	365.0					
Total [g]	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0

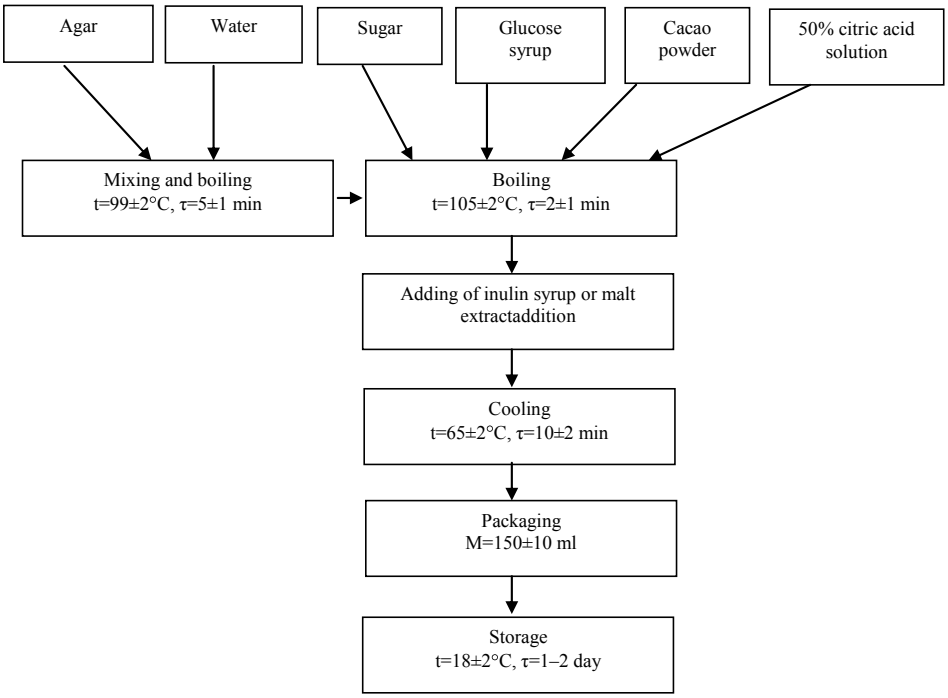


Fig. 1. The technological process of preparing experimental jellies

Sensory evaluation

The hedonic evaluation and line scale methods were used based on ISO 4121:2003 "Sensory analysis – Guidelines for the use of quantitative response scales". A 9-point hedonic scale (9 – extremely like, 5 – neither like nor dislike, and 1 – extremely dislike) was used to determine degree of acceptance of the experimental jellies with inulin syrup or malt extract.

A panel of 25 panellists, consisting of 21 females and 4 males at age from 23 to 68, took part in this study. Panellists evaluated appearance, odour, sour taste, aftertaste, hardness and colour. The samples of experimental jellies (2×2 cm) were presented to each panellist in random order. Taking into account that the large number of samples had to be evaluated (12 samples), the samples were assessed in two sessions – 6 samples per session. The samples with the highest scores were selected for the second set of experiments. The most acceptable jelly sample was established using the ranking test (ISO 4121:2003).

Statistical analysis

The results were processed by mathematical and statistical methods. Data were subjected to one way analysis of variance (ANOVA) and Two-Way analysis of variance (ANOVA) using the statistical analysis software SPSS 14.0 for Windows, significance was defined at $p<0.05$.

Results and Discussion

The results of sensory evaluation of jellies with inulin syrup using hedonic scale and analysis of variance are summarized in Table 3.

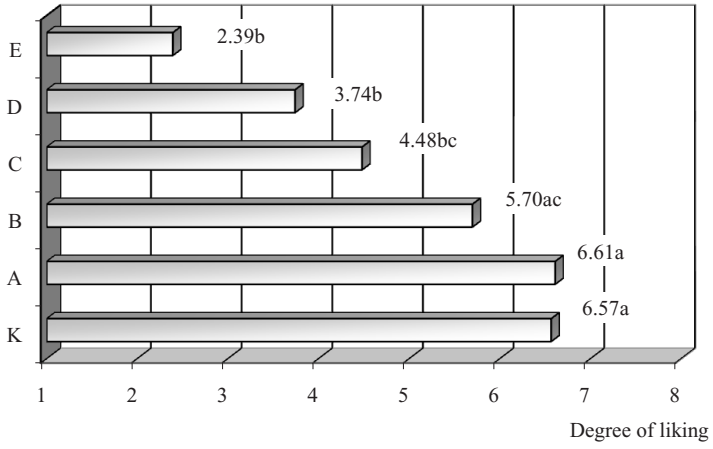
Table 3

Results of analysis of variance of jellies with inulin syrup using hedonic scale

Source of Variation	Sum of squares, SS	Degree of freedom, df	Mean square, MS	F_{cal}	F_{crit}
Panellists	97.30	22.00	4.422	2.61	1.63
Jellies with inulin syrup	325.30	5.00	65.06	38.40	2.30
Error	186.36	110.00	1.69		
Total	608.95	137.00			

$\alpha \leq 0.05$

The results of the analysis of variance show that $F_{cal}=38.40>F_{crit}=2.30$ therefore significant differences in the degree of liking among the jelly samples with inulin syrup. The degree of liking of jellies with inulin syrup, evaluated by hedonic scores is presented in Figure 2.



Values, marked with the same letters, are not significantly different ($p>\alpha_{0.05}$)

Fig. 2. Evaluation results of jellies with inulin syrup using 9-point hedonic scale.

According to the hedonic scale panellists rated jelly samples with inulin syrup in the range from 2 (dislike very much) to 7 (like moderately). Results of the hedonic scores show that the panellists liked ($p<0.05$) samples K (control) and A (20% of sugar substituted by inulin syrup) the most, because those were pleasantly sweet with aftertaste similar to chocolate. Analysis shows that there is no significant difference in hedonic scores among the samples K,

A and B (p>0.05). The sample B did not differ from the sample C, but significant difference exist between sample D and E in the degree of liking. The samples D and E are significantly different from samples K, A and B in degree of liking. The samples E and D had pronounced aftertaste of Jerusalem artichoke and pronounced sour taste, which panellists did not like.

The assessment results of the intensity of sensory properties – appearance, odour, sour taste, aftertaste, hardness and colour of jellies with inulin syrup are presented in Figure 3.

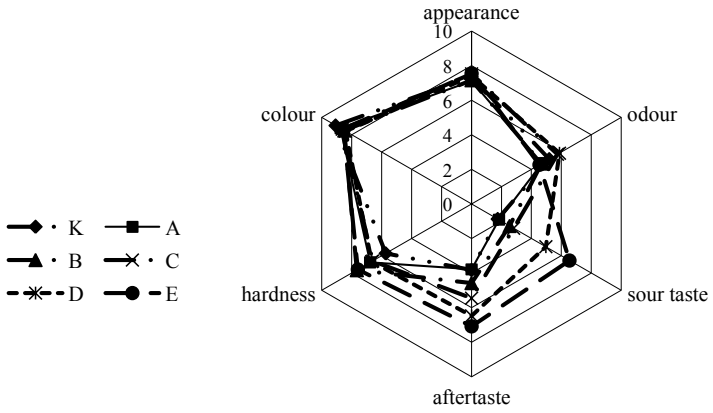


Fig. 3. Intensity of sensory properties of jellies with inulin syrup

Evaluation of intensity of sensory properties of jellies with inulin syrup shows that there is no significant difference (p>0.05) in appearance, colour and odour, but there is significant difference in intensity of sour taste, aftertaste and hardness (p<0.05).

The results of sensory evaluation of jellies with malt extract and analysis of variance are summarized in Table 4.

Table 4

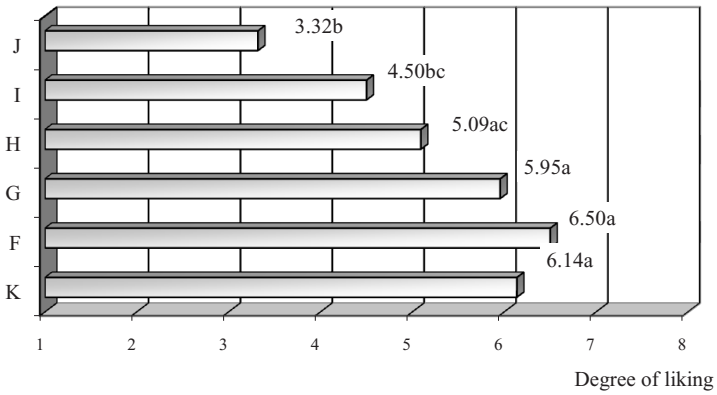
Results of analysis of variance of jellies with malt extract using hedonic scale

Source of Variation	Sum of squares, SS	Degree of freedom, df		Mean square, MS	F_{cal}	F_{crit}	
Panellists		71.89	22.00	3.27	12.07	1.64	
Jellies with malt extract		560.14	5.00	112.029	4.13	2.30	
Error		297.88	110.00	2.70			
Total		754.31	137.00				

$\alpha \leq 0.05$

The results of the analysis of variance show that $F_{cal}=4.13>F_{crit}=2.30$ therefore there are significant differences in the degree of liking among the samples of jellies with malt extract.

The results of hedonic evaluation of jellies with malt extract are presented in Figure 4.



Values, marked with the same letters, are not significantly different ($p>\alpha_{0.05}$)

Fig. 4. Evaluation results of jellies with malt extract using 9-point hedonic scale

According to the hedonic scale panellists rated jelly samples with malt extract in the range from 3 (dislike moderately) to 7 (like moderately). Results of the hedonic scores show that the panellists liked ($p<0.05$) the most the samples K (control) and F (20% of sugar substituted by malt extract), because those were pleasantly sweet. Analysis shows that there is no significant difference in hedonic scores among the samples K, F, G and H ($p>0.05$). The sample H did not differ from the sample I, but significant difference exist in degree of liking comparing to the sample J. The samples I (80% of sugar substituted by malt extract) and J (100% of sugar substituted by malt extract) had very pronounced taste of malt extract and unpleasant aftertaste.

The assessment results of the intensity of sensory properties – appearance, odour, sour taste, aftertaste, hardness and colour of jellies with malt extract are presented in Figure 5.

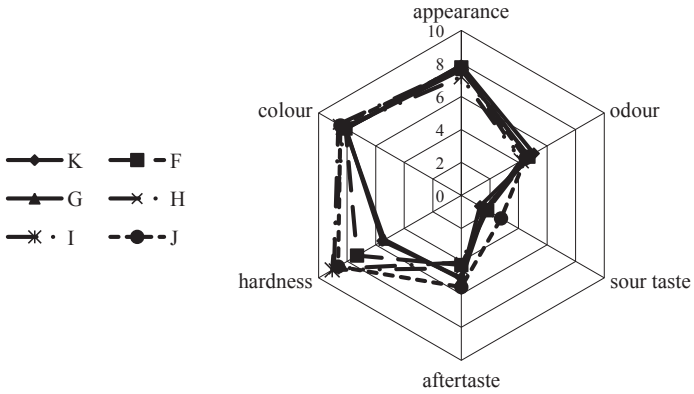
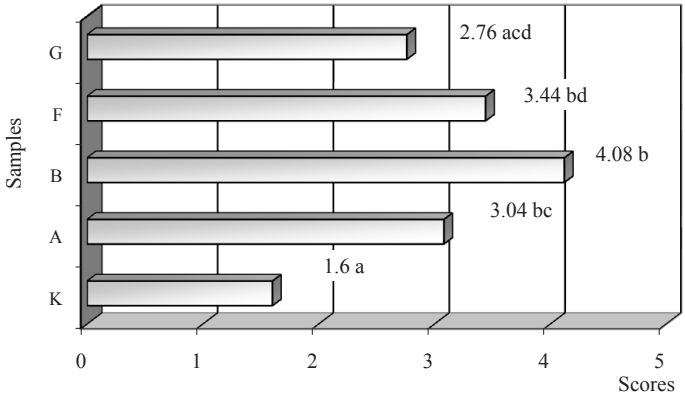


Fig. 5. Intensity of sensory properties of jellies with malt extract

Evaluation of intensity of sensory properties of jellies with malt extract shows that there is no significant difference ($p>0.05$) in appearance, odour, sour taste aftertaste and colour, but there exist significant difference in intensity of aftertaste ($p<0.05$).

After evaluation of the obtained hedonic scores the following 6 samples were selected for further studies: K (control), A (20% of sugar substituted by inulin syrup), B (40% of sugar substituted by inulin syrup), F (20% of sugar substituted by malt extract) and G (40% of sugar substituted by malt extract). Ranking test results show that significant difference exists among analyzed samples (Figure 6).



Values, marked with the same letters, are not significantly different ($p>\alpha_{0.05}$)

Fig. 6. Ranking test results for jellies with inulin syrup and malt extract

Data analysis allow drawing a conclusion that the panellists liked the best the sample K (control), followed by the sample G with 40% of sugar substituted by malt extract. Panellists found that the samples have chocolate-like taste, tender texture and pleasant aroma. The sample A (20% of sugar substituted by inulin syrup) was confessed to be the third best sample, which had a little sourness giving a refreshing taste to the sample. The sample B (40% of sugar substituted by inulin syrup), which had unpleasantly sour taste and aftertaste typical to Jerusalem artichoke. Panellists described the sample F as too sweet with pronounced aftertaste of malt extract.

Conclusions

Results of the hedonic evaluation show that the panellists liked ($p<0.05$) samples K (control) and A (when 20% of sugar was substituted by inulin syrup), because they were pleasantly sweet with aftertaste similar to chocolate.

Evaluation of intensity of sensory properties of jellies with inulin syrup show that there is no significant difference ($p>0.05$) in appearance, colour and odour, but there exist significant difference in intensity of sour taste, aftertaste and hardness ($p<0.05$).

Results of the hedonic evaluation show that the panellists liked ($p<0.05$) samples K (control) and F (when 20% of sugar was substituted by malt extract), because they were pleasantly sweet.

Evaluation of intensity of sensory properties of jellies with malt extract show that there is no significant difference ($p>0.05$) in appearance, odour, sour taste, aftertaste, and colour, but there exist significant difference in intensity of aftertaste ($p<0.05$).

The obtained results of sensory evaluation of the samples showed that the agar-agar jelly with 20% of sugar substituted by inulin syrup and 40% – by malt extract have a good score.

Acknowledgements

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References

Blancher G., Chollet S., Kesteloot R., Nguyen H.D., Cuvelier G., Sieffermann J.M., 2007. French and Vietnamese: How do they describe texture characteristics of the same food? A case study with jellies. Food Quality and Preference, nr. 18, 560–575.

Barrangou L.M., Daubert C.R., Foegeding E.A., 2006. Textural properties of agarose gels. I. Rheological and fracture properties. Food Hydrocolloids, nr. 20, 184–195.

Bayarri S., Duran L., Costell E., 2004. Influence of sweeteners on the viscoelasticity of hydrocolloids gelled systems. Food Hydrocolloids, nr. 18, 611–619.

Ekpong A., Ngarmsak T., Winger R.J., 2006. Comparing sensory methods for the optimisation of mango gel snacks. Food Quality and Preference, nr. 17, 622–628.

Figuerola F. E., 2007. Berry jams and jellies. [in:] Berry Fruit. CRC Press, New York, 367–386.

Frack A., 2002. Technological functionality of inulin and oligofructose. British Journal of Nutrition, nr. 87, 287–291.

Glibowski P., 2009. Rheological properties and structure of inulin-whey protein gels. International Dairy Journal, nr. 19, 443–449.

Glibowski P., Wasko A., 2008. Effect of thermochemical treatment on the structure of inulin and its gelling properties. International Journal of Food Science and Technology, nr. 43, 2075–208.

ISO 4121:2003. Sensory analysis-Guidelines for the use of quantitative response scale.

Kaur N., Gupta A.K., 2002. Applications of inulin and oligofructose in health and nutrition. Journal of Bioscience, nr. 27, 703–714.

Kealy T., 2006. Application of liquid and solid rheological technologies to the textural characterisation of semi-solid foods. Food Research International, nr. 39, 265–276.

Kronberga M., Karklina D., Murniece I., Kruma Z., 2011. Changes of agar-agar gel properties after replacing sucrose by inulin syrup. Foodbalt 2011. Conference Proceedings, Jelgava, 137–145.

Kronberga M., Karklina D., 2011. Changes of marmelade structural properties depending on different sweet matters.Research for rural development 2011. LLU, Jelgava.

Kronberga M., Karklina D., 2010. Food suplements in optimal diet formation. Foodbalt 2010.Conference Proceedings, TTU, Tallin, 27–31.

Linnemann A.R., Benner M., Verkerk R., van Boekel M.A., 2006. Consumer-driven food product development. Trends in Food Science and Technology, nr 17, 184–190.

Moskowitz H.R., Reisner M., Itty B., Katz R., Krieger B., 2006. Steps towards a consumer-driven "concept innovation machine" for food and drink. Food Quality and Preference, nr. 17, 536–551.
Panouille M., Larreta-Garde V., 2009. Gelation behavior of gelatin and alginate mixtures. Food Hydrocolloids, Rol. IV, nr. 23,1074–1080.
Peleg M., 2006. On fundamental issues in texture evaluation and texturization. Food Hydrocolloids, nr. 20, 405–414.
Roberfroid M., 2005. Inulin – Type Fructans. Functional Food Ingredients. BocaRaton, Florida, p. 359.
Дубцов Г.Г., Сиданова М.Ю., Кузнецова Л.С., 2001. Ассортимент и качество кулинарной и кондитерской продукции. Мастерство, Москва, 230 с.
Павлова Н.С., 2000. Сборник основных рецептур сахаристых кондитерских изделий. ГИОРД, Санкт-Петербург, 232 с.

6

THE QUALITY OF SELECTED CARROT VARIETIES

Introduction

The carrot is one of the most popular vegetables cultivated and consumed in Poland. About her nutrition value decide the chemical constitution of granary root. This vegetable is a rich and valuable source of such compounds as: β-carotene, saccharides, mineral components and vitamins, among which the most present are vitamins: A, E, from group B and the ascorbic acid [Adamiecki F. 2001, Grudzień K., Sikora E. 2002, Sady W., Robak J., Wiech K. 2000]. The content of saccharose in the carrot carries out about 8,7 g per 100 g of edible part whereof 4,4 g determines content of saccharine and 2,4 g the alimentary fiber. Saccharides structure in the carrot shape on gustatory and reological properties of products. The content of these components in the carrot is first of all variety features [Borowska J., Zadernowski R., Kowalska M., Szajek A. 2003, Kowalska M., Borowska J., Zadernowski R., Szajek A. 2003]. Carotenoids perform the essential part in the creation of carrot root color. In the human body carotenoids keep such chemical reactivity as in plants by catching free radicals and active atomic oxygen. This is especially important for heavily working peoples, record-seeking sportsmen and people being in the situation of the prolonged stress. The diet rich into carotenoids diminishes of coronary disease, tumours of the lungs, urinary diseases and skin problems [Kowalska M., Borowska J., Zadernowski R., Szajek A. 2003, Godlewska Z., 1991, Kleszkowska E. 2001]. About the nutritive value of the carrot decide also contracted in roots mineral components and alkaline salts regulating the water economics of the human body. Mineral components delivered along with the food realize important matter in the behavior of the human-body acid-alkaline equilibrium [Adamiecki F. 2001, Grudzień K., Sikora E. 2002, Sady W., Robak J., Wiech K. 2000, Mosiewicz R. 2002, Godlewska Z. 1992).

In the winter-spring season the carrot is present in the consumer meal not only as the raw product but also in the preserved form [Czarniecka-Skubina E., Dudzińska B., Zalewski St. 1997]. Frozen vegetables gain from year to year the greater acknowledgment among consumers [Górecka D., Flaczek E. 2000, Górska-Warsewicz A. 2003]. To the most important advantages of frozen food belongs: all around the year accessibility, the comfort in preparation, economic, the improvement of the wholesome safety by the elimination of secondary microbiological contagious, the high nutritive value, the good product information the many months persistence without perceptible quality changes the lack of waste material [Górecka D., Flaczek E. 2000, Górska-Warsewicz A. 2003]. The carrot belongs to vegetable assorts especially useful to the consolidation in the frozen form. For growing requirements both on the part of the industry as and consumers turns the attention not only on the profitable surface of the finished product as frozen mixed vegetables but also on his high nutritive value [Bąkowski J. 2003, Bąkowski J. 2002].

The carrot is consumed all around the year as fresh product, in the form of salads, however in the greatest degree is used after thermal treatment to determine the perfect material in the culinary art. The heat treatment has principle meaning in the meals production and leads to changes of appearance, consistency, colour, taste and chemical constitution of semi-manufactured products and grants their characteristic sensory properties [Gołaszewska B., Czarniecka-Skubina E. 2000, Grzesińska W. 1997, Platta A., Kolenda H., Pyryt B. 2003]. During the heat treatment nutritive components as vitamins and mineral components decay or leaching away to the solution [Gołaszewska B., Czarniecka-Skubina E. 2000, Pyryt B., Kolenda H. 2000].

The loss of mineral compounds, caused by wash out or eliminated in water environment is measured between several percent to half of theirs total amount. It depends of vegetables sort and crumble degree [Grzesińska W. 1997, Sikorski Z. 1997]. Decline of soluble mineral compounds contained in vegetables is lowest in case of beginning culinary processes from boiling water because of shortest cooking time and contact with water. During storage period or food processing mineral compounds can liberate from complexes with other organic components what can change their biological properties [Sikorski Z. 1997, Czarniecka-Skubina E., Dudzińska B., Zalewski St. 1997].

Among such valuable substances as β-carotene, saccharides, proteins, vitamins and mineral compounds, the raw carrot contains also another components like nitrates (V, III) and heavy metals (Cd, Pb), which presence decreases nutrition value [Czarniecka-Skubina E., Dudzińska B., Zalewski St. 1997, Wojtasik A., Baryłko-Pikielna N. 1995]. Consumption of vegetables participates in delivering of these heavy metals to human body in about of 40% of theirs total amount [Sady W. 2001, Sikorski Z. 2000, Świderski F. 1999, Wieczorek C., Kostrzewa M. 1997].

The capacity of these compounds is very important especially in case of carrot and carrot products consumption by babies, children, elder people and as diet food [Czarniecka-Skubina E., Dudzińska B., Zalewski St. 1997, Wieczorek C., Kostrzewa M. 1997, Jędrzejczak R. 1992]. The root vegetables are remarkably exposed for heavy metals penetration coming from soil and ground water during cultivation period [Sady W. 2001, Wieczorek C., Kostrzewa M., 1997, Śmigiel D. 1994]. One of the targets to qualify the presence of heavy metals in food is assurance if these potentially noxious compounds are present in daily aliment in such quantities which could influence negatively for people's health [Wojtasik A., Baryłko-Pikielna N. 1995, Wieczorek C., Kostrzewa M. 1997, Czapski J., Grajek W., Pośpiech E., 1999, Sikorski Z. 1997].

The common feature of raw materials and food products is non-durability, which means susceptible for natural and constant transformation in chemical, physical, biological and microbiological feature. The character of quality changes depends on sorts of products and used technology in manufacture and consolidation. The main terms for good quality in frozen food are: used raw material, good process, proper package, proper freezing process and proper storage process [Kowalczuk I. 2000].

Food safety is a main purpose to satisfied customers expectation. Among soiling in food which caused menace people health nitrates are limited by the Minister of Health and Welfare. Nitrates are treat as a conservative additives but also as potential cancerous substance. Since vegetables are consumed in large quantities, appearance of nitrates could caused civilising illness. It is said that 60–80% percent of nitrates in daily diet proceed from vegetables [Szymczak 1999].

The sensory analysis plays a significant role in food industry and gastronomic production, because it ensures the production on the appropriate level and constitutes an indispensable factor in the continuous improvement of the quality of the goods produced. The sensory characteristics are: taste, smell, appearance including colour, and consistency of the food that can be distinguished and evaluated with the help of human senses [Ewan J. 1992]. The sense organs in people allow identifying the quality of the impression and determining its intensity as well as stating to what degree this impression is desirable or undesirable [Baryłko-Pikielna N. 1998].

In general, the quality evaluation of vegetables is defined by the senses relative to the product and their sensory attraction. Cooking processes aim at giving vegetables the right consistency, appearance, smell and taste [Zalewski St. 1988, Zalewski St. 1992]. The most important factors in choosing vegetables and vegetables products are sensory features independent of the socio-demographic profile presented by Polish respondents [Czarnocińska J., Babicz-Zielińska E., Wądołowska L., Przysławski J., Schlegel-Zawadzka M. 2004, Czarnocińska J., Wądołowska L., Babicz-Zielińska E., Przysławski J., Schlegel-Zawadzka M. 2003]. The factors influencing the choice of vegetables are their freshness and taste [Babicz-Zielińska E., Zagórska A. 1998].

The object of those researches was the qualification of mineral components, heavy metal. nitrates (V) and (III), total carotenoids and total saccharides contents in fresh carrot samples and to determine the influence of carrot converting degree (freezing process) and cooking methods on the retention of analyzed compounds. In this work was to define the sensory quality of selected carrot varieties after cooking them with various methods. In the research the influence of carrot varieties, the form of material, the time of storage and the cooking processes on the sensory feature of the cooked carrots was studied. The scope of the research included: 1. the estimation of the sensory feature of six carrot varieties after the traditional cooking process, in a pressure cooker and in a steam cooker; 2. the estimation of the sensory feature of raw and frozen carrot varieties cooked in the traditional way taking into account the tested material storage period.

Materials and methods

The research took place after collecting selected carrot varieties from the field and preparing the frozen carrots and after the third and the sixth month of storage of the raw and frozen carrots. The tested material used in the experiment consisted of six carrot varieties: Nigel, News, Nandrin, Nipomo, Nerac and Niagara.

The examined carrot samples were cooked in traditional way (starting from boiling water) in time of 25 minutes, in the pressure cooker in time of 2 minutes and in the steam cooker in time of 30 minutes. The examined vegetables were blanched and deep frozen at -22°C. After freezing process carrot samples were cooked only in traditional way (starting the process in boiling water) in time of 15 minutes.

The concentration of mineral compounds and heavy metals were analyzed by Atomic Spectroscopy (Ca, K, Na – ESA; Mg – ASA; Pb, Cd – GF ASA). The analyses were performed in Research Laboratory – Spectral Analysis, Department of Commodity Science, Gdynia Maritime University, Poland. The influence of freezing and cooking processes on changes of total carotenoids and total saccharides concentration in selected carrot varieties

was analyzed according to the PN standards. The influence of freezing and cooking process on changes in concentration nitrates (V) and (III) in carrot was analyzed by Griess colorimetry technique according to PN-A-75112:1992. Fruit, vegetable. Defining the concentration of nitrates (V) and (III). Concentration of nitrates (V) and (III) was analysed in three stages: after harvested carrots, after three months of freezing storage and after six months of freezing storage.

The sensory estimation of the cooked carrots was analysed with the use of the points method in the range from 1 for the minimum value to 5 for the maximum value. Four quality distinctive factors were taken into consideration: general appearance, smell, consistency and taste. The scope of the research included the sensory evaluation of the raw and frozen carrot varieties cooked in the traditional way taking into account the tested material storage period.

Results and discussion

The contents of mineral compounds in fresh samples of carrot varieties Nigel, Niagara and Nipomo were as follows: Ca 58.75–64,47 mg/100 g fresh weight, Mg 21.79–30.25 mg/100 g fresh weight, Na 19.45–38.64 mg/100 g fresh weight, K 287.03–370.13 mg/100 g fresh weight. After various thermal processes concentration of calcium (Ca) decreased to the level of 20.09–53,49 mg/100 g, magnesium (Mg): 7.67–17,4 mg/100 g, natrium (Na): 14.99–33.79 mg/100 g, potassium (K): 135.72–297,49 mg/100 g. Freezing process of various carrot samples influenced on decreases of Ca concentration in about 43%, Mg – in ~28%, Na – in ~30%, K – in ~16%, in comparison to fresh samples. Thermal process of frozen carrot samples resulted in further decrease of Ca concentration in about 46%, Mg – in ~41%, Na – in ~44%, K – in ~71%, in comparison to primary detected in frozen carrot samples (Table 1 and Table 2).

The loss of mineral compounds, caused by wash out or eliminated in water environment is measured between several percent to half of theirs total amount. It depends of vegetables sort and crumble degree [Wieczorek C., Kostrzewa M. 1997, Sikorski Z. 1997]. Decline of soluble mineral compounds contained in vegetables is lowest in case of beginning culinary processes from boiling water because of shortest cooking time and contact with water. During storage period or food processing mineral compounds can liberate from complexes with other organic components what can change their biological properties [Czarniecka-Skubina E., Dudzińska B., Zalewski St., 1997; Sikorski Z. 1997].

The total carotenoids and total saccharides contents in fresh samples of carrot varieties Nigel, Niagara and Nipomo were as follows: carotenoids 4.16–6,2 mg/100 g fresh weight, saccharides 7.26–8.09 g/100 g fresh weight. After various thermal processes concentration of carotenoids decreased to the level of 2.67–5.51 mg/100 g and saccharides concentration to the level of 2.68–7.0 g/100 g. Freezing process of various carrot samples influenced on decrease of carotenoids concentration in about 5% and concentration of saccharides in about 53%, in comparison to fresh samples. The traditional thermal process of frozen carrots caused the decrease of carotenoids concentration to 3.37–5.46 mg/100 g and saccharides to 1.94–3.58 g/100 g (Table 3 and Table 4).

Table 1

Concentration of mineral compounds in raw carrot samples before and after cooking methods (mg/100 g fresh weight)

Specified mineral compounds	Cooking methods	Carrot varieties		
		Nipomo	Niagara	Nigel
Ca	Raw carrot	58.75	62.10	64.47
	Carrot cooked in traditional way	21.31	24.75	20.09
	Carrot cooked in the pressure cooker	22.25	32.15	20.99
	Carrot cooked in the steam cooker	37.32	53.49	41.31
Mg	Raw carrot	26.46	21.79	30.25
	Carrot cooked in traditional way	11.72	9.83	7.67
	Carrot cooked in the pressure cooker	14.14	12.87	9.76
	Carrot cooked in the steam cooker	15.18	17.4	15.00
Na	Raw carrot	36.93	38.64	19.45
	Carrot cooked in traditional way	16.08	24.78	14.99
	Carrot cooked in the pressure cooker	17.58	25.87	16.60
	Carrot cooked in the steam cooker	19.82	33.79	18.08
K	Raw carrot	370.13	309.59	287.03
	Carrot cooked in traditional way	216.23	181.87	135.72
	Carrot cooked in the pressure cooker	230.15	197.41	210.61
	Carrot cooked in the steam cooker	231.28	217.97	297.49

Table 2

Concentration of mineral compounds in frozen carrot samples before and after cooking methods (mg/100 g fresh weight)

Specified mineral compounds	Cooking methods	Carrot varieties		
		Nipomo	Niagara	Nigel
Ca	Raw frozen carrot	36.49	38.02	31.15
	Frozen carrot cooked in traditional way	16.15	21.75	19.50
Mg	Raw frozen carrot	16.75	17.82	22.42
	Frozen carrot cooked in traditional way	11.74	10.23	11.44
Na	Raw frozen carrot	16.89	31.95	18.22
	Frozen carrot cooked in traditional way	14.68	14.14	8.88
K	Raw frozen carrot	284.67	246.32	282.76
	Frozen carrot cooked in traditional way	117.66	55.47	90.97

Table 3

Concentration of total carotenoids in carrot samples before and after cooking methods (mg/100 g fresh weight)

	Specified carrot samples and cooking methods	Carrot varieties		
		Nipomo	Niagara	Nigel
Concentration of carotenoids	Raw carrot	5.82	4.16	6.2
	Carrot cooked in traditional way	5.06	3.95	3.88
	Carrot cooked in the pressure cooker	3.15	3.52	2.67
	Carrot cooked in the steam cooker	5.51	4.00	3.12
	Raw frozen carrot	5.63	3.82	5.92
	Frozen carrot cooked in traditional way	5.01	3.37	5.46

Table 4

Concentration of saccharides in carrot samples before and after cooking methods (g/100 g fresh weight)

	Specified carrot samples and cooking methods	Carrot varieties		
		Nipomo	Niagara	Nigel
Concentration of saccharides	Raw carrot	8.09	7.70	7.26
	Carrot cooked in traditional way	5.79	3.61	4.25
	Carrot cooked in the pressure cooker	5.21	2.68	3.98
	Carrot cooked in the steam cooker	6.31	4.99	7.00
	Raw frozen carrot	3.94	2.88	4.01
	Frozen carrot cooked in traditional way	3.58	1.94	3.54

The heavy metals contents in fresh samples of carrot varieties Nigel, Niagara and Nipomo were as follows: Pb 0.11–0.15 mg/kg fresh weight, Cd 0.07–0.24 mg/kg fresh weight. After various thermal processes concentration of Pb decreased to the level of 0.07–0.1 mg/kg and Cd concentration to the level of 0.004–0.05 mg/kg. Freezing process of various carrot samples influenced on decrease of Pb concentration in about 20% and concentration of Cd in about 52%, in comparison to fresh samples. The traditional thermal process of frozen carrots caused the decrease of Pb concentration to 0.05–0.06 mg/kg and Cd to 0.002–0.01 mg/kg (Table 5 and Table 6).

Table 5

Concentration of heavy metals in raw carrot samples before and after cooking methods (mg/kg fresh weight)

Specified heavy metals	Cooking methods	Carrot varieties		
		Nipomo	Niagara	Nigel
Pb	Raw carrot	0.15	0.11	0.11
	Carrot cooked in traditional way	0.08	0.07	0.07
	Carrot cooked in the pressure cooker	0.09	0.09	0.08
	Carrot cooked in the steam cooker	0.09	0.1	0.08
Cd	Raw carrot	0.08	0.24	0.07
	Carrot cooked in traditional way	0.01	0.004	0.01
	Carrot cooked in the pressure cooker	0.01	0.01	0.01
	Carrot cooked in the steam cooker	0.02	0.01	0.05

Table 6

Concentration of heavy metals in frozen carrot samples before and after cooking methods (mg/kg fresh weight)

Specified heavy metals	Cooking methods	Carrot varieties		
		Nipomo	Niagara	Nigel
Pb	Raw frozen carrot	0.08	0.1	0.11
	Frozen carrot cooked in traditional way	0.06	0.06	0.05
Cd	Raw frozen carrot	0.04	0.14	0.01
	Frozen carrot cooked in traditional way	0.01	0.002	0.002

The marked concentration of Cd and Pb in fresh and frozen carrot increased maximum admissible levels defined by Regulation of Ministry of Health and Welfare in Poland from 30 April 2004. For root vegetables established maximum admissible amounts of heavy metals are: for Pb – 0,1 mg/kg fresh weight, for Cd – 0.08 mg/kg fresh weight.

The concentration of nitrates (V) and nitrates (III) in raw material was much higher than in all varieties in frozen carrot (Table 7 and Table 8).

Table 7

Concentration of nitrates (V) (mg $NaNO_3$/kg fresh carrot) in fresh carrot before and after cooking method (1st stage)

Carrot	Carrot varieties					
	Nigel	News	Nandrin	Nipomo	Nerac	Niagara
Raw carrot	32.895	34.086	47.575	20.995	11.312	12.108
Carrot cooked in traditional way	8.701	8.356	37.120	3.067	1.713	10.279

Table 8

Concentration of nitrates (III) (mg $NaNO_2$/kg fresh carrot) in fresh carrot before and after cooking method (1st stage)

Specified carrot samples	Carrot varieties					
	Nigel	News	Nandrin	Nipomo	Nerac	Niagara
Raw carrot	0.533	0.628	0.127	0.184	0.148	0.091
Carrot cooked in traditional way	0.086	0.320	0.112	0.037	0.086	0.086

The result of freezing process in –22°C showed that the content of nitrates (V) and (III) in all sorts of frozen carrot was much lower than fresh carrot. The lowest content of nitrates (V) was proved in frozen Nipomo carrot and the highest in frozen Nandrin carrot. The fall in frozen Nipomo carrot was 89% and 83% in frozen Nandrin carrot in comparison to fresh sorts of carrot. The lowest content of nitrates (III) was proved in frozen Nandrin carrot and the highest in frozen Nerac carrot. The fall in frozen Nandrin carrot was 83% and 77% in frozen Nerac carrot in comparison to fresh sorts of carrot. Freezing storage process caused a fall in content of nitrates (V) but a rise in content of nitrates (III) (Table 9 and Table 10).

Table 9

Concentration of nitrates (V) (mg $NaNO_3$/kg fresh carrot) in frozen carrot before and after cooking method (1st stage)

Specified carrot samples	Carrot varieties					
	Nigel	News	Nandrin	Nipomo	Nerac	Niagara
Raw frozen carrot	4.369	5.811	8.563	2.318	2.772	5.322
Frozen carrot cooked in traditional way	1.967	3.276	3.644	1.153	1.823	3.007

Table 10

Concentration of nitrates (III) (mg $NaNO_2$/kg fresh carrot) in frozen carrot before and after cooking method (1st stage)

Specified carrot samples	Carrot varieties					
	Nigel	News	Nandrin	Nipomo	Nerac	Niagara
Raw frozen carrot	0.051	0.048	0.035	0.047	0.119	0.203
Frozen carrot cooked in traditional way	0.020	0.039	0.028	0.025	0.076	0.042

After three months of freezing storage capacity of content of nitrates (V) fall about 50% in comparison to frozen carrot at the beginning of the freezing process. The lowest content of nitrates (V) was in Nipomo carrot – 2.169 mg $NaNO_3$/kg fresh carrot in frozen carrot and 1.130 mg $NaNO_3$/kg fresh carrot in frozen and cooked carrot. The highest content of nitrates (V) was in Nandrin carrot – 8.189 mg $NaNO_3$/kg fresh carrot in frozen carrot and 3.480 mg $NaNO_3$/kg fresh carrot in frozen and cooked carrot .

The content of nitrates (III) fall about 25% in comparison to frozen carrot at the beginning of the freezing process. The lowest content of nitrates (III) was in Nipomo carrot – 0.026 mg $NaNO_2$/kg fresh carrot in frozen carrot and 0.025 mg $NaNO_2$/kg fresh carrot in frozen and cooked carrot. The highest content of nitrates (III) was in Niagara carrot – 0.050 mg $NaNO_2$/kg fresh carrot in frozen carrot and 0.039 mg $NaNO_2$/kg fresh carrot in frozen and cooked carrot (Table 11 and Table 12).

Table 11

Concentration of nitrates (V) (mg $NaNO_3$/kg fresh carrot) in frozen carrot before and after cooking method (2nd stage)

Specified carrot samples	Carrot varieties					
	Nigel	News	Nandrin	Nipomo	Nerac	Niagara
Raw frozen carrot	4.330	5.794	8.189	2.169	2.529	4.419
Frozen carrot cooked in traditional way	1.963	3.205	3.480	1.130	1.841	1.863

Table 12

Concentration of nitrates (III) (mg $NaNO_2$/kg fresh carrot]) in frozen carrot before and after cooking method (2nd stage)

Specified carrot samples	Carrot varieties					
	Nigel	News	Nandrin	Nipomo	Nerac	Niagara
Raw frozen carrot	0.044	0.045	0.035	0.026	0.041	0.050
Frozen carrot cooked in traditional way	0.037	0.030	0.026	0.025	0.044	0.039

After six months freezing storage capacity of content of nitrates (V) fall about 62% in comparison to frozen carrot at the beginning of the freezing process.

The lowest content of nitrates (V) was in Nipomo carrot – 0,528 mg $NaNO_3$/kg fresh carrot in frozen carrot and 0.406 mg $NaNO_3$/kg fresh carrot in frozen and cooked carrot. The highest content of nitrates (V) was in Nandrin carrot – 2.652 mg $NaNO_3$/kg fresh carrot in frozen carrot and 2.542 mg $NaNO_3$/kg fresh carrot in frozen and cooked carrot.

The content of nitrates (III) rise about 86% in comparison to frozen carrot at the beginning of the freezing process. The lowest content of nitrates (III) was in Nipomo carrot – 0.069 mg $NaNO_2$/kg fresh carrot in frozen carrot and 0.060 mg $NaNO_2$/kg fresh carrot in frozen and cooked carrot. The highest content of nitrates (III) was in Nigel carrot – 0.182 mg $NaNO_2$/kg fresh carrot in frozen carrot and 0.156 mg $NaNO_2$/kg fresh carrot in frozen and cooked carrot (Table 13 and Table 14).

Table 13

Concentration of nitrates (V) (mg $NaNO_3$/kg fresh carrot) in frozen carrot before and after cooking method (3rd stage)

Specified carrot samples	Carrot varieties					
	Nigel	News	Nandrin	Nipomo	Nerac	Niagara
Raw frozen carrot	1.389	2.249	2.652	0.528	1.746	1.748
Frozen carrot cooked in traditional way	1.211	2.014	2.542	0.406	1.475	1.473

Table 14

Concentration of nitrates (III) (mg $NaNO_3$/kg fresh carrot) in frozen carrot before and after cooking method (3rd stage)

Specified carrot samples	Carrot varieties					
	Nigel	News	Nandrin	Nipomo	Nerac	Niagara
Raw frozen carrot	0.182	0.070	0.091	0.069	0.139	0.081
Frozen carrot cooked in traditional way	0.156	0.065	0.077	0.060	0.138	0.063

The examination results obtained from the evaluated sensory features have shown that the transformations occurring during the coking process influenced the quality. The size and the character of transformations depended on the used method of cooking. The type of the applied cooking method had the influence on the four quality distinctive factors which were taken into consideration in the experiment.

The general quality evaluation of the carrot samples cooked in the traditional way was defined in the range between 4.04 points (Nandrin carrot variety) and 4.85 points (Nigiel carrot variety). The carrot samples cooked in the pressure cooker were estimated in the range between 3.92 points (News carrot variety) and 4.65 points (Nipomo carrot variety). The carrot samples cooked in the steam cooker were estimated in the range between 3.81 points (News carrot variety) and 4.88 points (Nipomo carrot variety). The Nigiel carrot variety and the Nipomo carrot variety gained the highest sensory evaluation by the points method with regard to the cooking methods used. The News carrot variety obtained the lowest sensory evaluation by the points method with regard to the cooking methods used (Table 15).

Table 15

Sensory assessments of the fresh carrots after selected cooking methods (points)

Carrot varieties	Cooking methods	Sensory assessment (1–5 points)				General quality evaluation x±δ
		General appearance x±δ	Smell x±δ	Consistency x±δ	Taste x±δ	
Nigel	in the traditional way	5.0±0.00	4.8±0.41	4.8±0.41	4.8±0.41	4.85±0.31
	in the pressure cooker	4.3±0.22	4.5±0.55	3.5±0.55	4.0±0.63	4.04±0.26
	in the steam cooker	5.0±0.00	4.5±0.55	4.2±0.75	4.7±0.52	4.54±0.26
News	in the traditional way	4.8±0.14	4.3±0.82	4.3±0.52	4.5±0.55	4.46±0.42
	in the pressure cooker	4.2±0.14	3.8±0.41	4.0±0.63	3.8±0.41	3.92±0.37
	na parze	4.3±0.22	3.8±0.41	4.0±0.89	3.5±0.55	3.81±0.26
Nandrin	in the traditional way	5.0±0.00	4.3±0.52	3.8±0.75	3.7±0.52	4.04±0.33
	in the pressure cooker	4.5±0.25	4.0±0.00	4.0±0.63	3.8±0.41	4.00±0.34
	in the steam cooker	4.8±0.14	4.8±0.41	4.7±0.52	4.2±0.75	4.54±0.44
Nipomo	in the traditional way	4.8±0.14	3.8±0.75	4.5±0.55	4.3±0.52	4.31±0.38
	in the pressure cooker	4.8±0.14	4.5±0.55	4.2±0.41	5.0±0.00	4.65±0.26
	in the steam cooker	5.0±0.00	4.5±0.52	5.0±0.00	5.0±0.00	4.88±0.13
Nerac	in the traditional way	4.7±0.22	4.5±0.55	4.2±0.75	4.3±0.52	4.38±0.30
	in the pressure cooker	4.2±0.47	4.3±0.52	4.2±0.41	3.8±0.41	4.08±0.14
	in the steam cooker	4.5±0.25	4.2±0.75	4.2±0.41	4.3±0.52	4.27±0.33
Niagara	in the traditional way	4.8±0.14	4.5±0.55	4.7±0.52	4.5±0.55	4.58±0.44
	in the pressure cooker	4.7±0.22	4.0±0.89	4.2±0.41	4.0±0.63	4.13±0.46
	in the steam cooker	4.5±0.25	4.2±0.75	4.0±0.63	4.3±0.52	4.23±0.27

It was presumed in the work that the storage period has an influence on the quality distinctive factors in the cooked vegetables. The general sensory evaluation of the selected raw carrot varieties cooked in the traditional way after three months of storage was defined in the range between 3.33 points (Nerac carrot variety) and 4.48 points (Nigel carrot variety), and after 6 months of storage it was defined in the range between 2.75 points (Nerac carrot variety) and 3.06 points (Nigiel and Nandrin carrot varieties) (Table 16).

The general sensory evaluation of the frozen carrot samples cooked in the traditional way was defined in the range between 3.21 points (Nandrin carrot variety) and 3.88 points (Nigiel carrot variety). The frozen carrot samples cooked after three months of storage were defined in the range between 2.63 points (Niagara carrot variety) and 3.94 points (Nigiel carrot variety), and after six months of storage they were defined in the range between 2.44 points (Niagara carrot variety) and 2.96 points (Nigiel carrot variety). Among the examined

frozen carrot varieties, the Nigiel carrot variety gained the highest sensory quality by the points method with regard to the storage period (Table 17).

The statistical analysis of the obtained sensory results have shown the essential influence of the cooking methods on the taste and the essential influence of the storage period on the general appearance of the cooked carrot samples. It also has shown the essential influence of the storage time and the carrot variety on the smell and the consistency of the cooked frozen samples of the selected carrot varieties.

The sensory estimation of the selected carrot varieties after cooking: in the traditional way, in the pressure cooker and in the steam cooker has shown that the traditional cooking way gives the most valuable product as far as the sensory feature is concerned. The cooking process in the pressure cooker gives the least valuable product as far as the sensory feature is concerned.

Table 16

Sensory assessments of the fresh carrots cooked in the traditional way (points)

Carrot varieties	Time of storage period (months)	Sensory assessment (1–5 points)				General quality evaluation x±δ
		General appearance x±δ	Smell x±δ	Consistency x±δ	Taste x±δ	
Nigel	0	5.0±0.00	4.8±0.41	4.8±0.41	4.8±0.41	4.85±0.31
	3	4.3±0.22	4.8±0.41	4.7±0.52	4.2±0.41	4.48±0.27
	6	4.2±0.47	3.2±0.75	2.7±0.52	2.7±0.82	3.06±0.52
News	0	4.8±0.14	4.3±0.82	4.3±0.52	4.5±0.55	4.46±0.42
	3	3.3±0.22	3.3±0.52	3.0±0.89	3.8±0.75	3.44±0.59
	6	3.8±0.47	3.1±0.75	3.0±0.89	2.8±0.75	3.05±0.75
Nandrin	0	5.0±0.00	4.3±0.52	3.8±0.75	3.7±0.52	4.04±0.33
	3	4.2±0.14	3.5±0.55	4.0±0.89	3.3±0.52	3.65±0.45
	6	4.0±0.10	2.5±0.55	2.5±0.52	3.5±0.55	3.06±0.30
Nipomo	0	4.8±0.14	3.8±0.75	4.5±0.55	4.3±0.52	4.31±0.38
	3	4.2±0.14	4.0±0.89	3.8±0.41	3.5±0.84	3.79±0.38
	6	4.2±0.14	3.0±0.10	2.5±0.52	2.7±0.55	2.94±0.26
Nerac	0	4.7±0.22	4.5±0.55	4.2±0.75	4.3±0.52	4.38±0.30
	3	3.5±0.25	3.3±0.52	3.0±0.63	3.5±0.55	3.33±0.34
	6	4.0±0.10	3.0±0.63	3.7±0.52	1.5±0.55	2.75±0.25
Niagara	0	4.8±0.14	4.5±0.55	4.7±0.52	4.5±0.55	4.58±0.44
	3	4.0±0.10	4.0±0.63	4.2±0.82	3.7±0.52	3.92±0.42
	6	4.2±0.56	3.2±0.82	3.0±0.10	2.5±0.55	3.03±0.37

Table 17

Sensory assessment of the frozen carrots cooked in the traditional way (points)

Carrot varieties	Time of storage period (months)	Sensory assessment (1–5 points)				General quality evaluation x±δ
		General appearance x±δ	Smell x±δ	Consistency x±δ	Taste x±δ	
Nigel	0	3.8±0.14	4.2±0.41	3.2±0.75	4.2±0.75	3.88±0.41
	3	4.7±0.22	3.3±0.52	4.3±0.52	3.8±0.41	3.94±0.10
	6	3.8±0.14	2.7±0.52	3.0±0.10	2.8±0.41	2.96±0.30
News	0	3.2±0.14	4.3±0.52	3.3±0.52	3.7±0.52	3.69±0.31
	3	3.5±0.25	3.5±0.55	3.3±0.52	3.0±0.10	3.27±0.38
	6	3.3±0.56	2.7±0.52	3.2±0.75	2.5±0.55	2.81±0.54
Nandrin	0	3.3±0.22	3.3±0.52	3.3±0.84	3.0±0.00	3.21±0.39
	3	4.3±0.22	3.2±0.41	2.5±0.55	2.8±0.41	3.02±0.25
	6	3.0±0.10	2.8±0.41	3.2±0.41	2.0±0.90	2.63±0.32
Nipomo	0	3.5±0.25	3.7±0.52	3.8±0.41	3.3±0.82	3.56±0.49
	3	3.3±0.22	3.0±0.63	2.8±0.41	2.3±0.52	2.75±0.44
	6	3.3±0.22	2.3±0.52	2.8±0.41	2.2±0.41	2.52±0.38
Nerac	0	3.3±0.22	4.5±0.55	3.0±0.63	2.5±0.84	3.23±0.34
	3	3.3±0.22	3.2±0.41	3.0±0.10	3.0±0.89	3.08±0.34
	6	3.3±0.22	3.2±0.41	3.2±0.75	2.3±0.52	2.88±0.39
Niagara	0	4.0±0.10	4.2±0.41	3.5±0.55	3.0±0.10	3.54±0.20
	3	3.2±0.47	2.8±0.41	2.3±0.41	2.5±0.55	2.63±0.38
	6	3.3±0.22	2.7±0.52	2.2±0.41	2.2±0.75	2.44±0.50

Conclusions

The obtained results indicates that highest decrease of mineral compounds in fresh carrot samples was observed after applied traditional cooking method: Ca (in 64%), Mg (in 63%), Na (in 41%), K (in 45%). Freezing process of various carrot samples influenced on decreases of Ca concentration in about 43%, Mg – in ~28%, Na – in ~30%, K – in ~16%, total carotenoids – in ~5% and total saccharides – in 53%~, in comparison to fresh samples.

The highest total carotenoids concentration was observed in the samples of NIGEL carrot variety (6.2 mg/100 g for fresh samples, 5.92 mg/100 g for frozen samples). Thermal process decreased carotenoids concentration in the researched carrot samples. The significantly decrease of carotenoids concentration (in 42%) was observed after applied cooking method in the pressure cooker.

The highest total saccharids concentration was observed in the samples of NIPOMO carrot variety (8.09 g/100 g for fresh samples, 3.94 g/100 g for frozen samples) and in the samples of NIGEL carrot variety (4.01g/100 g for frozen samples). Cooking methods in the pressure cooker reduced the primary concentration of saccharides in 48%.

The highest Pb concentration was observed in the samples of NIPOMO carrot variety (0.15 mg/kg fresh weight). Thermal process decreased Pb concentration in the researched carrot samples. The significantly decrease of Pb concentration (in 41%) was observed after applied traditional cooking method. The highest Cd concentration (0.24 mg/kg for fresh samples, 0.14 mg/kg for frozen samples) was observed in the samples of NIAGARA carrot variety. Traditional cooking process reduced the primary concentration of Cd in 93%.

The statistical evaluation ($p<0,05$) indicated substantial influence of cooking methods on trends in Ca, Mg and Pb total carotenoids and total saccharides concentrations in researched fresh carrot samples.

The result of freezing process in –22°C showed that the content of nitrates (V) and (III) in all sorts of frozen carrot was much lower than fresh carrot. Freezing and cooking process reduced the concentration of nitrates (V) and (III) in all analyzed samples of carrots. Storage process caused the fall in the concentration of nitrates (V) but the growth in the concentration of nitrates (III). In all analyzed samples of carrots, mean nitrate levels were found to be below 400 mg $NaNO_3$/kg raw materials.

Comparing the three types of cooking methods, cooking in the traditional way is the most efficient of all the applied methods. Although the vegetables cooked in the steam cooker obtained the very high general quality, the carrots cooked in the traditional way obtained higher marks. Cooking in the pressure cooker is the least effective of all the applied methods during the experiment.

The sensory estimation of the analysed carrot samples cooked in the traditional way taking into account the storage time and the material form has shown that the raw Nigel carrot variety obtained the most valuable sensory feature of all other varieties. The time of storage had the negative influence on the final quality of the raw carrots. The storage process caused that the general quality of the vegetables was lower than of the fresh carrots. During the 1st stage of the research, after harvesting the selected carrot varieties, the lowest sensory estimation had the raw Nandrin carrot variety, after three and six months of the storage process the lowest sensory estimation had the raw Nerac carrot variety. The frozen Nandrin carrot variety had the lowest sensory estimation in the 1st stage of the research. The frozen Niagara carrot variety had the lowest sensory estimation after three and six months of the storage period.

The storage period and the freezing process caused that the general quality of the vegetables was lower than of the fresh carrots. The differences were quite significant.

References

Adamiecki F., 2001. Przechowywanie warzyw korzeniowych. Ins. Warz., Skierniewice.

Babicz-Zielińska E., Zagórska A., 1998. Factors affecting the preferences for vegetables and fruits. Pol. J. of Food and Nut. Sci., 4 (7/48), 755–62.

Baryłko-Pikielna N., 1998. Analiza sensoryczna w zapewnieniu jakości żywności. Przem. Spoż., 12, 25–28, 50.

Bąkowski J., 2002. Przydatność i jakość warzyw do zamrażalnictwa. Przem. Spoż., 6, 8–11.

Bąkowski J., 2003. Wpływ procesów technologicznych na jakość przetworów z marchwi. Ins. Warz. Ogólnopolska Konf., Skierniewice, 25–30.
Borowska J., Zadernowski R., Kowalska M., Szajek A., 2003.Związki biologicznie aktywne w odmianach marchwi. XXXIV Sesja Naukowa Komitetu Nauk o Żywności PAN nt.: Jakość polskiej żywności w przededniu integracji Polski z Unią Europejską, Wrocław, 113.
Czapski J., Grajek W., Pośpiech E., 1999. Surowce, technologia i dodatki a jakość żywności. Wyd. Akad. Rol., Poznań.
Czarniecka-Skubina E., Dudzińska B., Zalewski St., 1997. Wpływ stopnia przetworzenia na jakość i poziom skażeń marchwi. Przem. Spoż., 8, 42–44.
Czarnocińska J., Wądołowska L., Babicz-Zielińska E., Przysławski J., Schlegel-Zawadzka M., Factors influencing the choice of vegetables and fruit consumed by the school youth from Szczecin. Pol. J. of Food and Nut. Sci., 2003, 12 (53), 95–101.
Czarnocińska J., Babicz-Zielińska E., Wądołowska L., Przysławski J., Schlegel-Zawadzka M., 2004. Czynniki wyboru żywności a modyfikacje w odżywianiu, [w:] Wybrane problemy nauki o żywieniu człowieka u progu XXI wieku. Warszawa, 302–306.
Ewan J., Analiza statystyczna wyników ocen sensorycznych. Przem. Spoż, 1992, 12, 319–321.
Gołaszewska B., Czarniecka-Skubina E., 2000. Wpływ procesów technologicznych na jakość wybranych warzyw. Konf. Naukowo-Techniczna nt.: Żywienie człowieka. Hotelarstwo. Piekarstwo, Bydgoszcz, 97–103.
Godlewska Z., 1991. Co trzeba wiedzieć o witaminach. Przeg. Gastron., 1–3, 14–16 (1), 15–17 (2), 17–18 (3).
Godlewska Z., 1991. Składniki mineralne w żywieniu człowieka. Przeg. Gastron., 6, 9–10.
Godlewska Z., 1992. Składniki mineralne w żywieniu człowieka (II). Przeg. Gastron., 1, 12–13.
Górecka D., Flaczek E., 2000. Mrożone jak świeże. Przeg. Gastron., 3, 12–13 (in Polish).
Górska-Warsewicz A., 2002. Rynek produktów mrożonych. Przem. Spoż., 6, 8–11, 15–16.
Górska-Warsewicz A., 2003. Konsumenci żywności mrożonej. Przem. Spoż., 2, 14–15.
Grzesińska W., 1997. Gotowanie na parze. Przeg. Gastron., 11, 3–4, 6.
Grudzień K., Sikora E., 2002. Uprawa marchwi i pietruszki korzeniowej. Ins. Warz., Skierniewice.
Jędrzejczak R., 1992. Kadm w środowisku i w żywności. Cz.II, Występowanie kadmu w produktach spożywczych, w tym i dla niemowląt niemowląt małych dzieci. Przem. Ferm i Owoc.-Warz., 36, 1.
Kleszkowska E., Wpływ wybranych pierwiastków i witaminy C na funkcjonowanie organizmu ludzkiego. Żywn., Żyw., Prawo a Zdrow., 2001, 1, 78–85.
Kowalczuk I., Freezing food products. Food Serv., 2000, 1, 43–47.
Sikorski Z., Zmiany składników żywności wskutek przechowywania i obróbki. Konf. Nauk. nt. Żywienie a zdrowie, Gdańsk, 1997, 1–3.
Kowalska M., Borowska J., Zadernowski R., Szajek A., Charakterystyka cukrowców błonnika przemysłowych odmian marchwi. XXXIV Sesja Naukowa Komitetu Nauk o Żywności PAN nt: Jakość polskiej żywności w przededniu integracji Polski z Unią Europejską, Wrocław, 2003, 133.
Mosiewicz R., 2002. Karotenoidy, schwytane promienie słoneczne. Przem. Ferm. i Owoc.-Warz., 4, 2–3.
Platta A., Kolenda H., Pyryt B., 2003. Ocena zmian jakości marchwi jadalnej pod wpływem różnych metod obróbki termicznej. XXXIV Sesja Naukowa Komitetu Nauk o Żywności PAN nt.: Jakość polskiej żywności w przededniu integracji Polski z Unią Europejską, Wrocław, 148.
Pyryt B., Kolenda H., 2000. Kształtowanie jakości i wartości odżywczej wybranych warzyw korzeniowych pod wpływem różnych metod termicznej obróbki kulinarnej. XXXI Sesja Naukowa Komitetu Technologii i Chemii Żywności PAN, Poznań, 353.
Sady W., 2001. Czynniki ograniczające zawartość azotanów i metali ciężkich w warzywach. Przem. Ferm. i Owoc.-Warz., 5, 21–239.

Sady W., Robak J., Wiech K., 2000. Uprawa marchwi. Wyd. Plantpress, Kraków.
Sikorski Z., 1997. Zmiany składników żywności wskutek przechowywania i obróbki. Konf. Naukowa nt.: Żywienie a zdrowie, Gdańsk, 1–3.
Sikorski Z., 2000. Chemia żywności. Skład, przemiany i właściwości żywności. WNT, Warszawa.
Szymczak J., Prescha A., 1999. Concentration of nitrates (V) and (III) in vegetables in Wrocław in the years 1996–1997. Rocz. PZH, 1, 17–23.
Śmigiel D., 1994. Kumulacja metali ciężkich (Pb, Cd) w wybranych warzywach różnych odmian. Rocz. PZH, 45, 279.
Świderski F., 1999. Towaroznawstwo żywności przetworzonej. Wyd. SGGW, Warszawa.
Wieczorek C., Kostrzewa M., 1997. Culinary processing impact on lead and cadmium content in carrot. Rocz. PZH, 48, 2.
Wojtasik A., Baryłko-Pikielna N., 1995. Stopień potencjalnego zagrożenia zdrowia ze strony metali ciężkich zawartych w racji pokarmowej. Żyw. Człow. i Metab., 1 (XXII), 3–15.
Zalewski St., 1988. Obróbka termiczna warzyw i owoców. Przeg. Gastron., 4, 3–5.
Zalewski St., 1992. Optymalizacja jakości żywności. Przem. Spoż., 2, 32–37.

7

SENSORY AND RHEOLOGICAL PROPERTIES OF THE GRILL SAUSAGES, PACKED IN VACUUM OR MODIFIED ATMOSPHERE AND COOL STORAGE OR AT NEAR CRYOSCOPIC TEMPERATURE

Introduction

The safety and sensory properties are the most important quality parameters of meat products [Czernircka-Skiba et al. 2009, Szmańko, Dzieszuk 2007a]. If the properties related to safety can be less recognized by the consumer when choosing foods, that sensory properties are fully accessible and always taken under consideration. Although the sensory properties are the subjective, the attempts towards objective assess are made [Fortuna, Krysińska 2009]. It is possible in of the texture of the product, which the sensory analysis often is reflected in the results of texture instrumental profile tests [Juszczak 2005].

The technological process should be shaping optimally sensory and texture profile of products, and the used conditions could not have worse them.

Therefore in studies (aimed at increasing the stability of grill sausages), the impact of experimental factors was analyzed: the packaging method and storage period on sensory and rheological properties of discriminants of these meat products.

Materials and methods

The experimental material was the medium ground grill sausage produced in industrial conditions in three production batches. The protein content in meat products I, II and III of the production batch respectively was marked at the level of 13.62, 14.52 and 12.65%. The grill sausages were in vacuum packed after the 24-hour cooling storage. 5 link of sausages were placed in the plastic bags (in the laminate PA/PE) were placed. During the packing it was used 90% of the air elimination or inert gas atmosphere [80% N_2, 20% CO_2]. The meat products were packed in the plastic bags: 80 HS MULTISEVEN TOP (top foil), and HIGH GLOSS FP (bottom foil). The grill sausages were stored in the refrigerator at 3±1°C, or in a state of deep cooling (at near cryoscopic temperature -3±1°C). The raw material was storage for 0 (control-K), 7, 14, 21, 28 days.

Rheological measurements were showed using an equipment to test strength Zwick/Roell Z010. Rheological analysis included hardness, springiness, cohesiveness, gumminess and chewiness. The experimental storage meat products were analyzed, already thermo stabilized to the temperature of 20°C. The analytical sample was cut in the shape of a cylinder with a height of 15 mm and 25 mm in diameter. Samples were subjected to twice the com-

pression set at 70% deformation and relaxation time trials of 50 seconds. The speed of the head was set at 60 mm/min [Bourne 1982].

Sensory evaluation was carried using score assessment [PN-ISO 6658 1998]. Five points scores of intensity (very strong) and similar for desirability: from 1 point (undesirable) to 5 point (very much desirable). Products were prepared as half of chubs and 2,5 mm slices presented to panelists and disposable dishes in white glow light [250 lx]. The next sensory parameters were investigated: 1 – outward appearance, 2 – colour, 3 – juiciness, 4 – texture, 5 – flavour, 6 – smell, 7 – saltiness, 8 – general sensory analyses. For 4, 5, 6 and 7 both intensity and desirability scale were used. Sensory evaluation of grill sausages was carried out by a 5-point scale immediately after storing as well as after heating them in a microwave oven to a temperature 71ºC in geometrical centre.

Statistical analysis of the results was carried out using STATISTICA 9.0 software where averages, standard deviations, least significant differences and estimation of differences between mean values at $p<0.05$ were calculated.

Results and discussion

The meat products storage at near cryoscopic temperature (-3°C) for 7 and 14 days was more encourage the hardness of the meat, rather than in the cooling conditions. The higher values of these parameter vacuum packed products were determined (Table 2). However, comparing the main effects (mean values of various experimental groups without periods of storage or method packaging), there was not any effect of the methods packaging as well as the storage temperature of the hardness of grill sausages.

The hardness of grill sausages can be the result of the content of proteins, their emulsifying capacity and also water holding capacity (Table 1). A large impact on the parameters had the physicochemical properties used of fat and properly selected polysaccharides [Dzieszuk et al. 2005, Jarmoluk et al. 2007, Szmańko et al. 2007].

In these studies the biggest influence at the hardness probably had physicochemical properties applied protein and fat storage raw material. as well as changes in protein-fat system.

The cohesiveness was one of the most stable rheological parameter of experimental meat products (Table 2). None of the experimental factors: the packaging method, the storage temperature and the storage period had an effect on this discriminant.

The gumminess of stored meat products for 7 days showed a trend to high to values as compared with these parameters of control samples (Table 2). Further the storage period generated dynamically reduce of the present value of the discriminant. Comparing the main effects there were any effect of method packaging as well as the storage temperature in the level of these discriminant (Table 2).

The highest values of chewiness vacuum packaging grill sausages were determined after 7 days of storage (Table 3). Further time of storage resulted in a difficult to interpret the decrease in the value of chewiness. By analyzing the main effects had no the packaging method and storage temperatures have no effects on the chewiness of the experimental products.

The highest springiness of grill sausage after 7 days of storage was observed (Table 3). Further the storage period of meat products resulted in a systematic decrease in the value of these parameters. By analyzing the main effects only thermal conditions resulted in signifi-

cant statistically in differences the springiness of individual groups of experimental sausages. The stored meat products at 3°C were characterized by higher springiness than products kept at -3°C.

Table 1

Variability of water holding capacity of the grill sausages (%), n=18

Experimental group			Parameters				
Storage temperature (°C)/ Packaging method			Water holding capacity				
			3		-3		NIR
			vacuum	map	vacuum	map	
Storage period [days]	K	$\bar{x}$	78.29^{B}	78.29^{B}	78.29^{B}	78.29^{B}	–
		sd	1.46	1.46	1.46	1.46	
	7	$\bar{x}$	76.82^{A}	77.01^{AB}	76.50^{A}	76.45^{A}	0.902
		sd	1.19	1.01	1.26	1.12	
	14	$\bar{x}$	76.40^{A}	76.42^{A}	76.13^{A}	76.08^{A}	0.971
		sd	0.92	0.92	1.17	0.82	
	21	$\bar{x}$	76.13^{A}	75.94^{A}	75.75^{A}	75.81^{A}	0.908
		sd	1.26	1.40	1.32	1.37	
	28	$\bar{x}$	75.61^{A}	75.70^{A}	75.44^{A}	75.33^{A}	1.045
		sd	1.20	1.32	1.34	1.34	
NIR			1.428	1.527	1.617	1.543	
$\bar{x}_{p\ (n=90)}$			76.65	76.69	76.42	76.39	
NIR			1.101		0.882		
$\bar{x}_{t\ (n=180)}$			76.67		76.41		
NIR			0.606				

$\bar{x}$ – mean value for the experimental group sd – standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

Table 2

Variability of textural parameters of grill sausages, n=18

Experimental group			Parameters														
Storage temperature [°C] / Packaging method			Hardness (N)					Cohesiveness					Gumminess				
			3		-3		NIR	3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period [days]	K	$\bar{x}$	81.34^{B}	81.34^{B}	81.34^{C}	81.34^{AB}	–	0.16	0.16	0.16	0.16	–	12.43^{AB}	12.43^{A}	12.43^{A}	12.43^{AB}	–
		sd	3.66	3.66	3.66	3.66		0.02	0.02	0.02	0.02		1.48	1.48	1.48	1.48	
	7	$\bar{x}$	76.39^{bAB}	71.81^{aA}	7.96^{bC}	80.57^{cB}	7.390	0.17	0.17	0.17	0.16	0.033	13.00^{C}	13.72^{C}	13.37^{B}	13.45^{B}	1.774
		sd	0.34	5.28	4.13	5.17		0.01	0.02	0.02	0.03		1.24	1.20	0.71	1.91	
	14	$\bar{x}$	78.61^{aAB}	78.16^{aAB}	83.44^{bC}	77.40^{aB}	8.699	0.17	0.17	0.15	0.17	0.023	12.75^{AB}	12.69^{A}	12.78^{A}	13.90^{AB}	1.279
		sd	12.57	6.78	2.34	1.06		0.02	0.02	0.01	0.01		2.00	0.06	0.80	0.47	
	21	$\bar{x}$	68.99^{bA}	70.63^{bA}	72.26^{bB}	62.65^{aA}	6.001	0.17	0.17	0.18	0.17	0.021	11.49^{abA}	13.19^{cB}	12.76^{bcA}	10.61^{aA}	1.386
		sd	2.47	1.27	4.82	4.68		0.02	0.01	0.01	0.02		0.68	0.53	0.93	0.74	
	28	$\bar{x}$	70.31^{abA}	75.37^{bAB}	64.40^{aA}	66.80^{aA}	7.420	0.18	0.17	0.17	0.18	0.020	12.37^{abAB}	12.80^{bA}	11.88^{aA}	11.65^{aAB}	0.815
		sd	5.17	2.89	1.42	3.93		0.03	0.02	0.01	0.01		0.23	0.64	0.42	0.32	
NIR			11.940	8.028	6.391	6.350		0.028	0.027	0.032	0.032		2.340	1.696	1.702	2.109	
$\bar{x}_{p\ (n=90)}$			75.13	75.46	76.08	74.15		0.17	0.17	0.16	0.17		12.40	12.97	12.64	12.21	
NIR			4.899		6.437			0.012		0.013			0.819		0.958		
$\bar{x}_{(n=180)}$			75.29		75.12			0.17		0.17			12.69		12.43		
NIR			4.146					0.018					0.639				

$\bar{x}$ – mean value for the experimental group sd – standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

Table 3

Variability of textural parameters of the grill sausages, n=18

Experimental group			Parameters									
Storage temperature [°C] /Packaging method			Springiness (mm)					Chewiness (N*mm)				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period (days)	K	$\bar{x}$	8.60^{AB}	8.60	8.60^{A}	8.60^{BC}	–	0.69	0.69	0.69	0.69	–
		sd	3.94	3.94	3.94	3.94		0.08	0.08	0.08	0.08	
	7	$\bar{x}$	9.65^{bC}	8.83^{a}	9.70^{bB}	9.14^{abBC}	5.762	0.74	0.75	0.72	0.68	0.645
		sd	3.83	4.95	3.18	4.32		0.31	0.71	0.29	0.40	
	14	$\bar{x}$	9.15^{bBC}	9.14^{b}	8.54^{aA}	9.24^{bC}	4.374	0.70	0.72	0.67	0.72	0.670
		sd	4.33	5.52	4.53	5.02		0.46	0.47	0.20	0.19	
	21	$\bar{x}$	8.29^{bA}	8.96^{cA}	8.67^{bcA}	7.40^{aA}	4.835	0.72	0.68	0.68	0.70	0.699
		sd	3.47	6.36	4.94	3.63		0.37	0.25	0.83	0.63	
	28	$\bar{x}$	8.76^{cAB}	9.15^{d}	8.35^{bA}	7.87^{aB}	3.450	0.71	0.72	0.68	0.68	0.617
		sd	2.79	3.88	4.68	1.47		0.36	0.35	0.29	0.31	
NIR			7.318	6.810	6.244	5.989		0.620	0.777	0.774	0.675	
$\bar{x}_{p\ (n=90)}$			8.89	8.94	8.77	8.45		0.71	0.71	0.69	0.70	
NIR			5.770		6.982			0.301		0.283		
$\bar{x}_{t\ (n=180)}$			8.91		8.61			0.71		0.69		
NIR			4.605					0.219				

$\bar{x}$ – mean value for the experimental group sd – standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c. – mean values in the same row denoted by different capital letters are significantly differ at level of p≤0.05

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of p≤0.05

The outward appearance of unheated control samples analyzed degree higher than the stored meat products (Table 4). Further the storage period has been steadily reducing the value of this discriminant. Generally higher degree was observed in meats stored at lower temperatures. The highest degree received grill sausage from group – 3V7. After 28 days of stored at -3°C meat degree remained at the level of good degree. The meat products stored for 28 days in cooling conditions (3V28 and 3M28) had a lower degree about 0.20–0.27 point. A similar effect of experimental factors on the outward appearance of the warm as in unheated grill sausages was observed (Table 5). The degree of unheated grill sausages was just 0.1 points higher than the warm experimental products.

During the time of storage of grill sausages the systematic lowering of the value of color intensity of unheated and warm meat products was observed. This trend showed a relationship with chroma of colour, marked in other studies [Górecka et al. 2011].

Table 4

Variability of sensory properties of unheated grill sausages (points)

Experimental group			Parameters									
Storage temperature (°C) /Packaging method			General sensory analysis					Outward apperance				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period (days)	K	$\bar{x}$	4.38^{D}	4.38^{C}	4.38^{B}	4.38^{B}	–	4.43^{D}	4.43^{C}	4.43^{B}	4.43^{B}	–
		sd	0.23	0.23	0.23	0.23		0.32	0.32	0.32	0.32	
	7	$\bar{x}$	4.32^{CD}	4.37^{BC}	4.31^{AB}	4.24^{AB}	0.369	4.29^{aC}	4.33^{abC}	4.43^{bB}	4.33^{abB}	0.151
		sd	0.14	0.20	0.20	0.10		0.21	0.21	0.21	0.21	
	14	$\bar{x}$	4.23^{C}	4.34^{BC}	4.32^{AB}	4.32^{AB}	0.112	4.05^{B}	4.10^{B}	4.09^{A}	4.06^{A}	0.078
		sd	0.24	0.15	0.15	0.10		0.19	0.18	0.09	0.07	
	21	$\bar{x}$	4.10^{B}	4.15^{B}	$4.28A^{B}$	$4.26A^{B}$	0.266	4.03^{aB}	4.10^{aB}	4.18^{aA}	4.41^{bB}	0.212
		sd	0.14	0.20	0.20	0.20		0.17	0.16	0.26	0.25	
	28	$\bar{x}$	3.71^{aA}	3.68^{aA}	4.17^{bA}	4.17^{bA}	0.251	3.80^{aA}	3.73^{aA}	4.03^{bA}	4.07^{bA}	0.175
		sd	0.10	0.20	0.14	0.17		0.22	0.22	0.07	0.09	
NIR			0.115	0.183	0.180	0.175		0.115	0.186	0.185	0.176	
$\bar{x}_{p\ (n=90)}$			4.15	4.16	4.29	4.27		4.12	4.14	4.24	4.26	
NIR			0.193		0.183			0.187		0.144		
$\bar{x}_{t\ (n=180)}$			4.16		4.28			4.13		4.22		
NIR			0.147					0.187				

$\bar{x}$ – mean value for the experimental group sd – standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a. b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

Table 5

Variability of sensory properties of warm grill sausages (points)

Experimental group			Parameters									
Storage temperature (°C)/ Packaging method			General sensory analysis					Outward apperance				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period (days)	K	$\bar{x}$	4.43^{D}	4.43^{C}	4.43^{B}	4.43^{A}	–	4.53^{C}	4.53^{D}	4.53^{B}	4.53^{B}	–
		sd	0.03	0.03	0.03	0.03		0.30	0.30	0.30	0.30	
	7	$\bar{x}$	4.40^{C}	4.37^{C}	4.44^{B}	4.50^{AB}	0.264	4.42^{abC}	4.29^{aC}	4.53^{bB}	4.42^{abB}	0.151
		sd	0.16	0.18	0.14	0.06		0.32	0.23	0.23	0.27	
	14	$\bar{x}$	4.24^{aBC}	4.28^{aBC}	4.32^{aB}	4.61^{bBC}	0.146	4.03^{AB}	4.11^{B}	4.09^{A}	4.05^{A}	0.188
		sd	0.13	0.12	0.02	0.01		0.19	0.18	0.09	0.07	
	21	$\bar{x}$	4.10^{aB}	4.16^{aB}	4.31^{bB}	4.70^{cC}	0.236	4.13^{B}	4.09^{B}	4.20^{A}	4.17^{A}	0.212
		sd	0.13	0.15	0.11	0.13		0.17	0.16	0.26	0.25	
	28	$\bar{x}$	3.82^{aA}	3.77^{aA}	4.15^{bA}	4.50^{cAB}	0.255	3.89^{abA}	3.81^{aA}	4.07^{bcA}	4.14^{cA}	0.201
		sd	0.15	0.04	0.13	0.01		0.22	0.11	0.09	0.11	
NIR			0.183	0.165	0.136	0.167		0.197	0.113	0.139	0.192	
$\bar{x}_{p\ (n=90)}$			4.20	4.20	4.33^{a}	4.55^{b}		4.20	4.17	4.28	4.26	
NIR			0.177		0.188			0.194		0.157		
$\bar{x}_{t\ (n=180)}$			4.29[a]		4.44[b]			4.18		4.27		
NIR			0.175					0.217				

$\bar{x}$ – mean value for the experimental group sd – standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values foridentically packaged grill sausages at the same temperature

a, b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

In all experimental groups, the color intensity of warm meat products assessed about 0.8 of a point higher than the unheated grill sausages (Table 6 and 7).

Table 6

Variability of sensory properties of unheated grill sausages (points)

Experimental group			Parameters									
Storage temperature [°C] / Packaging method			Colour - intensity					Colour – desirability				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period [days]	K	$\bar{x}$	4.40^{D}	4.40^{C}	4.40^{B}	4.40^{B}	–	4.60^{D}	4.60^{C}	4.60^{B}	4.60^{B}	–
		sd	0.28	0.28	0.28	0.28		0.39	0.39	0.39	0.39	
	7	$\bar{x}$	4.29^{aC}	4.31^{aBC}	$4.39a^{bB}$	4.43^{bB}	0.111	4.57^{dCD}	4.46^{cBC}	4.33^{bAB}	4.23^{aA}	0.279
		sd	0.20	0.20	0.20	0.24		0.21	0.26	0.23	0.22	
	14	$\bar{x}$	4.05^{B}	4.11^{B}	4.05^{A}	4.06^{A}	0.137	4.35^{BC}	4.31^{B}	4.29^{A}	4.29^{A}	0.186
		sd	0.20	0.15	0.06	0.06		0.22	0.25	0.21	0.18	
	21	$\bar{x}$	4.11^{B}	4.16^{B}	4.09^{A}	4.09^{A}	0.220	4.26^{B}	4.28^{B}	4.24^{A}	4.24^{A}	0.151
		sd	0.09	0.20	0.20	0.18		0.25	0.26	0.30	0.30	
	28	$\bar{x}$	3.90^{abA}	3.84^{aA}	4.02^{bA}	4.02^{bA}	0.117	3.98^{bA}	3.74^{aA}	4.18^{bA}	$4.11b^{A}$	0.234
		sd	0.22	0.21	0.13	0.11		0.15	0.16	0.27	0.11	
NIR			0.105	0.155	0.121	0.184		0.223	0.218	0.302	0.292	
$\bar{x}_{p\ (n=90)}$			4.15	4.16	4.19	4.20		4.35	4.28	4.33	4.30	
NIR			0.153		0.144			0.216		0.158		
$\bar{x}_{t\ (n=180)}$			4.16		4.20			4.32		4.31		
NIR			0.169					0.203				

$\bar{x}$ – mean value for the experimental group sd – standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

Table 7

Variability of sensory properties of warm grill sausages (points)

Experimental group			Parameters									
Storage temperature [°C] / Packaging method			Colour – intensity					Colour – desirability				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period [days]	K	$\bar{x}$	4.44^{D}	4.44^{C}	4.44^{B}	4.44^{B}	–	4.56^{C}	4.56^{D}	4.56^{B}	4.56^{B}	–
		sd	0.31	0.31	0.31	0.31		0.31	0.31	0.31	0.31	
	7	$\bar{x}$	4.34^{C}	4.33^{C}	4.29^{B}	4.41^{B}	0.111	4.49^{C}	4.43^{CD}	4.57^{B}	4.57^{B}	0.151
		sd	0.24	0.22	0.22	0.23		0.24	0.22	0.21	0.23	
	14	$\bar{x}$	4.09^{B}	4.08^{B}	4.05^{A}	4.07^{A}	0.133	4.30^{B}	4.30^{BC}	4.33^{A}	4.33^{A}	0.130
		sd	0.14	0.18	0.07	0.14		0.29	2.33	0.26	0.26	
	21	$\bar{x}$	4.09^{B}	4.10^{B}	4.13^{A}	4.14^{A}	0.220	4.20^{B}	4.20^{B}	4.19^{A}	4.18^{A}	0.185
		sd	0.11	0.17	0.24	0.24		2.31	0.29	2.42	0.26	
	28	$\bar{x}$	3.07^{abA}	3.92^{aA}	4.10^{bA}	4.09^{bA}	0.135	4.02^{aA}	3.88^{aA}	4.24^{bA}	4.24^{bA}	0.211
		sd	0.30	0.17	0.12	0.09		2.11	2.24	2.14	0.27	
NIR			0.097	0.122	0.149	0.096		0.145	0.188	0.201	0.207	
$\bar{x}_{p\ (n=90)}$			4.19	4.17	4.22	4.23		4.31	4.27	4.38	4.38	
NIR			0.145		0.118			0.170		0.146		
$\bar{x}_{t\ (n=180)}$			4.18		4.23			4.29		4.38		
NIR			0.170					0.186				

$\bar{x}$ – mean value for the experimental group sd – standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

After 7 and 14 days of storage the color desirability unheated grill sausages, stored at 3ºC was higher evaluated. The storage meat products at lower temperature received higher goods degree after 28 days of storage. These trends were not observed during the degree of warm meat products. The storage of these meat products generated debasement the point degree desirability of color. After 28 days of storage the assessment below good was observed only in two experimental groups 3M and 3M (Table 6 and 7).

In the sensory evaluation of smell intensity unheated grill sausages were observed two basic trends. The meat products stored at lower temperatures and vacuum packed characterized by slightly higher value of the color intensity (Table 8). The difference in the degree of these products analyzed in cold and warm conditions solely on the fact, that the warm grill sausages were evaluated by approximately 0.2–0.3 points higher (Table 9).

Table 8

Variability of sensory properties of unheated grill sausages (points)

Experimental group			Parameters									
Storage temperature [°C] / Packaging method			Smell – intensity					Smell - desirability				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period [days]	K	$\bar{x}$	4.37^{C}	4.37^{B}	4.37^{B}	4.37^{BC}	–	4.30^{D}	4.30^{D}	4.30	4.30	–
		sd	0.32	0.32	0.32	0.32		0.37	0.37	0.37	0.37	
	7	$\bar{x}$	4.32^{BC}	4.30^{B}	4.21^{AB}	4.38^{C}	0.366	4.27^{D}	4.27^{D}	4.22	4.21	0.138
		sd	0.20	0.22	0.22	0.23		0.17	0.22	0.22	0.25	
	14	$\bar{x}$	4.32^{BC}	4.29^{B}	4.32^{AB}	4.31^{BC}	0.130	4.02^{aC}	4.02^{aC}	4.28^{b}	4.30^{b}	0.204
		sd	0.22	0.20	0.20	0.22		0.12	0.16	0.20	0.23	
	21	$\bar{x}$	4.18^{B}	4.23^{B}	4.22^{AB}	4.21^{AB}	0.215	3.76^{aB}	3.71^{aB}	4.19^{b}	4.21^{b}	0.377
		sd	0.23	0.23	0.26	0.25		0.23	0.15	0.24	0.28	
	28	$\bar{x}$	4.00^{bA}	3.78^{aA}	4.13^{bA}	4.08^{bA}	0.175	3.03^{aA}	3.00^{aA}	4.14^{b}	4.13^{b}	0.215
		sd	0.27	0.28	0.19	0.10		0.27	0.34	0.21	0.14	
NIR			0.167	0.174	0.201	0.164		0.187	0.168	0.257	0.209	
$\bar{x}_{p\,(n=90)}$			4.23	4.19	4.25	4.27		3.88	3.86	4.23	4.23	
NIR			0.150		0.100			0.371		0.094		
$\bar{x}_{t\,(n=180)}$			4.21		4.26			3.87^{a}		4.23^{b}		
NIR			0.137					0.197				

$\bar{x}$ – mean value for the experimental group sd – standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

Table 9

Variability of sensory properties of warm grill sausages (points)

Experimental group			Parameters									
Storage temperature [°C] / Packaging method			Smell - intensity					Smell - desirability				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period (days)	K	$\bar{x}$	4.37^{B}	4.37^{B}	4.37^{BC}	4.37^{B}	–	4.53^{D}	4.53^{C}	4.53^{C}	4.53^{B}	–
		sd	0.30	0.30	0.30	0.30		0.33	0.33	0.33	0.33	
	7	$\bar{x}$	4.34^{B}	4.35^{B}	4.39^{C}	4.34^{B}	0.149	4.33^{D}	4.36^{BC}	4.36^{B}	4.31^{B}	0.259
		sd	0.25	0.24	0.24	0.24		0.18	0.22	0.22	0.25	
	14	$\bar{x}$	4.35^{B}	4.36^{B}	4.33^{BC}	4.33^{B}	0.148	4.03^{aC}	4.30^{bB}	4.30^{bB}	4.34^{bB}	0.206
		sd	0.24	0.19	0.19	0.20		0.13	0.12	0.19	0.22	
	21	$\bar{x}$	4.23^{AB}	4.26^{B}	4.25^{AB}	4.17^{A}	0.130	3.70^{aB}	4.29^{bB}	4.09^{bA}	4.36^{bB}	0.356
		sd	0.23	0.25	0.27	0.25		0.23	0.12	0.25	0.31	
	28	$\bar{x}$	4.13^{bA}	3.97^{aA}	4.22^{bA}	4.18^{bA}	0.129	3.17^{aA}	4.00^{bA}	4.00^{bA}	4.00^{bA}	0.374
		sd	0.15	0.14	0.15	0.20		0.31	0.29	0.38	0.24	
NIR			0.145	0.177	0.127	0.104		0.236	0.219	0.166	0.232	
$\bar{x}_{p\ (n=90)}$			4.28	4.26	4.31	4.28		3.95^{a}	4.30^{b}	4.26	4.31	
NIR			0.113		0.172			0.382		0.249		
$\bar{x}_{t\ (n=180)}$			4.27		4.30			4.12		4.28		
NIR			0.106					0.359				

$\bar{x}$ - mean value for the experimental group sd –standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

The smell desirability was observed lower than the intensity (especially of stored meats). The good degree of unheated as well as warm grill sausages stored in cooling conditions, was maintained up to 14 days of storage. The grill sausages stored at near cyroscopic temperature remained the good degree until the end period storage of the study. Comparing the main effects found that meat products stored at -3°C, compared with the stored in cooling conditions, characterized by lower assessment of the smell desirability (Table 8 and 9).

The juiciness was evaluated orally. This feature depends on the degree of water holding capacity and intramuscular fat content of meat products. Juiciness can not be to the extent excessive, or too small. Juiciness of meat depends on their structure, water content, water holding capacity, as well as the presence of intramuscular fat. It can be assumed that the effect of juiciness due to the presence of fat will be more accentuated in the warm experimental products.

Up to 21 days of storage the juiciness of unheated grill sausages remained at a similar level as control samples. Subsequent storage (28 days) resulted in a reduction an assessment of these parameters. Significant differences noted in the case of meat products experimental groups: 3M and – 3V (Table 10).

Table 10

Variability of sensory properties of unheated grill sausages (points)

Experimental group			Parameters									
Storage temperature [°C] / Packaging method			Texture					Juiciness				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period (days)	K	$\bar{x}$	4.29^{B}	4.29^{B}	4.29	4.29	–	4.22^{B}	4.22^{B}	4.22	4.22^{AB}	–
		sd	0.25	0.25	0.25	0.25		0.23	0.23	0.23	0.23	
	7	$\bar{x}$	4.25^{abB}	4.35^{bB}	4.18^{ab}	4.10^{a}	0.188	4.15^{AB}	4.20^{B}	4.17	4.25^{B}	0.120
		sd	0.21	0.19	0.19	0.24		0.17	0.18	0.18	0.21	
	14	$\bar{x}$	4.29^{B}	4.27^{B}	4.31	4.36	0.101	4.35^{bB}	4.30^{abB}	4.29^{ab}	4.25^{aB}	0.089
		sd	0.22	0.20	0.21	0.24		0.21	0.22	0.26	0.22	
	21	$\bar{x}$	4.26^{B}	4.29^{B}	4.26	4.29	0.180	4.29^{B}	4.24^{B}	4.2	4.29^{B}	0.159
		sd	0.25	0.28	0.32	0.28		0.23	0.25	0.28	0.24	
	28	$\bar{x}$	3.90^{aA}	3.90^{aA}	4.14^{b}	4.10^{ab}	0.212	3.93^{A}	3.96^{A}	4.09	4.09^{A}	0.168
		sd	0.26	0.31	0.16	0.24		0.30	0.27	0.11	0.09	
NIR			0.179	0.122	0.201	0.267		0.227	0.143	0.211	0.139	
$\bar{x}_{p\ (n=90)}$			4.20	4.22	4.24	4.23		4.19	4.18	4.21	4.22	
NIR			0.132		0.101			0.122		0.080		
$\bar{x}_{t\ (n=180)}$			4.21		4.23			4.19		4.22		
NIR			0.105					0.091				

$\bar{x}$ – mean value for the experimental group sd – standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

There was no effect of the method packaging and storage temperature on the juiciness experimental meat products. However, after 28 days of storage the juiciness the experiment grill sausages stored in cooling conditions assessed below good degree. The reported reduction of the juiciness could be caused by weight loss.

The juiciness of experimental warm grill sausages in sensory evaluation was obtained of approximately 0.6–0.7 points higher mean values compared with unheated meat products. Probably a higher degree juiciness of warm meat products influenced fat, which in these

sausages were amount about 34% [Górecka et al. 2011]. The degree of juiciness of meat received higher scores than good. An exception were the products of the experimental groups 3V and 3M (not heat treated), which assessed below (Table 11).

Table 11

Variability of sensory properties of warm grill sausages (points)

Experimental group			Parameters									
Storage temperature [°C] / Packaging method			Texture					Juiciness				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period (days)	K	$\bar{x}$	4.26^{B}	4.26^{B}	4.26	4.26^{AB}	–	4.28	4.28^{AB}	4.28^{B}	4.28	–
		sd	0.30	0.30	0.30	0.30		0.26	0.26	0.26	0.26	
	7	$\bar{x}$	4.26^{B}	4.33^{B}	4.26	4.29^{AB}	0.098	4.25	4.31^{B}	4.29^{B}	4.30	0.112
		sd	0.19	0.22	0.22	0.23		0.22	0.29	0.29	0.23	
	14	$\bar{x}$	4.33^{BC}	4.37^{B}	4.32	4.33^{B}	0.112	4.34	4.39^{B}	4.29^{B}	4.25	0.115
		sd	0.20	0.14	0.16	0.25		0.25	0.12	0.15	0.19	
	21	$\bar{x}$	4.38^{C}	4.31^{B}	4.31	4.29^{AB}	0.147	4.27	4.32^{B}	4.38^{B}	4.31	0.195
		sd	0.25	0.24	0.31	0.29		0.28	0.24	0.31	0.29	
	28	$\bar{x}$	4.10^{A}	4.13^{A}	4.23	4.17^{A}	0.152	4.10	4.11^{A}	4.17^{A}	4.16	0.113
		sd	0.19	0.10	0.16	0.14		0.26	0.09	0.11	0.07	
NIR			0.113	0.119	0.144	0.129		0.271	0.177	0.101	0.166	
$\bar{x}_{p\ (n=90)}$			4.26	4.28	4.27	4.27		4.25	4.28	4.28	4.26	
NIR			0.180		0.174			0.104		0.168		
$\bar{x}_{t\ (n=180)}$			4.25		4.27			4.27		4.27		
NIR			0.169					0.176				

$\bar{x}$ – mean value for the experimental group sd –standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

The point degree texture of unheated meat products for 21 days remained unchanged (Table 10). During the further storage of meat products (experimental groups 3V and 3M) significant reduction assessment of these parameters were observed. The method packaging and storage temperature have not affect on the degree of the analyzed parameter.

Determined sensory texture showed no correlation with instrumentally measured rheological parameters. The meat storage of experimental conditions generated reduction flavor intensity unheated grill sausages (Table 12). After 28 days assessment of stored unheated meat products have deteriorated to a level below good degree. Significant reduction in the value of these parameters was also in the case meats of experimental group – 3V28.

Table 12

Variability of sensory properties of unheated grill sausages (points)

Experimental group			Parameters									
Storage temperature [°C] / Packaging method			Flavour – intensity					Flavour – desirability				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period [days]	K	$\bar{x}$	4.27^{B}	4.27^{B}	4.27^{B}	4.27^{B}	–	4.25^{D}	4.25^{C}	4.25	4.25	–
		sd	0.24	0.24	0.24	0.24		0.22	0.22	0.22	0.22	
	7	$\bar{x}$	4.15^{b}	4.30^{B}	4.31^{B}	4.20	0.164	4.20^{D}	4.31^{C}	4.21	4.19	0.259
		sd	0.17	0.19	0.19	0.19		0.17	0.21	0.21	0.21	
	14	$\bar{x}$	4.21^{B}	4.31^{B}	4.21^{AB}	4.29	0.165	3.95^{aC}	4.01^{aB}	4.19^{b}	4.26^{b}	0.149
		sd	0.23	0.20	0.14	0.22		0.20	0.16	0.14	0.24	
	21	$\bar{x}$	4.18^{B}	4.21^{B}	4.28^{B}	4.22	0.136	3.57^{aB}	3.81^{bB}	4.24^{c}	4.19^{c}	0.217
		sd	0.20	0.25	0.28	0.26		0.17	0.20	0.30	0.24	
	28	$\bar{x}$	3.78^{aA}	3.88^{aA}	4.06^{bA}	4.0^{b}	0.175	2.79^{aA}	3.00^{aA}	4.00^{b}	4.10^{b}	0.374
		sd	0.26	0.29	0.27	0.14		0.44	0.35	0.31	0.15	
NIR			0.179	0.237	0.169	0.211		0.152	0.235	0.352	0.179	
$\bar{x}_{p\ (n=90)}$			4.12	4.19	4.23	4.21		3.75	3.88	4.18	4.20	
NIR			0.149		0.192			0.397		0.122		
$\bar{x}_{t\ (n=180)}$			4.16		4.22			3.81^{a}		4.19^{b}		
NIR			0.105					0.276				

$\bar{x}$ – mean value for the experimental group sd – standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

The intensity flavor in the warm grill sausages was assessed higher than the unheated products: the difference ranged from 0.05 to 0.25 points (Table 13). The products of one group 3M28 not reached a level of good degree.

Table 13

Variability of sensory properties of warm grill sausages (points)

Experimental group			Parameters									
Storage temperature [°C] / Packaging method			Flavour – intensity					Flavour – desirability				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period (days)	K	$\bar{x}$	4.36^{C}	4.36^{B}	4.36	4.36	–	4.28^{CD}	4.28^{C}	4.28^{B}	4.28^{B}	–
		sd	0.30	0.30	0.30	0.30		0.23	0.23	0.23	0.23	
	7	$\bar{x}$	4.21^{aB}	4.41^{bC}	4.28^{a}	4.28^{a}	0.095	4.49^{D}	4.31^{C}	4.39^{B}	4.30^{B}	0.369
		sd	0.22	0.23	0.23	0.25		0.15	0.26	0.26	0.24	
	14	$\bar{x}$	4.20^{aB}	4.27^{abB}	4.32^{b}	4.31^{b}	0.101	4.06^{aC}	4.03^{aB}	4.34^{bB}	4.35^{bB}	0.225
		sd	0.25	0.22	0.13	0.21		0.18	0.16	0.18	0.24	
	21	$\bar{x}$	4.27^{BC}	4.32^{B}	4.30	4.32	0.126	3.51^{bB}	2.83^{aA}	4.31^{cB}	4.32^{cB}	0.227
		sd	0.23	0.22	0.29	0.29		0.22	0.17	0.28	0.27	
	28	$\bar{x}$	4.03^{aA}	3.90^{aA}	4.21^{b}	4.20^{b}	0.153	2.93^{bA}	2.68^{aA}	3.84^{cA}	3.90^{cA}	0.215
		sd	0.15	0.23	0.14	0.10		0.35	0.35	0.36	0.37	
NIR			0.128	0.168	0.154	0.164		0.239	0.152	0.259	0.149	
$\bar{x}_{p\ (n=90)}$			4.21	4.23	4.29	4.29		3.85	3.63	4.23	4.23	
NIR			0.126		0.166			0.138		0.160		
$\bar{x}_{t\ (n=180)}$			4.23		4.29			3.74^{a}		4.23^{b}		
NIR			0.111					0.356				

$\bar{x}$ – mean value for the experimental group sd –standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

Flavor desirability reflects the actual degree of acceptance of this parameter of experimental meat products, after experimental period's storage. In the case unheated grill sausages, keeping in refrigerated caused a dynamic, systematic reduction assessment of this discriminant, after 28 days of even less than sufficient to degree (3V). The use of storage at near cryoscopic temperature favored maintaining to the end of the period storage the good evaluated of meat products. The packaging used methods did not affect the flavour. Storage unheated grill sausages at near cryoscopic temperature generates significantly higher flavour desirability.

Flavor desirability warm grill sausages stored at 3°C for 14 days assessed was described as good. Up to 21 days grill sausage stored at 3°C preserved good degree. After another 7 days, it was only slightly lower than the good degree.

Saltiness: the intensity and desirability as classified at the level of the good degree or slightly above. Good degree remained during the entire experiment, irrespective of the method of packaging and storage temperature. Flavor desirability assessed by about 0.5 points higher than the intensity (Table 14 and 15).

General sensory analysis of unheated grill sausages stored at near cryoscopic temperature for the duration of the experiment remained at a high level the degree. After the end study it was only 0.2 lower than the degree control samples. After 28 days of storage the significant differences occurred in the samples – 3V and – 3M. Packaging used methods did not affect the results of the degree. Meats stored at 3°C preserved a rating of good for 21 days. The statistically significantly higher degree unheated meat products stored at -3°C, compared in refrigerated conditions was observed after 28 days of storage. In the case warm grill sausages the trends was observed after 14 days of storage.

Table 14

Variability of sensory properties of unheated grill sausages (points)

Experimental group			Parameters									
Storage temperature [°C] / Packaging method			Saltiness – intensity					Saltiness – desirability				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period [days]	K	$\bar{x}$	4.13^{B}	4.13^{B}	4.13^{B}	4.13^{C}	–	4.57	4.57^{AB}	4.57	4.57^{B}	–
		sd	0.24	0.24	0.24	0.24		0.06	0.06	0.06	0.06	
	7	$\bar{x}$	4.07^{A}	4.07^{A}	4.03^{A}	4.01^{A}	0.033	4.54	4.64^{B}	4.58	4.35^{A}	0.317
		sd	0.17	0.19	0.19	0.19		0.04	0.02	0.57	0.3	
	14	$\bar{x}$	4.05^{A}	4.05^{A}	4.04^{A}	4.06^{AB}	0.067	4.57	4.64^{B}	4.61	4.60^{B}	0.212
		sd	0.23	0.20	0.14	0.22		0.02	0.09	0.03	0.07	
	21	$\bar{x}$	4.06^{A}	4.06^{A}	4.06^{A}	4.07^{B}	0.036	4.56	4.61^{AB}	4.58	4.50^{AB}	0.266
		sd	0.20	0.25	0.28	0.26		0.10	0.16	0.13	0.17	
	28	$\bar{x}$	4.06^{A}	4.06^{A}	4.07^{AB}	4.07^{B}	0.040	4.56	4.44^{A}	4.58	4.58^{B}	0.251
		sd	0.26	0.28	0.27	0.14		0.10	0.10	0.08	0.21	
NIR			0.056	0.054	0.062	0.053		0.187	0.173	0.151	0.212	
$\bar{x}_{p\ (n=90)}$			4.07	4.07	4.07	4.07		4.56	4.58	4.58	4.52	
NIR			0.030		0.035			0.166		0.114		
$\bar{x}_{t\ (n=180)}$			4.07		4.07			4.57		4.55		
NIR			0.034					0.163				

$\bar{x}$ – mean value for the experimental group sd – standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

Table 15

Variability of sensory properties of warm grill sausages (points)

Experimental group			Parameters									
Storage temperature [°C] / Packaging method			Saltiness - intensity					Saltiness - desirability				
			3		-3		NIR	3		-3		NIR
			vacuum	map	vacuum	map		vacuum	map	vacuum	map	
Storage period (days)	K	$\bar{x}$	4.09	4.09	4.09	4.09	–	4.57	4.57	4.57	4.57	–
		sd	0.23	0.23	0.23	0.23		0.34	0.34	0.34	0.34	
	7	$\bar{x}$	4.07	4.06	4.05	4.05	0.036	4.55	4.60	4.66	4.57	0.213
		sd	0.10	0.06	0.08	0.07		0.25	0.26	0.26	0.28	
	14	$\bar{x}$	4.06	4.05	4.05	4.06	0.020	4.57	4.67	4.64	4.61	0.112
		sd	0.08	0.07	0.06	0.06		0.30	0.20	0.23	0.31	
	21	$\bar{x}$	4.04	4.07	4.04	4.04	0.034	4.52	4.54	4.60	4.69	0.266
		sd	0.05	0.07	0.05	0.04		0.40	0.41	0.30	0.20	
	28	$\bar{x}$	4.04	4.00	4.05	4.03	0.036	4.50	4.51	4.50	4.50	0.251
		sd	0.05	0.04	0.09	0.07		0.43	0.42	0.43	0.43	
NIR			0.055	0.042	0.039	0.049		0.119	0.227	0.199	0.219	
$\bar{x}_{p\ (n=90)}$			4.06	4.05	4.06	4.05		4.54	4.58	4.59	4.59	
NIR			0.023		0.025			0.171		0.182		
$\bar{x}_{t\ (n=180)}$			4.05		4.06			4.56		4.59		
NIR			0.124					0.154				

$\bar{x}$ – mean value for the experimental group sd – standard deviation

$\bar{x}_t$ – mean values for grill sausages storage at the same temperature

$\bar{x}_p$ – mean values for identically packaged grill sausages at the same temperature

a, b, c. – mean values in the same row denoted by different capital letters are significantly differ at level of $p \leq 0.05$

A, B, C – mean values in the same columns denoted by different capital letters are significantly differ at level of $p \leq 0.05$

The experimental results confirmed the previous studies, when was observed positive impact stored meat at near cryoscopic temperature on their sensory evaluation [Szmańko and Dzieszuk 2007b, Szmańko 1998, Szmańko et al. 2004a, 2004b, 2005, 2007].

Conclusions

The storage meat products in the experimental conditions resulted in reduction values of texture, hardness and springiness as well as gumminess. However did not have affected the cohesiveness and chewiness. The storage grill sausages at near cryoscopic temperature (-3°C) compared to the storage of refrigerated (3°C) resulted in a lower cohesiveness. The method packaging had no effect on the texture of meat products.

The grill sausages vacuum packed in the plastic bags or inert gas atmosphere stored in refrigerated conditions kept for 21 days of storage conserved good qualities, and conditions at near cryoscopic for 28 days. The meat products stored at -3°C had significantly higher desirability of smell and flavor compared with the stored refrigeration.

References

Bourne M., 1982. Ford texture and viscosity: Koncept and measurement. Academic Press, New York.

Czarniecka-Skubina E., Przybylski W., Jaworska D., Czyżo A., Bieńkowska A., 2009. The assurance of quality and safety of ford production on the example of meat and meat products. Food quality and safety. Ed. G. Krasnowska and A. Pęksa. Wrocław, 34–44.

Dzieszuk W., Dworecka E., Szmańko T., 2005. Wpływ dodatku skrobi modyfikowanej na jakość kutrowanych kiełbas parzonych. Acta Science Polish Technologia Alimentaria. 4 (1), 111–121.

Fortuna T., Krysińska P., 2007. Elektroniczny nos i język – zastosowanie w przemyśle spożywczym. Laboratorium Przemysłowe 7/8, 44–47.

Górecka J., Szmańko T., Bilyk O., Kęsy Z., Świątkowski G., 2011. Physical properties of grill sausages depending on packaging and storage conditions (in printing).

Jarmoluk A., Zimoch A., Tomaszek A., 2007. Wpływ mąki kukurydzianej na zmienność wybranych cech jakościowych homogenatów mięsnotłuszczowych. Roczniki Instytutu Przemysłu Mięsnego i Tłuszczowego. XLV/1, 133–144.

Juszczak L., 2005. Tekstura żywności. Laboratorium Przemysłowe 2, 40–44.

PN-ISO 6658. 1998. Analiza sensoryczna. Metodologia. Wytyczne ogólne (Sensory analysis Methodology. General guidance.

Szmańko T., 1998. Ocena efektywności przechowywania wędzonek w temperaturze bliskiej krioskopowej oraz w stanie zamrożonym (badania modelowe). Zeszyty Naukowe AR Wrocław Rozprawy 334, CLIV, 1–124.

Szmańko T., Duda Z., Szczepański J., 2004a. Wpływ przechowywania wędzonek w temperaturze bliskiej krioskopowej i w stanie zamrożonym na ich jakość sensoryczną. Żywność. Nauka. Technologia. Jakość. 1, (38), 105–119.

Szmańko T., Duda Z., Szczepański J., Dworecka E., 2004b. Zmiany przechowalnicze tłuszczu oraz zanieczyszczenie mikrobiologiczne wędzonek w zależności od warunków przechowywania. Żywność. Nauka. Technologia. Jakość. 2, (39), 46–58.

Szmańko T., Dzieszuk W., 2007a. Jakość i bezpieczeństwo mięsa i przetworów mięsnych. Prace Instytutu Zarządzania i Inżynierii Rolnej PWSZ w Sulechowie. Technologia Żywności i Żywienie Człowieka. 1, 101–108.

Szmańko T., Dzieszuk W., 2007b. Przechowywanie mięsa i przetworów mięsnych w stanie głębokiego schłodzenia. Prace Instytutu Zarządzania i Inżynierii Rolnej PWSZ w Sulechowie. Technologia Żywności i Żywienie Człowieka. 1, 95–100.

Szmańko T., Korzeniowska M., Kołodziejczyk J., 2007. The effect of plasma and myogel. Addition on the quality of homogenised sausages. Polish Journal Food Nutricial Science, Vol. 57, No. 4 (C), 529–534.

Szmańko T., Malicki A., Cichoń A., Brużewicz S., Dworecka E., 2005. Quality of sopocka pork loin wrapped directly post thermal treatment or after chilling and stored at near cryoscopic temperature. Polish Journal Food Nutricial Science 14/55, 111–116.

8

PHYSICOCHEMICAL PROPERTIES OF COOKED TUBERS OF BLUE AND RED POTATO

Introduction

Coloured flesh potatoes, particularly purple/blue or red, are getting more and more interesting for consumers in different countries. In studies undertaken for 10 years concerning the influence of environment factors and conditions of cultivations variety of full tubers, has been emphasized their significance as the source of pro-healthy compounds, particularly anthocyanins [Brown et al. 2003, Lachman, Hamouz 2005; Lachman et al. 2008, Hejtmánková et. al. 2009]. Varieties with coloured flesh are less known in comparison to varieties with cream, yellow or white flesh. Potatoes with coloured flesh became from the South America where they occurred in different colours: purple, pink, orange or yellow. The colour of flesh is very often similar to skin colour.

At the beginning the potatoes with coloured flesh were not perceived as the food components. The researchers were focused mainly on the development of different varieties with light flesh colour. As the result for many consumers potato is associated only with white or yellow colour. The edible potato should be characterized by many organoleptic features and have appropriate chemical composition [Pęksa 2008, Lisińska et al. 2009]. The most important organoleptic features are: taste of cooked tubers, their aroma and texture. Many varieties of coloured flesh potatoes are characterized by excellent culinary qualities, but these potatoes are not popular in cultivation and in trade. In the last few years potatoes with coloured flesh occurred in retail trade in some European countries, like Great Britain, and they enlarged their popularity on the American market. The Purple Majesty variety is this kind of potato. It is accessible in the trade of UK and Scotland, is characterized by intensive purple colour and it contains 10 times more antioxidants, including anthocyanins, in comparison to potatoes with light flesh [Clark et al. 2010]. Moreover in the USA are popular varieties, like All Blue and Russian Blue, with dull blue-purple flesh and skin colour. Others like Salad-Blue with dark blue skin and blue-purple flesh, which after cooking have dull purple colour, and their consistency is similar to King Edward variety popular in Great Britain, Congo variety similar to Salad Blue with buttery flavour and floury texture, Highland Burgundy Red variety with white flesh with prominent pink ring and dark red skin, Salad Red variety similar to Salad Blue, but with pink flesh, Cardinal variety - red with red flesh, Urenika - with blue skin and flesh come from New Zeland [Washington State Potato Commission]. The colour is not directly a taste component of flavour, but it can influence the perception of taste [Jansky 2010]. However, the sensory evaluation of coloured flesh potatoes have not yet been published.

The flavour and taste have important significance in determining the quality of potatoes. The flavour is created by aromatic volatile compounds in potatoes, which are synthesized in a plant during metabolic processes and are modificated during preparing them for consump-

tion in the industry. The increased temperature during the potato processing significantly increased the amount of different volatile compounds in tubers. Basing the initial data, 159 volatile compounds in raw potatoes, 182 – in cooked potatoes and 392 – in baked potatoes were determined [Dresow, Böhm, 2009]. The specific aroma of raw potato is depended on the genetic feature of variety and is changing under the influence of conditions of cultivation (fertilization), storage and conditions of processing which can also influence on the sensory quality of cooked tubers [Reyes et al. 2004].

The composition of volatile compounds is determined genetically and depends on the amounts, type and enzymes activity taking part in producing the aromatic compounds in tubers. The most important volatile compounds in potato responsible for the flavour are the products of fat degradation as well as the result of Maillard'a reaction and sugar degradation during heating [Oruna-Koncha et al. 2002]. Investigations of different authors [Desjardins et.al. 1995, Oruna-Koncha et al. 2002, Jansky 2010, Morris et al. 2010] confirm the fact that differences in flavour among varieties of potatoes are the result of quantitative than qualitative differences. However, there is a lack of comparative analysis concerning the volatile compounds in raw potatoes [Oruna-Koncha et al. 2002]. There is also not enough information about the typical flavour of cooked potato with reference to existing differences in varieties. Thybo et al. [2006] proved the influence of varieties on the composition of aromatic compounds in cooked tubers after peeling. In varieties like Berber, Arkula, Marabel, Sara, Folva and Agria they ascertained that the variety was responsible for differences in flavour.

The texture of potatoes after cooking is a feature deciding about the consumption quality but at the same time it influences on the release the flavor volatile compounds and relishes a suitable taste [Jansky 2010]. The mealiness which is typical for mealy potato and in the sensory evaluation it is determined as dry and granular, and the waxiness (its contrast) which characterized the potato by moist and gummy decide about the flavor and aroma of cooked tubers except the content of dry substances, including starch, sugars, proteins, mineral compounds and nitrogen compounds. The mealiness of potato is considered as one of the readily described components of flavour during the sensory evaluation [Martens, Thybo 2000, Thybo et al. 2000, Surmacka Szczesniak 2002, Nourian et al. 2003]. Also the hardness of cooked potato can affect its taste and flavour reception. Potato varieties differing in cell wall thickness and pectin substances composition in walls and middle lamellae will be different in potato tissue resistant to shearing, resulting in a hard, particulate mouthfeel [Thybo et al. 2006].

Confirmed by many investigations the pro-healthy influence of natural antioxidants occurred in plants, like polyphenols and anthocyanins, enlarged the interest of potato with coloured flesh as the source of such compounds. In breeding, cultivation and technological tests there is emphasized the significant content of polyphenolic and anthocyanins compounds in potatoes with purple/blue and red flesh even after heat treatment, including baking and cooking. In the literature there is no information about the influence of difference in varieties of potatoes with the same flesh colour on the type and content of volatile compounds, on the colour of raw and cooked tubers as well as on the texture and organoleptic features of cooked tubers.

The aims of this study were to investigate the sensory properties, volatiles, discoloration and the texture of cooked purple and red potatoes compared with yellow potatoes to establish whether they could possessed suitable material for human diet.

Materials and methods

Raw material

As the raw material ten potato varieties of coloured flesh have been taken for the experiment. They consisted of five blue/purple-fleshed varieties: Blaue Elise (BE) of 19,48% moisture content, Blaue St. Gallee (BStG) of 19,24% moisture content, Blue Congo (BC) of 21,37% moisture content, Valfi (V) 19,93% moisture content and Vitelotte (Vi) of 28,86% moisture content, four red-flesh potatoes: Highland Burgundy Red (HBR) of 23,14% moisture content,Herbie 26 (H26) of 19,17% moisture content, Rosalinde (R) – registered as Rosemarie of 20,62% moisture content and Rote Emma (RE) of 17,64% moisture content and one yellow-fleshed variety: Agria (A) of 19,70% moisture contentfrom the growing season of 2009. The potatoes were grown in the experimental plots belonging to testing station of The Central Institute for Supervising and Testing in Agriculture at Přerov nad Labem (The Czech Republic).

The samples of potato tubers were harvested after reaching full maturity. After harvest mechanically damaged, greened and sprouted potatoes were rejected. Tubers were stored for 5 months at 4°C. There were selected samples of 10 tubers of similar weight of individual tuber (60–80 g) from the samples of each variety weighted 20 kg.

Boiling procedure

Each of the tuber was washed. Duplicate samples of 5 tubers were immersed in a boiling water bath for about 20 minutes until they were cooked through, measured by a fork. Cooked tubers were air-cooled and drained on a sheet of filter paper for 5 minutes and afterwards their sensory attributes (aroma, taste and flavour, hardness,). were evaluated by a panel of 5 trained people. There was served one hot tuber from each sample of tubers. The attributes were evaluated on a 1–4 point scale. The description of the numbers respected to particular attributes is given in Table 1. For texture analysis cooked tubers were destined and for colour measurement raw and cooked tubers were taken. For these analyses the whole potatoes were cooked with skin in a boiling water bath, like for the sensory evaluation. For volatiles determination duplicate samples of 3 tubers were taken.

Table 1

Description of cooked potato attributes corresponding to the points of sensory evaluation [Beschreibende Sortenliste Für Kartoffeln 1993, Van Marle et al. 1997]

Attribute	Points	Description
1	2	3
Aroma	1	strong or medium, typical potato aroma
	2	faint to medium, typical potato aroma, still pure
	3	declined or faint potato aroma
	4	untypical and inappropriate aroma for edible potatoes
Taste and flavour	1	aromatic potatoes of typical, strong flavour
	2	potatoes of mild flavour and typical, pleasant taste
	3	potatoes of less intensive taste and flavour
	4	potatoes of untypical, disagreeable taste

Table 1 cont.

1	2	3
Hardness	1 2 3 4	very hard or hard potatoes quite hard potatoes mealy potatoes, a rather loose potatoes breaking up into pieces
Mealiness	1 2 3	slightly mealy potatoes moderate mealy potatoes very mealy potatoes, a loose

Texture evaluation

An Instron type 5 544 texture-measuring device with Merlin software was used for texture of boiled potatoes evaluation. Whole boiled and cooled potato tubers were cut by knife in to sticks of square cross-section (10 mm x 40 mm height). The minimal force (N) necessary to cut a stick was measured using a share blade at blade displacement rate of 250 rpm. Results are the means of 18 measurements

Colour determination

Raw and cooked tubers were cut longitudinally into halves and colour of the samples was evaluated by measuring values L, a, b of Hunter's system [Clydesdale 1976], using Minolta Chroma Meter CR-200. These parameters represent: *L* – brightness (on a lightness--darkness scale) whereas positive and negative *a* values determine the redness and greenness, and positive and negative *b* values determine yellowness and blueness, respectively. The Chroma Meter was calibrated against a white-standard. Measurements were done three times on 3–4 tuber's halve and the average of ten readings was calculated. There were individual differences in *L, a* and *b* estimated.

Volatile components analysis

The volatiles were obtained using steam distillation extraction methodology. Approximately 300 g of investigated potatoes were chopped and placed in 2 L round-bottomed flask. The distillation were performed in drying apparatus, a volatiles were extracted into the organic phase (cyclohexane). After 2 h of the process, organic phase were collected, dried over anhydrous Na_2SO_4 and frozen (-16^{o}C) until the gas chromatography-mass spectrometry (GC-MS) were performed. More then 30 compounds were identified. For some cases the nuclear magnetic resonance was done, for establishing structures of the predominated compounds – sesquiterpenes.

Statistical analysis

The data were analyzed statistically using a Statistica 9.0 programme. For comparison, the results obtained were analyzed using one-way analysis of variance with the application of Duncan's test ($P \leq 0.05$). One-way analysis of variance was used for determining, the significance of differences between the features of studied potatoes of different flesh colour.

Results and discussion

The results of sensory evaluation of the aroma of boiled potatoes of purple/blue and red fleshed varieties when compared to yellow-fleshed Agria variety are presented in Fig. 1. As it can be noticed from the figure the aroma most of studied samples of blue and one red-fleshed (Rote Emma) varieties was similar in its typical character and the level of intensity. These potatoes characterized pleasant, clear and distinct potato aroma (points in the range 1–1.75 in 4 points' scale). The aroma, also natural and clear but of slightly weaker intensity was stated for cooked potatoes of yellow-fleshed Agria, blue-fleshed Blaue Elise and red-fleshed Highland Burgundy (all 2 points). After boiling the aroma of tubers of Herbie 26 (2.5 points) and Rosalinde (2.25) red-fleshed varieties occurred weak and untypical.

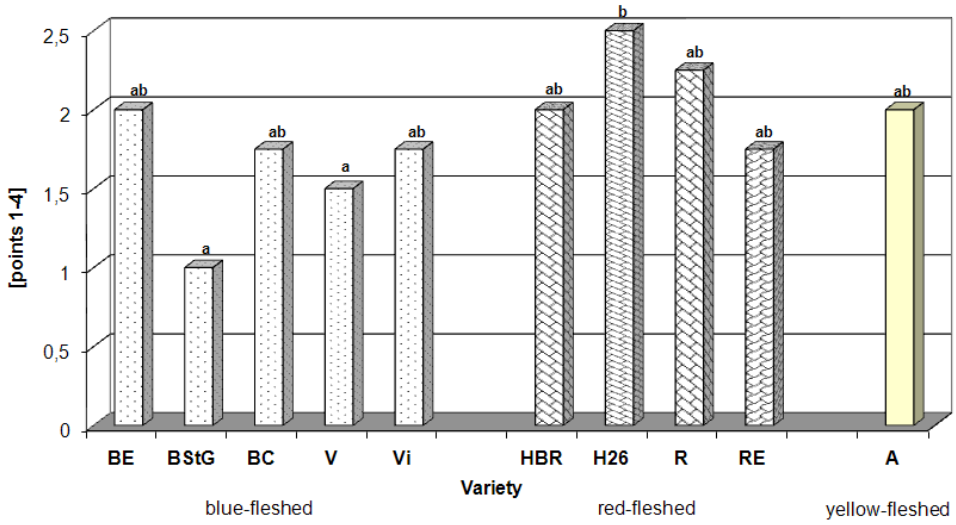

Fig. 1. The influence of potato variety on the aroma cooked tubers

As it appears from figure 2 there were found significant differences between blue, red and yellow-fleshed potatoes with respect to their flavour and taste after boiling. Blue/purple-fleshed potatoes of Blaue Elise, Blaue St. Gallee, Blue Congo and Valfi varieties were of similar flavour and taste like yellow-fleshed Agria (points in the range 1.5–2). They characterized natural, mild and aromatic, pleasant potato taste and flavour. Potatoes of blue-fleshed Vitelotte, red-fleshed Rosalinde, red-fleshed Highland Burgundy Red and Rosalinde characterized much less aromatic and intensive flavour and taste (points in the range 2.75–3.25) which were evaluated in the sensory analyses as untypical.

Though pigments such anthocyanins and carotenoids are not thought to directly influence flavour there are known reports [Jansky 2010] that carotenoid degradation products following cooking of sweet potato can contribute to their flavour. The untypical aroma and taste of cooked potato could be connected with the presence of skin on the tubers during cooking. Some soluble cellular components are likely to be important in flavour and affect on taste parameters, like for example bitter, sour, sweet or umami [Dresow, Böhm 2009, Morris

et al. 2010, Ulrich et al. 2000]. In potato tubers during processing are produced hundreds of volatile compounds which can affect the sensory quality. Boiled potatoes contain high levels of lipid degradation products like aldehydes and ketones, which contribute to floral, fruity or fatty flavour and products of lipid oxidation, which contribute to earthy aroma. On the potato taste and flavour acceptance affects also texture of cooked potato [Jansky 2010]. It influence the release of volatile flavour components during chewing. This can affect consumer preferences and sensory evaluation of cooked potato texture parameters, like hardness, firmness, adhesiveness, graininess, mealiness or moistness. However the most important is mealiness and their descriptors mealy and non-mealy as the best describing texture of cooked potato [Van Marle et al. 1997]. Some authors [Martens, Thybo 2000] stated that is also the best sensory attribute which relates to instrumental measurements of potato tissue texture.

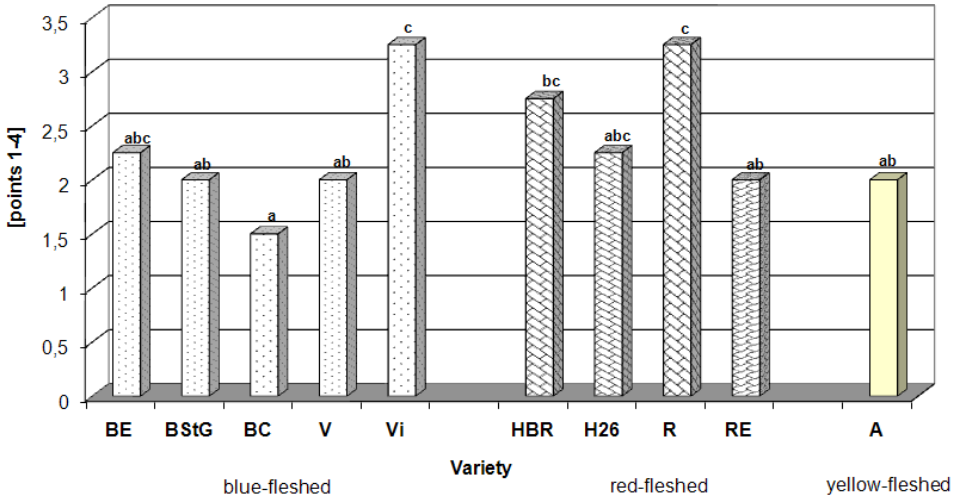

Fig. 2. The influence of potato variety on the taste and flavours of cooked tubers

Figure 3 presents the influence of potato variety on the mealiness of boiled colour-fleshed tubers. Studied blue-fleshed potatoes were evaluated mostly as slightly mealy potato with fine or rather fine structure (points in the range 1–1,5), however Vitelotte found to be a bit more mealy than others studied blue-fleshed varieties. Among red-fleshed varieties Highland Burgundy and Herbie 26 characterized more meal. rather loose structure (1,6 point in the 3 points scale) but Rosalinde and Rote Emma boiled tubers represented potatoes non mealy or slightly mealy with rather fine structure, similarly like Agria and blue-fleshed potatoes.

Important culinary property of table potato varieties is the hardness of boiled tubers. From Figure 4 it appears that only Blaue Elise tubers were evaluated as hard or very hard (1 point in 4 points' scale), significantly more hard than cooked tubers of blue/purple flesh colour Blaue St. Gallee and red-fleshed Highland Burgundy, Herbie 26 and Rosalinde, which were characterized as more floury type potatoes (points in the range 2.12–2,25). It is also very easy to notice that the hardness of nearly all studied blue and red-fleshed potato varieties was evaluated very similar like popular yellow-flesh Agria variety. Studied potatoes could be classified in B-C cooking type. Within this classification 4 types are described: A type – as an especially firm, non-mealy potato with a fine structure, B – as a firm, slightly mealy potato

with a fine or rather fine structure, C – as a rather loose, mealy potato and D – as a loose, very mealy potato.

Differences between studied varieties of coloured fleshed potato in their sensory properties after boiling resulted not only from variety but also could be the result of the effect of storage conditions (studied potatoes were stored for 5 months in 4°C) on varieties of different susceptibility on storing. Probable changes in tubers concerned mechanical properties of tubers' tissue, type of products created during conversions of carbohydrates, like starch and pectins as well as protein or organic acids.

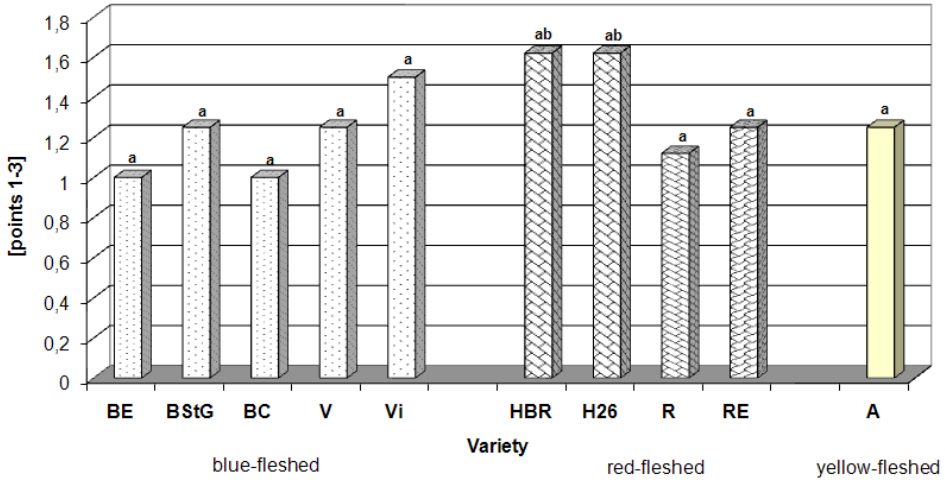

Fig. 3. The influence of potato variety on the mealiness of cooked tubers

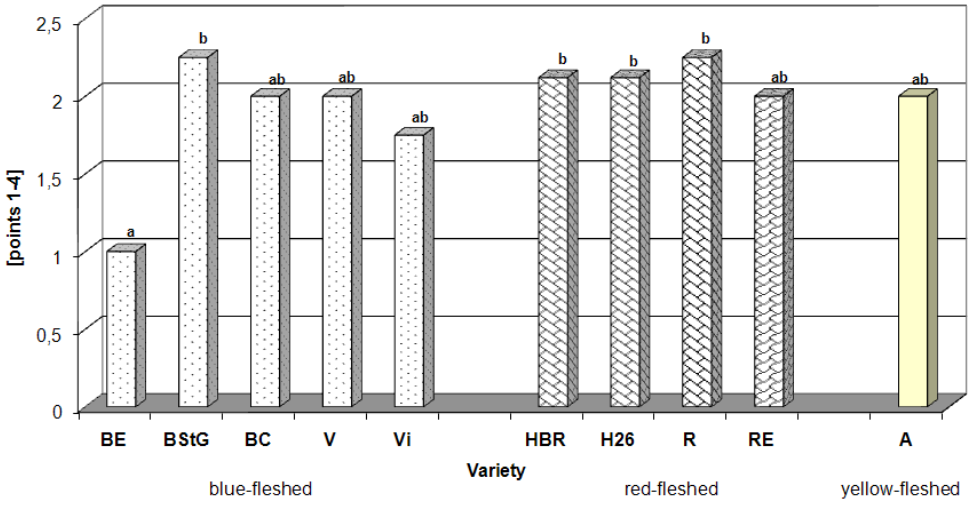

Fig. 4. The influence of potato variety on the hardness of cooked tubers

The results of texture measurements of boiled tubers of blue and red-fleshed potato varieties presented in Figure 5 confirm their soft consistence (low hardness). To cut cooked potato strips of square cross-section (10 mm x 40 mm height), the force mostly lower than 4 N was needed, similarly like for cutting strips of Agria variety known as slightly meal. rather loose potato. The highest force was needed to cut strips of cooked blue-fleshed Vitelotte (6,13 N).

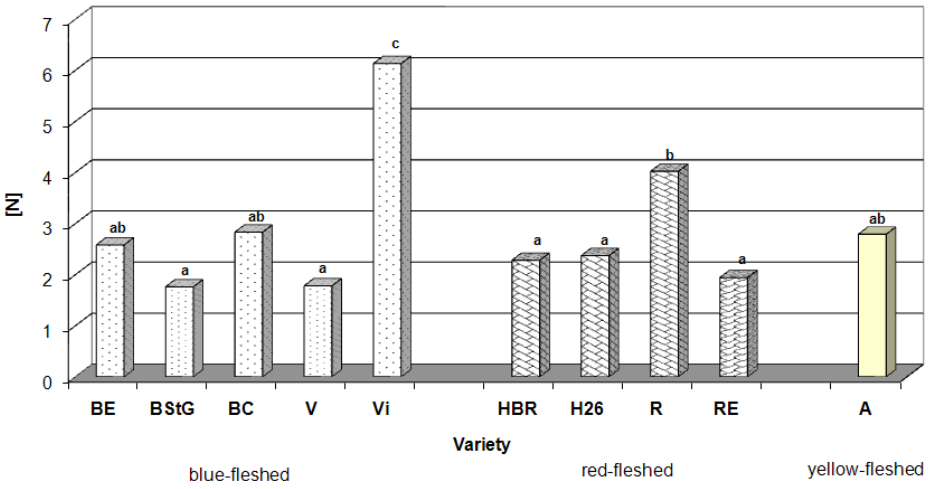

Fig. 5. The influence of potato variety on the teksture of cooked tubers

The texture of studied coloured-fleshed potatoes was similar to the texture of cooked potatoes studied by Kaur et al. [2002]. Hardness of those potatoes measured in TPA test after 30 minutes boiling was in the range 7–11,42 N.

Colour parameters *L, a, b* of Hunters' system as affected on potato variety and boiling process are shown in figures 6, 7 and 8. Blue coloured potato tubers, independently on the boiling effect, demonstrated lower values of parameter *L* (values in the range 31,92–41,67) comparingwith red-fleshed potatoes (values in the range 50,65–61,97) and Agria yellow-fleshed variety (77,72–77,90) (figure 6). There was stated only slight effect of boiling process on tubers' brightness. Among blue-fleshed varieties tubers of Vitelotte showed a larger increase in brightness after boiling (*L* values changed from 32,04 to 41,67) and similarly red-fleshed Herbie 26 (*L* values changed from 55,06 to 61,97). The associated changes both in *a* and *b* values (figures 7 and 8, respectively) as affected on boiling process were noticeable, particularly in tubers of blue/purple-fleshed varieties, and in tubers of red-fleshed varieties but only changes in *a* values (figure 7). The colour parameter "*a* value" of cooked potatoes of varieties Blaue Elise, Blaue St. Gallee, Blue Congo and Valfi showed noticeable decrease, however only in the case of Blue Congo statistically important (*a* values changed from 15,38 to 7,55). A share of "*a* value" in raw and cooked tubers' colour of red-fleshed varieties decreased significantly, particularly in tubers of Rosalinde variety (*a* values changed from 21,18 to 6,66). So, the intense of red colour in red-fleshed varieties decreased much more than in blue-fleshed varieties as an effect of boiling. As it appears from figure 7 yellow-fleshed Agria variety demonstrated more deep green colour after boiling (*a* values changed

from -10,38 to -16,21). Simultaneously, the changes in "*b* value" of colour parameter were directed to deep blue colour of blue-fleshed varieties after boiling. These phenomena were particularly intense in tubers of Blue Congo, Valfi and Vitelotte (*b* values changed from -8,07 to -16,67, from -8,54 to -17,48 and from -6,65 to -16,94, respectively) (figure 8). In the colour of red-fleshed varieties the values of *b* parameter were small and positive (yellow shade) and showed as an effect of boiling only slight increase in tubers of Rote Emma variety (*b* values changed from 1,87 to 4,94).

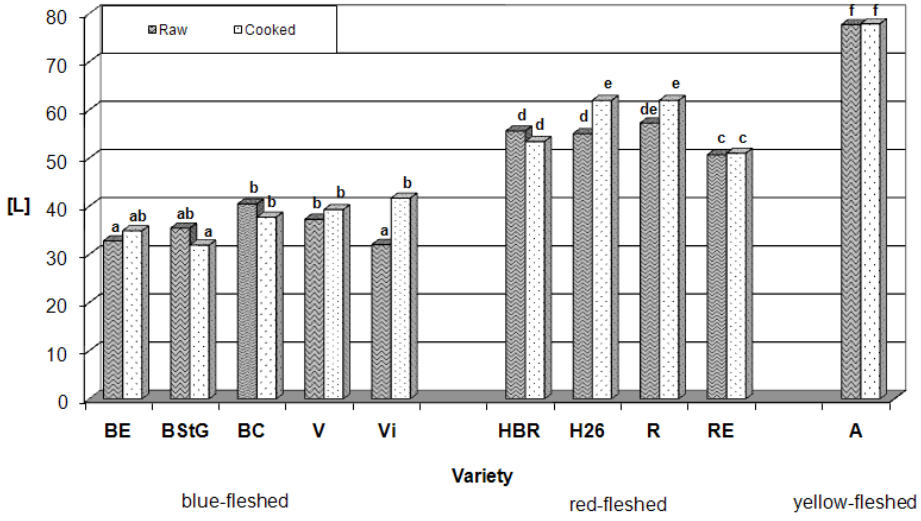

Fig. 6. The influence of potato variety on the lightness of raw and ccoked tubers

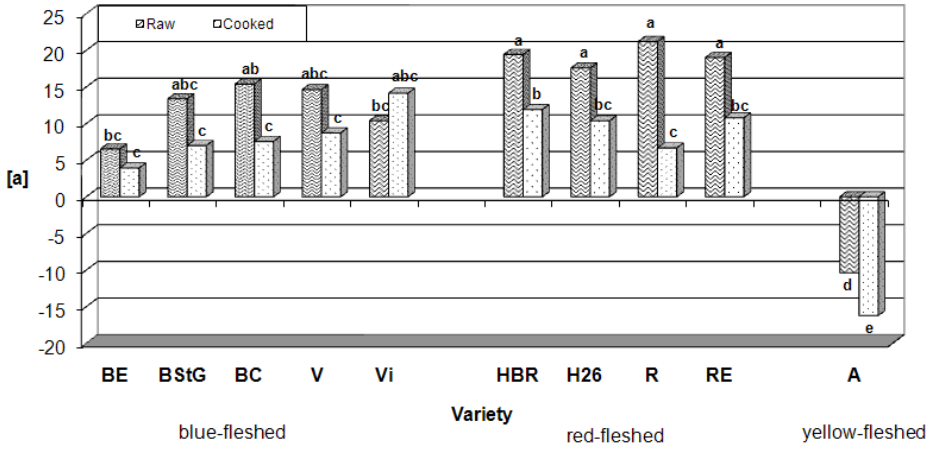

Fig. 7. The influence of potato variety on the share of red/green colour of raw and cooked tubers

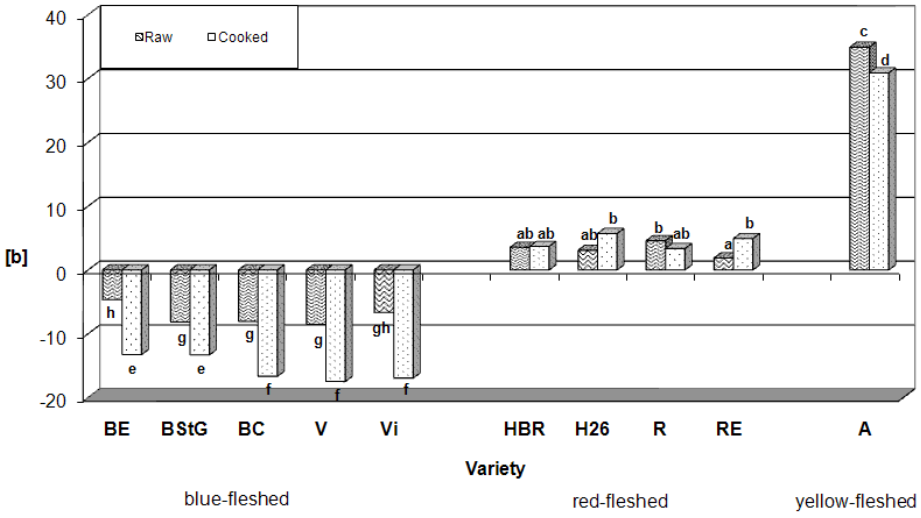

Fig. 8. The influence of potato variety on the share of yellow/blu colour of raw cooked tubers

On the base of the colour measurements can be stated that after boiling a tissue of blue--fleshed potatoes became navy-blue, the colour of red-fleshed pink of different intense (like Herbie 26, Rosalinde and Rote Emma) or slight purple and grey (like Highland Burgundy Red) and Agria colour of tissue became a slight less yellow with delicate green shadow.

More than 30 volatile compounds were identified in potato tubers of studied samples of 10 varieties. The most representative, 15 volatiles were chosen and presented in figure 9. Their amounts range from 0,7 up to 2735,1 µg/kg. Studied varieties differed a lot in the quantities of identified volatiles. The most abundant in volatiles compounds occurred tubers of blue-fleshed varieties, like Blue Congo and Valfi and among red-fleshed potatoes, Highland Burgundy Red and Rote Emma varieties. On the contrary, the least abundant in these compounds were blue-fleshed Vitelotte, red-fleshed Rosalinde and yellow-fleshed Agria. As it indicated from figure 9A Nootkatone was represented in the highest quantities, particularly in cooked tubers of Highland Burgundy Red, Rosalinde and Agria, and a new sesquiterpene determined in all studied varieties besides Vitelotte and Blue Congo which contained traces or small quantities of this volatile. In our opinion, the sesquiterpenes, alought predominated volatiles, had no significant influence on the aroma properties. Unidentified sesquiterpene was found in potatoes also in the experiments of another authors [Morris et al. 2010].

There were led many studies concerning volatile components of potato, but the information about aroma compounds present in coloured-fleshed potato varieties are not found in accessible literature. Authors characterizing volatiles in raw, steamed, baked or boiled potato state that varieties differ significantly in the composition of volatiles [Desjardins et al. 1995. Ulrich et al. 2000, Dresow, Böhm 2009, Jansky 2010]. They underline that factors, like the type of potato processing, environmental, agricultural and storage conditions influencing on the chemical composition of potatoes and their suceptibility on different transformations of tubers chemical components directly affect volatiles creation. Ulrich et.al. [2000] found that

methional, diacetyl and least five different substituted pyrazines were recognized as character impact compounds. Additionally they stated that off-flavour had caused: (E)-2 pentenal, 2-pentylfuran and some dienal. like for example: (E/E)-2,4-heptadienal, (E/E)-2,4-octadienal.

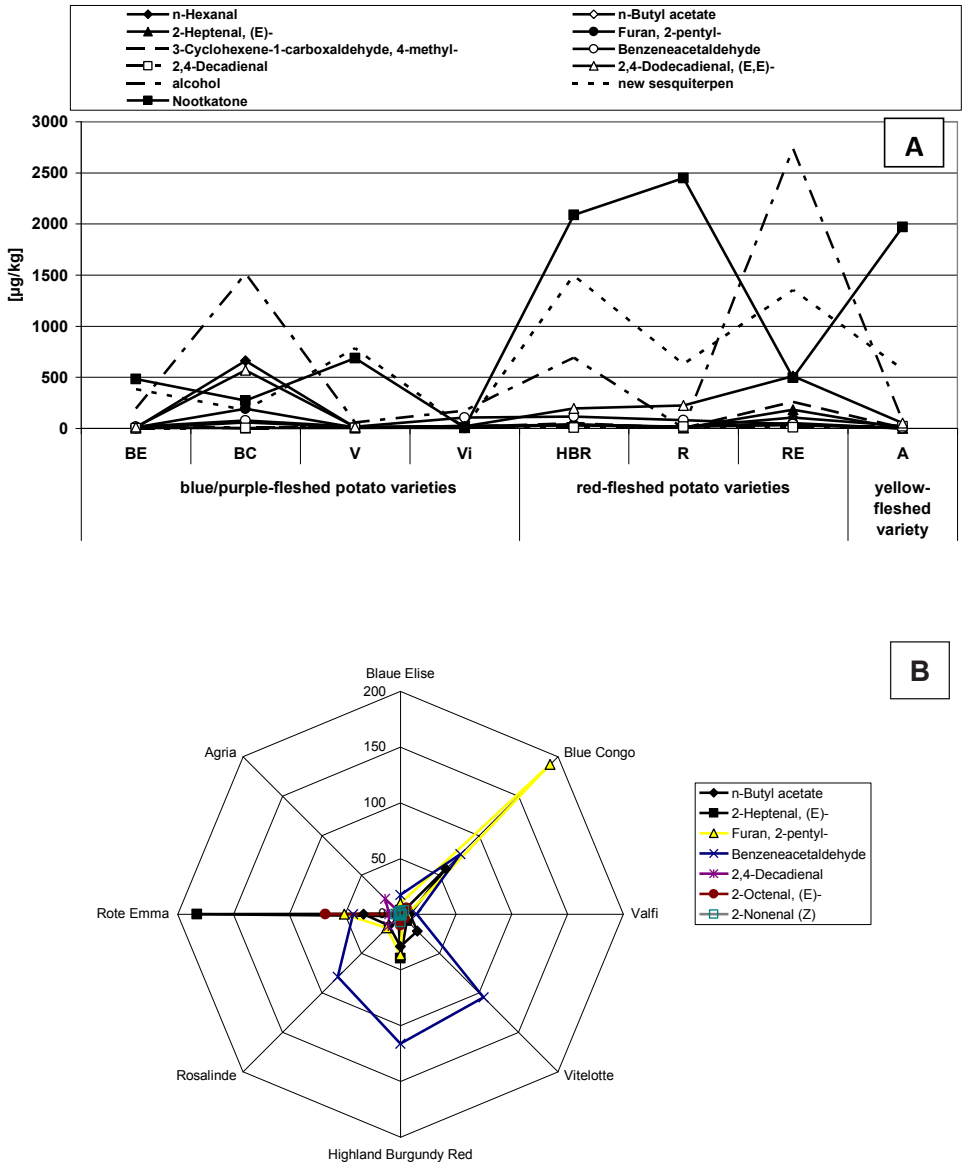

Fig. 9. (A and B). Chosen volatile compounds identified in blue, red and yellow-fleshed potato varieties

A lot of different alcohols and aldehydes were found in coloured-fleshed potatoes, mainly in Blue Congo, Highland Burgundy Red and Rote Emma. Most of them were of lipid degradation origin. Some of them were determined in the quantities over 200 μg/kg , like 2,4-Dodecadienal found in the quantities 567,2μg/kg in Blue Congo, in Rosalinde 223,5 μg/kg Rote Emma 511,2 μg/kg and in Highland Burgundy Red 193,7 μg/kg or 3-Cyclohexene-1-carboxaldehyde,4-metyl- determined in higher quantities in Rote Emma potatoes (258,2 μg/kg). They are presented in Figure 9A but others, appeared in lower than 200 μg/kg quantities, are shown in figure 9B. From figure 9B arises that dominated were compounds: 2-Hexenal and Furan, 2-pentyl, as well as n-Butyl acetate and 2-Octenal found only in Rote Emma, Blue Congo and in smaller quantities also in Highland Burgundy Red potatoes.

In spite most of medley linear alcohols and aldehydes were contained in small quantities in tubers they probably had the most important impact on the flavor of investigated potatoes, because of their proportionally high aroma impact values [Jansky 2010]. However in our studies methional had not be detected though it is counted as typical potato.

Thybo et al. [2006] proved the influence of potato variety on aromatic compounds composition in peeled, cooked potato tubers. They were stated in varieties Sava, Folva and Agria higher concentration such volatile components, like methional, linalool and cymene, but lower intensity of nonanal and decanal. As it results from their studies varieties Sara, Folva and Agria were evaluated higher with respect to aroma and taste. In their opinion the effect of methional, as the aldehyde responsible for cooked potato flavour was more distinct and the effect of nonanal responsible for fatty, rancid odour was lower.

Studied samples of blue/purple- and red-fleshed potato varieties characterized good sensory properties. They represented moderate mealy or mealy type potato and characterized typical, strong or weak potato taste and flavour besides Vitelotte, Highland Burgundy Red and Roasalinde varieties. The highest scores in sensory evaluation obtained blue/purple-fleshed potatoes of Blaue Elise, Blaue St. Gallee, Blue Congo and Valfi varieties. The most abundant in volatiles compounds were tubers of Blue Congo and Valfi blue-fleshed varieties and Highland Burgundy Red and Rote Emma varieties and the least abundant blue-fleshed Vitelotte and red-fleshed Rosalinde. After boiling a tissue of blue-fleshed potatoes became navy-blue and the colour of red-fleshed became pink of different intense or slight purple and grey.

References

Beschreibende Sortenliste Für Kartoffeln, Hamburg, 1993.

Brown C.R., Wrolstad R., Durst R., Yang C.P., Clevidence B., 2003. Breeding studies in potatoes containing high concentrations of anthocyanins. American Journal of Potato Research, 80, 241–250.

Clark J., Tsang C., Clapham M.E., 201. Phenolic composition and antioxidant capacity of a novel variety of purple potato. In: Proceedings of the Nutrition Society.OC123. Nutrition Society.

Desjardins A.E., McCormick S.P., Corsini D.L., 1995. Diversity of sesquiterpenes in 46 potato cultivars and breeding selections. Journal of Agricultural and Food Chemistry, 43, 2267–2272.

Dresow J.F., Böhm, 2009. The influence of volatile compounds of the flavour of raw, boiled and baked potatoes: impact of agricultural measures on the volatile components. Landbauforschung-vTI Agriculture and Forestry Research, 4 (59), 309–338.

Hejtmánková K., Pivec V., Trnkova E., Hamouz K, Lachamn J., 2009. Quality of coloured varietes of potatoes. Czech Journal of Food Science, 27, S310-S313.
Jansky S.H., 2010. Potato Flavor. American Journal of Potato Research 87, 209–217. Kaur L., Singh N., Singh Sodhi N., Singh Gujral H, 2002. Some properties of potatoes and their starches. I. Cooking, textural and rheological properties of potatoes. Food Chemistry 79,177–181.
Kaur L., Singh N., Singh Sodhi N., Singh Gujral H, 2002. Some properties of potatoes and their starches. I. Cooking, textural and rheological properties of potatoes. Food Chemistry 79,177–181.
Lachman J., Hamouz, K., 2005. Red and purple coloured potatoes as a significant antioxidant source in human nutrition – a review. Plant, Soil and Environment, 51, 477–482.
Lachman J., Hamouz K., Orsák M., Pivec V., Dvořak, P., 2008. The influence of flesh colour and growing locality on polyphenolic content and antioxidant activity in potatoes. Scientia Horticulturae 117, 109–114.
Lisińska G., Pęksa A., Kita A., Rytel E., Tajner-Czopek A., 2009. The quality of potato for processing and consumption., In: Yee N., Bussel W (Eds.) Food Potato IV. 3, Special Issue 2, 99–104.
Martens H.J., Thybo A.K., 2000. An integrated microstuctural, sensory and instrumental approach todescribe potato texture. Lebensm.-Wiss. U.-Technol. 33, 471–482.
Morris W.L., Shepherd T., Verral S.R., McNicol J.W., Taylor M.A., 2010. Relationship between volatile and non-volatile metabolites and attributes of processed potato flavour. Phytochemistry 71, 1765–1773.
Nourian F., Ramaswamy H.S., Kushalappa A.C., 2003. Kinetic changes in cooking quality of potatoes stored at different temperatures. Journal of Food Engineering 60, 257–266.
Oruna-Concha M.J., Bakker J., Ames J.M., 2002. Comparison of the volatile components of eight cultivars of potato after microwave baking. Lebensm.-Wiss. u.-Technol. 35, 80–86.
Pęksa A., 2008. Wartość żywieniowa ziemniaka i jego przetworów na tle innych produktów spożywczych. Wieś Jutra, 2 (115), 3–5.
Reyes L.F., Miller J.C. Jr., Cisneros-Zevallos L., 2004. Environmental conditions influence the content and Yeld of Anthocyanins and total phenolics in purple- and Red-flesh potatoes during tuber development. American Journal of Potato Research 81, 187–193.
Surmacka-Szczesniak A., 2002. Texture is a sensory property. Food Quality and Preference 13, 215–225.
Thybo A.K., Bechmann I.E., Martens M., Engelsen S.B., 2000. Prediction of sensory texture of cooked potatoes using uniaxial compression, near infrared spectroscopy and low field ^{1}H NMR spectroscopy. Lebensm.-Wiss. U.-Technol., 33, 103–111.
Thybo A.K., Christiansen J., Kaack K., Petersen M.A., 2006. Effect of cultivars, wound healing and storage on sensory quality and chemical composition in pre-peeled potatoes. LWT-Food Science Technology 39 (2), 166–176.
Ulrich D., Hoberg.E., Neugebauer W., Tiemann H., Darsow U., 2000. Investigation of the boiled potato flavor by human sensory and instrumental methods. American Journal of Potato Research 77, 111–117.
Washington State Potato Commission. All About Fresh Washington Potatoes. The spud syllabus. 108. Interlake Road, Moses Lake, WA 98837. www.potatoes.com
Van Marle J.T., Van Der Vuurst de Vries R., Wilkinson E.C., 1997. Sensory evaluation of the texture of steam-cooked table potatoes. Potato Research, 40, 79–90.

9

SENSORY PROPERTIES OF PUMPKIN TREATED WITH SUCROSE OSMOTIC SOLUTIONS FOLLOWED BY A VACUUM-MICROWAVE DRYING

Introduction

Sensory characteristic is one of the main factors in food products choice. High quality dried food, including fruits and vegetables, should be characterized by high crispiness, uniform colour and distinctive taste. Pumpkin is rich in vitamins, especially ascorbic acid, riboflavin and tocopherols, carotenoids, tannins and also minerals like magnesium, potassium, iron, phosphorus and selenium [Terazowa, Ito 2001, USDA National Nutrient Database 2004]. The fruit is widely consumed by humans and it also has some cultural aspects, especially in North America. Thanks to its specific flavour, taste and texture, pumpkin fruit can be manufactured for jam, juice, pomace and pickles. Another method of pumpkin processing is drying. Drying can be performed in different methods such as hot air drying, freeze drying, vacuum drying or microwave assisted drying.

Osmotic dehydration of vegetables is a possible pre-treatment applied for improving the quality of the finish product and reducing the energy consumption [Le Maguer 1988]. During the process of osmotic dehydration, three types of mass transfer occur at different intensity [Raoult-Wack 1994]. The first type is water flux from the raw material to the osmotic solution. The second type is the solids transfer from the solution to the raw material, while the third type consists of natural solutes migration from the raw material to the solution. The intensities of particular types of mass transfer are depended on the temperature, concentration and kind of the osmotic solution. The optimal concentration of sucrose solution assures high osmotic potential and improves the taste of the dried product.

Osmotic dehydration in sucrose solution was applied to many raw materials such as pepper [Falade, Oyedele 2010], strawberries [Piotrowski et al. 2004], apples [Falade et al. 2003] or pumpkin [Zenoozian, Devahastin 2009]. However, osmotically pre-dried raw material involves finish drying in order to reduce the moisture content until the safe level and to ensure the attractive texture of the finish product. Among several methods used for this purpose, vacuum-microwave (VM) drying seems to be appropriate. During VM drying the energy of microwaves is absorbed by water located in the whole volume of the material being dried. This creates a large vapour pressure in the centre of the material, allowing rapid transfer of moisture to the surrounding vacuum and preventing structural collapse [Lin et al. 1998]. As a consequence, the rate of drying is considerably higher than in traditional methods of dehydration [Sharma, Parasad 2004]. The puffing phenomenon, that accompanies the rapid process of dehydration, creates a porous texture of the food and facilitates obtaining a crispy and delicate texture [Sham et al. 2001], and in this way it reduces the product's density as well as shrinkage.

The VM technique has already been satisfactory applied to reduce the moisture content of many plant material. such as carrots [Cui et al. 2004], cranberries [Sunjka et al. 2004], strawberries [Krulis et al. 2005], peanuts [Delwiche et al. 1986], bananas [Mousa, Farid 2002], apples [Sham et al. 2001], pumpkin [Nawirska et al. 2009] and garlic [Cui et al. 2003]. However, at the beginning of VM dehydration the intensive water evaporation from the material being dried may exceed the vacuum pump capacity. This would require a reduction in the raw material subjected to drying or application of a large vacuum installation. This problem can be overcome by pre-drying of the material using osmotic dehydration in the sucrose solution. As a result of pre-drying the mass loads of a VM equipment can be radically decreased [Hu et al. 2006]. Pre-drying of the material by convective method before VM finish drying reduced the total cost of dehydration and improved the quality of dried tomatoes [Durance, Wang 2002], nutritional value of strawberries [Böhm et al. 2006] and improved the quality of beetroot cubes [Figiel 2010].

No scientific work has yet been reported on the combined drying of pumpkin consisted of osmotic pre-drying in sucrose solution and VM finish drying. This method of drying could make a significant contribution to the vegetable processing industry. However, it is not obvious what concentration of sucrose solution should be applied to ensure the best quality of dried product. Therefore the aim of this work was to determine the effect of sucrose concentration on the drying kinetics of pumpkin slices dehydrated by the osmotic pre-treatment and VM finish drying as well as quality of the finish product in terms of shrinkage, colour, texture and first of all sensory attributes.

Materials and methods

Sample preparation

Pumpkin of "Hokkaido" variety was purchased at a local marked. Slices of the raw material (5 mm thick and 18 mm in diameter) were prepared with the aid of a cutter (Gastrotech, Kraków, Poland) and a steel-made blanking tool, which was cylindrical in shape and pointed on one of the sides. The slices were mixed in a plastic container and then were dried by the combination of osmotic dehydration and vacuum-microwave drying.

Drying

Three osmotic solutions of sucrose 20, 40 and 60% were prepared in separate containers. The solutions were distributed into 70 ml beakers immersed in water bath of temperature 40°C. The ratio of osmotic solution to pumpkin slices was maintained at 3:1. The mass of the samples was measured after 0.5, 1, 2, 4 and 6 hours of the osmotic dehydration. The samples were taken out from the solution by using a tea strainer and the surplus moisture was gently eliminated from their surfaces with a tissue paper just before measuring of their mass.

VM finish drying was carried out in an SM-200 drier (Plazmatronika, Wrocław, Poland). Pre-dried in osmotic solutions samples of a mass corresponded to the initial mass of 60 g were placed in a cylinder rotating at a speed of 6 rev·min^{-1}. The pressure in the cylinder varied from 4 to 6 kPa. Microwave power amounted to 360 W.

The VM drying kinetics was determined on the basis of mass losses of pumpkin samples. The moisture ratio *MR* was determined from the equation:

$$MR = \frac{M(t) - M_e}{M_0 - M_e} \tag{1}$$

The moisture content of dehydrated samples was determined in vacuum dryer (SPT-200, ZEAMiL Horyzont, Krakow, Poland) for 24 hours at temperature 60°C.

Temperature measurement

During VM finish drying the vacuum-drum was rotating in order to avoid the local overheating of pumpkin samples. Nevertheless, the temperature of individual slices differed despite of the drum rotation. The temperature of pumpkin slices was measured with an infrared camera Flir i50 immediately after taking them out of the VM dryer. The external temperature of most heated slices was recorded. It was supposed that the temperature measured with this method reflected the course of mean temperature during drying. A direct internal temperature measurement of the slices in the drying chamber under vacuum is practically not possible because the measuring elements inserted into the dried material are heated by the microwave emission.

Density and shrinkage

Shrinkage *S* of the dried product were determined from the equation (2):

$$S = \frac{V_0 - V}{V_0} \tag{2}$$

The volume of pumpkin slices before drying V_0 and after drying V was determined with the use of a gas picnometer HumiPyc-M2 (InstruQuest Inc., USA).

Colour

Colour of dried samples was evaluated by a Minolta Chroma Meter CR-400 (Minolta Co. Ltd., Osaka, Japan). Instrumental colour data were expressed as CIE L^*, a^*, b^* coordinates, which define the colour in a three-dimensional space: L^* (dark – light), a^* (green – red) and b^* (blue – yellow). Samples before measurement were ground using an electric mill.

Texture Profile Analysis (TPA)

The TPA (Texture Profile Analysis) of pumpkin slices was determined with an Instron 5 566 strength-testing machine (Instron, High Wycombe, UK) equipped with the strain gauge of 1 kN range.In this test the sample was placed between flat plate and the cylindrical probe with diameter 5 mm fixed to the measuring head. While the test the head was moving at a speed of 60 mm·min^{-1}. The sample was subjected to double compression cycles imitating the double bite of the human jaws. Shifting of the head amounted to 50% of the initial sample height. The maximum force was achieved at first compression. Upward shift of the head caused decreasing of the compressive force and created a gap between the deformed sample and the surface of the probe. The subsequent compression took place at lower deformation of the slightly recovered sample. The test was completed at the initial position of the head.

On the basis of a TPA curve, three basic parameters were determined: hardness, cohesiveness and springiness. Hardness was defined as the first force peak on the TPA curve. Cohesiveness was the ratio of the force area during the second compression to that during the first compression. Springiness was understood as the recovered sample deformation in the second compression.

Sensory evaluation

Sensory evaluation with trained panel was used to discriminate the intensities of the main characteristics of dried product in terms of colour, flavour, taste and texture. The samples were tested by a panel of 8 panellists, ages 25 to 33 years (7 female and 1 mal. all members of the Wroclaw University of Environmental and Life Sciences), with sensory evaluation experience and trained in descriptive evaluation of fruits and vegetables.

Measurements were performed in individual booths according with ISO-PN 8586–1:1996 and ISO-PN 8589:1998 standards. The individual samples were scored for the intensity of evaluated attributes on a scale of 0 to 10, where:

- 0=Non perceptible intensity.
- 10=extremely high intensity.

The dried samples were presented in 100 mL plastic containers, which stood at room temperature for 30 min prior to analyses.

Results

Drying kinetics

The changes of pumpkin slices mass during osmotic dehydration in sucrose solution were shown in Figure 1. It was found that the mass of samples during osmotic pre-treatment was decreasing until the equilibrium stage. Eventually, the weight changes of pumpkin slices reached 0.52, 3.11 and 5 g for the sucrose solutions 20, 40 and 60% respectively. These weight changes resulted from water flux from the raw material to the osmotic solution and solids transfer from the solution to the raw material. However, water loss was higher than the sucrose gain. The experimental points show that the increase in sucrose concentration increased the mass loss of the pre-treated pumpkin samples. The final moisture content of all samples was different and amounted to 81.5, 67.7 and 47% wet basis for osmotic solution concentrations 20, 40 and 60% respectively.

The vacuum-microwave (VM) drying kinetics of pumpkin slices without pre-treatment as well as pre-dried in sucrose solution of concentrations 20, 40 and 60% was shown in Figure 3. It was found that the decrease in moisture content of the pumpkin slices during VM finish drying could be described with an exponential equation (3) at very high determination coefficient R^2 (Tab. 1).

$$MR = a \cdot e^{-k \cdot \tau} - b \tag{3}$$

The drying time of the samples without pre-treatment and pre-dried at sucrose concentration 20% was 33 min. This drying time decreased until 27 and 18 min after pre-treating in sucrose solution of concentrations 40 and 60% respectively.

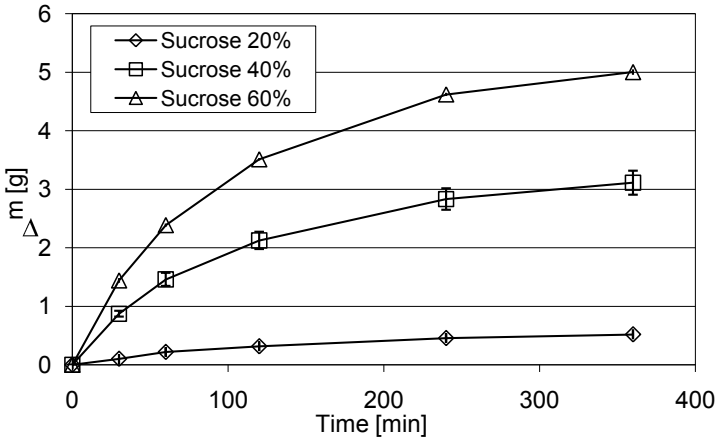

Fig. 1. Changes of weight of pumpkin slices during osmotic dehydration in sucrose solution

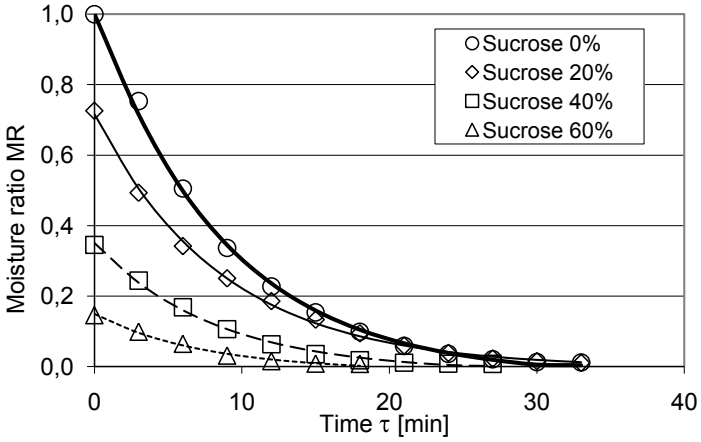

Fig. 2. VM drying kinetics of pumpkin slices pre-dried in different concentrations of sucrose solution

Table 1

Coefficients of the equation describing the drying kinetics of pumpkin slices

Sucrose concentration [%]	$MR = a \cdot e^{-k \cdot \tau} - b$			
	a	b	k	R^2
0	1.048	0.0276	0.115	0.9978
20	0.719	0.00296	0.116	0.9989
40	0.365	0.0149	0.123	0.9969
60	0.161	0.0123	0.134	0.9931

It was stated that while VM finish drying the temperature of samples was increasing until the certain moisture content and then was decreasing. The increase in sucrose concentration from 0 to 60% increased the peak temperature from 83 to 106°C (Fig. 3) in accordance with a power equation (4) at high coefficient of determination R^2 amounted to 0.9995.

$$T_{\max} = 1.54 \cdot Sc^{0.66} + 82.98 \tag{4}$$

One can presume, that the course of temperature versus moisture content depends on two phenomena [Figiel 2010]. The first is the generation of heat energy by water dipoles in microwave field [Tang 2005] while the other one is the absorbing of that energy by water evaporating from the surface of the material. The increase in the material temperature until critical moisture content results from the excess of the energy generated over the energy necessary for water evaporation. Naturally, the amounts of water generating the energy and water evaporating are decreasing with decreasing moisture content. Beyond the critical moisture content the energy generated by water dipoles is lower than the sum of the energy necessary for water evaporation and that transferred from the material to the ambient of lower temperature.

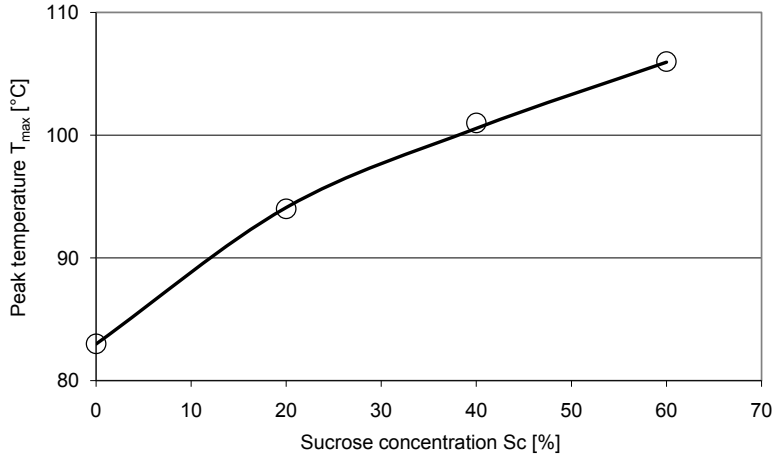

Fig. 3. Peak temperature of pumpkin slices during VM finish drying versus concentrations of sucrose solution used for osmotic pre-drying

Shrinkage

The increase in sucrose concentration of the osmotic solutions decreased shrinkage of VM finish dried pumpkin slices (Fig. 4). The highest value of shrinkage (59.6%) was stated for the sample without pre-treatment. The lowest value of shrinkage (41.0%) was determined for the sample pre-dried in the sucrose solution of concentration 40%. Torringa et al. [2001] also reported that the increase in concentration of the osmotic solution decreased the shrinkage of the mushroom samples finish dried by combined microwave-hot-air drying method. The VM method usually ensures lower shrinkage than traditional methods of drying due to the puffing phenomenon [Lin et al. 1998]. This study revealed that optimal addition of sucrose enhances the effect of puffing.

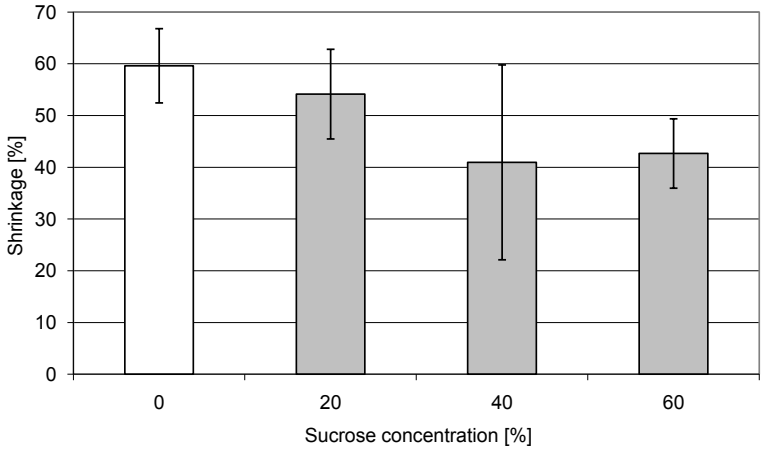

Fig. 4. Effect of sucrose concentration on shrinkage of VM finish dried pumpkin slices

Colour

The increase in sucrose concentration of the osmotic solutions slightly increased colour parameters L^* and b^*, but decreased parameter a^* of VM finish dried pumpkin slices (Fig 5). This means that the colour of the slices was getting lighter and was shifting towards yellowness and greenness. The values of L^*, a^* and b^* determined for the sample without pretreatment were 68.9, 15.6 and 57.5 respectively while the values determined for the sample pre-dried at the sucrose concentration 60% were 74.9, 12.6 and 60.2 respectively. Higher lightness usually makes the colour of the product more attractive for the potential consumers.

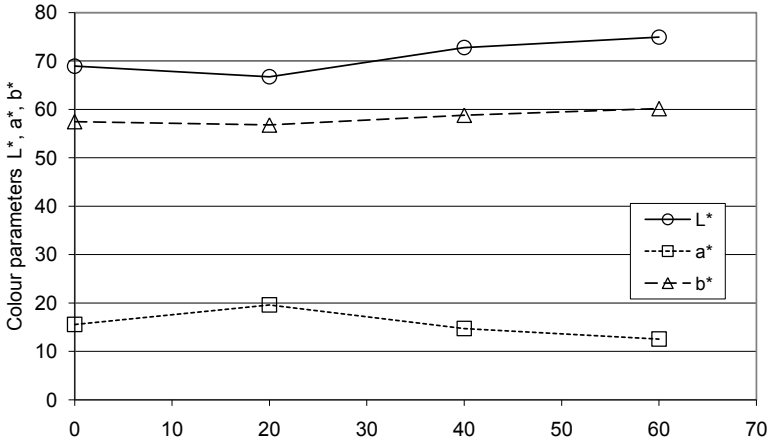

Fig. 5. Effect of sucrose concentration on colour parameters of VM finish dried pumpkin slices

TPA parameters

Generally, it can be stated that the increase in sucrose concentration of the osmotic solution increases the hardness of VM finish dried pumpkin slices (Fig. 6). However, the highest value of hardness (105.15 N) was found for the sample pre-dried at 40% of sucrose concentration.

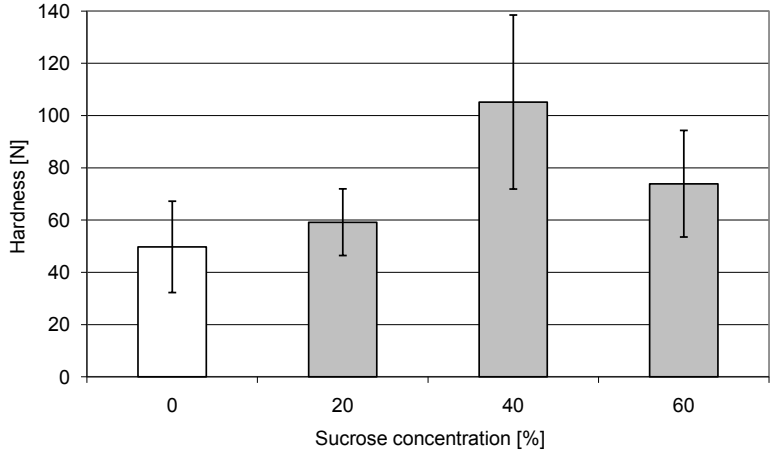

Fig. 6. Effect of sucrose concentration on hardness of VM finish dried pumpkin slices

On the other hand, the increase in sucrose concentration of the osmotic solution from 0 to 40% decreased the cohesiveness (Fig. 7) and springiness (Fig. 8) of the VM finish dried product from 0.51 to 0.09 J/J and from 1.57 to 0.93 mm respectively. However, the further increase in sucrose concentration to 60% slightly increased the values of these both parameters to 0.22 J/J and 1.17 mm respectively. The increased hardness associated with decreased cohesiveness and springiness subsequently may invoke the impression of increased crispiness. This is a positive effect, which increasing the attractiveness for the potential consumers [Szcześniak 1971].

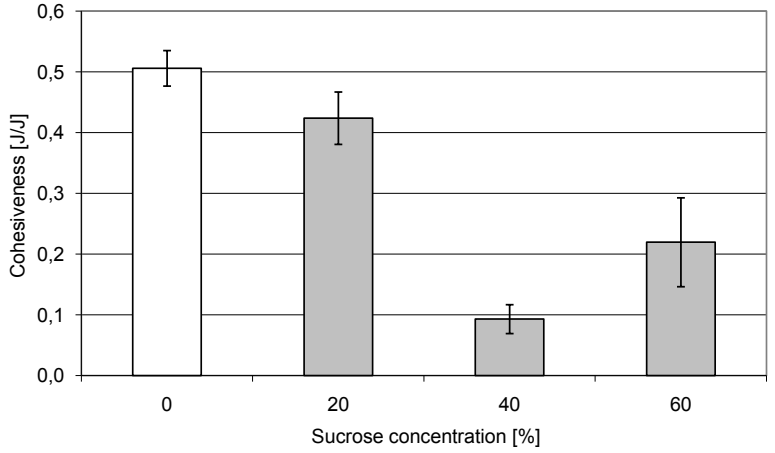

Fig. 7. Effect of sucrose concentration on cohesiveness of VM finish dried pumpkin slices

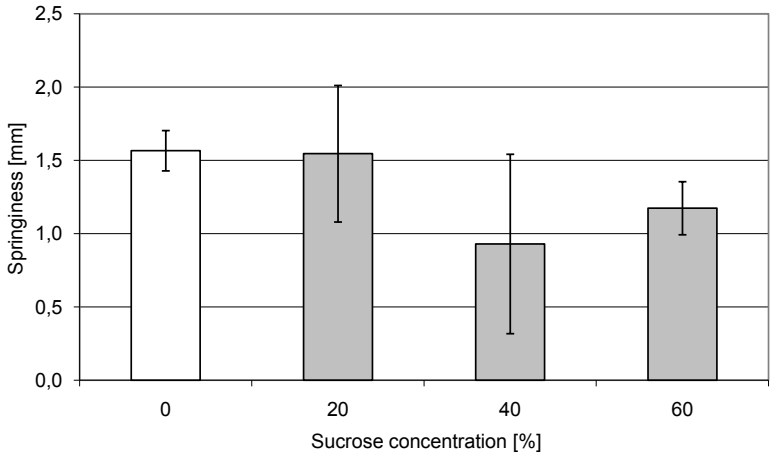

Fig. 8. Effect of sucrose concentration on springiness of VM finish dried pumpkin slices

Sensory evaluation

The results of the sensory assessment of appearance, flavour and taste for VM dried pumpkin samples osmotically pre-dried at different sucrose concentrations were presented in Fig. 9, while the results of the sensory assessment of texture for these samples were shown in Fig. 10.

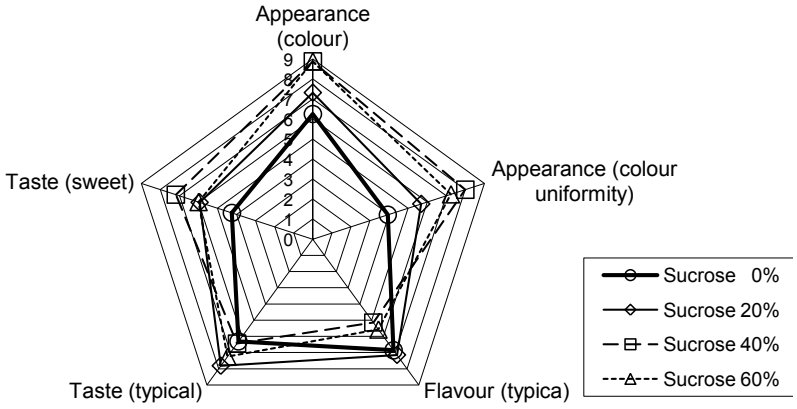

Fig 9. Sensory attributes of appearance, flavour and taste for pumpkin samples osmotically pre-dried at different sucrose concentrations

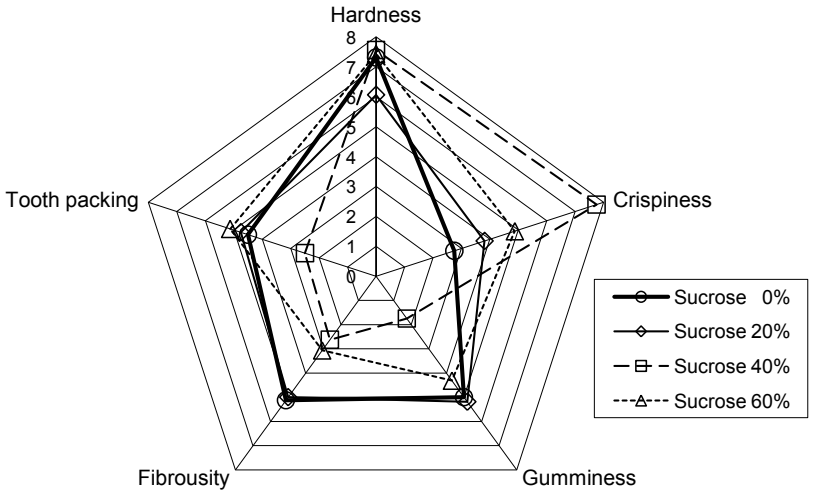

Fig. 10. Sensory attributes of texture for pumpkin samples osmotically pre-dried at different sucrose concentrations

In most cases the differences between mean values were not significant. However, the test reviled that the pumpkin samples without pre-treatment were characterised by nice flavour and the worst attributes of appearance, taste and texture. The samples pre-dried at the sucrose concentration 20% exhibited the excellent flavour and taste, while the samples treated with sucrose solution of concentration 40% were characterised by the lowest gumminess, fibrousity and tooth packing, excellent appearance as well as the highest hardness and crispiness. This excellent appearance was probably related to the high lightness and yellowness determined with the using of colorimeter. Higher lightness usually is more preferable and increased yellowness makes the colour of the dried pumpkin slices more natural. Additionally, high crispiness is a positive attribute of the food texture [Szcześniak 1971]. It can be stated that the best product in terms of flavour and taste requires the pre-treatment in sucrose solution of concentration 20% but in terms of appearance and texture involves pre-drying at sucrose concentration amounted to 40%.

The increased crispiness evaluated in sensory assessment was associated with decreased cohesiveness and springiness determined in TPA (Fig. 11). It was also found that for osmotically pre-dried samples the increase in TPA hardness from 59 to 74 N was confirmed by the significant increase in hardness evaluated by sensory panel. However, further increase in TPA hardness until 105 N was associated with the insignificant increasing of this sensory attribute (Fig. 12). As the final conclusion we recommend pre-drying the pumpkin slices in sucrose solution with concentration between 20 and 40% before VM finish drying in order to obtain the optimal quality of the finish product.

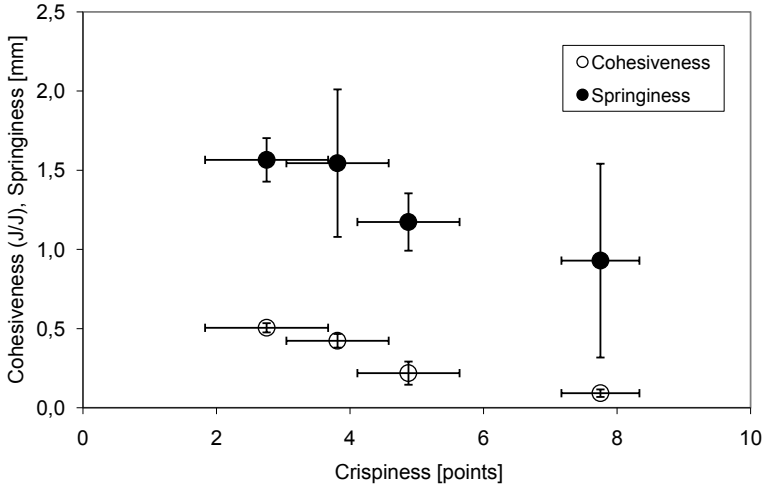

Fig. 11. Relationship between crispiness evaluated in sensory test and cohesiveness as well as springiness determined in TPA

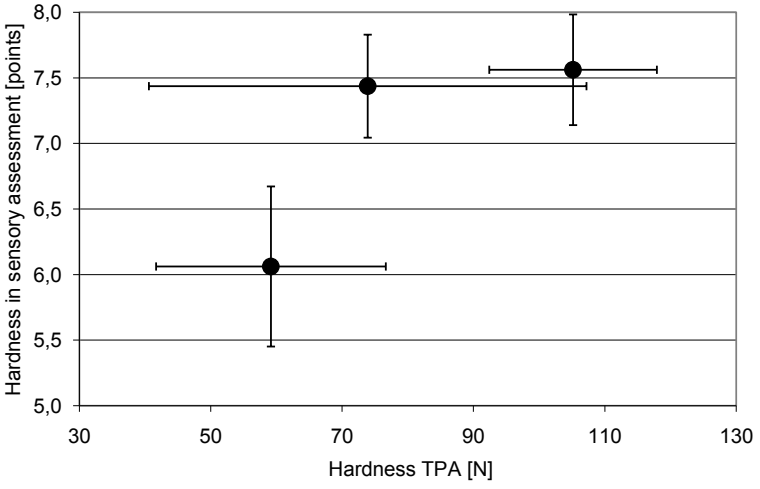

Fig. 12. Relationship between hardness determined in TPA and hardness evaluated in sensory assessment

Conclusions

1. During osmotic pre-treatment in sucrose solutions the mass of samples was decreasing until the equilibrium stage as the result of water flux from the raw material to the osmotic solution and solids transfer from the solution to the raw material.

2. The increase in sucrose concentration decreased the mass and final moisture content of the osmotically pre-dried samples.
3. The decrease in moisture content of the pumpkin slices during vacuum-microwave (VM) finish drying could be described with an exponential equation.
4. While VM finish drying the temperature of samples was increasing until the certain moisture content and then was decreasing as the result of the balance of energy generated within the dried material by dipoles of water and the energy necessary for water evaporation.
5. The increase in sucrose concentration decreased shrinkage, cohesiveness springiness as well as redness but in the same time increased hardness brightness and yellowness of the finish-dried product.
6. The best product in terms of flavour and taste requires pre-treatment in sucrose solution of concentration 20% but in terms of appearance and texture involves pre-drying at sucrose concentration amounted to 40%.
7. The increased crispiness evaluated in sensory assessment was associated with decreased cohesiveness and springiness determined in TPA.
8. The increase in TPA hardness was confirmed by the increase in hardness evaluated by sensory panel.
9. Optimal dried pumpkin slices quality can be achieved by application of the osmotic pre-drying in 20–40% sucrose solutions followed by a VM drying.

NOMENCLATURE

a^*	Redness
b^*	Yellowness
a, b	Equation coefficients
k	Drying constant [s^{-1}]
L^*	Lightness
MR	Moisture ratio
M_e	Equilibrium moisture content [kg/kg db]
M_0	Initial moisture content [kg/kg db]
R^2	Coefficient of determination
S	Shrinkage [%]
Sc	Sucrose concentration [%]
t	Time (min)
T_{max}	Peak temperature [°C]
TPA	Texture Profile Analysis
V	Volume [m^3]
V_0	Initial volume [m^3]
VM	Vacuum-microwave
Δm	Change of mass [g]

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References

Böhm V., Kühnert S., Rohm H., Scholze G., 2006. Improving the nutritional quality of microwave-vacuum dried strawberries: a preliminary study. Food Science and Technology International, 12, 67–75.

Cui Z.W., Xu S.Y., Sun D.W., 2003. Dehydration of garlic slices by combined microwave-vacuum and air drying. Drying Technology, 21 (7), 1173–1184.

Cui Z.W., Xu S.Y., Sun D.W., 2004. Microwave-vacuum drying kinetics of carrot slices. Journal of Food Engineering, 65, 154–164.

Delwiche S.R., Pearson J.L., Sanders T.H., Wilson D.M., Shupe W.L., 1986. Microwave vacuum drying effect on peanut quality. Peanut Science, 13 (1), 21–27.

Durance T.D., Wang J.H. 2002. Energy consumption, density, and rehydration rate of vacuum-microwave and hot-air convection-dehydrated tomatoes. Journal of Food Science, 67 (6), 2212–2216.

Falade K.O., Akinwale T.O., Adedokun O.O., 2003. Effect of drying methods on osmotically dehydrated cashew apples. European Food Research and Technology, 216, 500–5004.

Falade K.O., Oyedele O.O., 2010. Effect of osmotic pretreatment on air drying characteristics and colour of pepper (Capsicum spp) cultivars. Journal of Food Science and Technology, 47 (5), 488–495.

Figiel A., 2010. Drying kinetics and quality of beetroots dehydrated by combination of convective and vacuum-microwave methods. Journal of Food Engineering, 98, 461–470.

Hu Q.G, Zhang M., Mujumdar A.S, Xiao G.N., Sun J.C., 2006. Drying of edamames by hot air and vacuum microwave combination. Journal of Food Engineering, 77, 977–982.

Krulis M., Kuhnert S., Leiker M., Rohm H., 2005. Influence of energy input and initial moisture on physical properties of microwave–vacuum dried strawberries. European Food Research Technology, 221, 803–808.

Le Maguer, M., 1988. Osmotic dehydration: review and future direction. [in:] Proceedings of the International Symposium on Program in Food Preservation Process, CERIA, Brussels, p. 238.

Lin T.M., Durance T.D., Scaman C.H., 1998. Characterization of vacuum microwave, air and freeze dried carrot slices. Food Research International, 31 (2), 111–117.

Mousa N., Farid M., 2002, Microwave vacuum drying of banana slices, Drying Technology, 20, 2055–2066.

Nawirska A., Figiel A., Kucharska A.Z., Sokół-Łętowska A., Biesiada A., 2009. Drying kinetics and quality parameters of pumpkin slices dehydrated using different methods. Journal of Food Engineering, 94, 14–20.

Piotrowski D., Lenart A., Wardzyński A., 2004. Influence of osmotic dehydration on microwave-convective drying of frozen strawberries. Journal of Food Engineering, 65, 519–525.

Raoult-Wack A.L., 1994. Recent advances in the osmotic dehydration of foods. Trends in Food Science and Technology, 5(8), 255–260.

Sham P.W.Y., Scaman C.H., Durance T.D., 2001. Texture of vacuum microwave dehydrated apple chips as affected by calcium pretreatment, vacuum level, and apple variety. Journal of Food Science, 66 (9), 1341–1347.

Sharma G.P., Prasad S., 2004. Effective moisture diffusivity of garlic cloves undergoing microwave – convective drying. Journal of Food Engineering, 65, 609–617.
Sunjka P.S., Rennie T.J., Beaudry C., andRaghavan, G.S.V., 2004. Microwave–convective and microwave–vacuum drying of cranberries: a comparative study. Drying Technology, 22 (5), 1217–1231.
Szczesniak A.S., Kahn E.L., 1971. Consumer awareness of attitudes to food texture: adults. Journal of Texture Studies, 2, 280–295.
Tang J., 2005. Dielectric properties of foods. [in] H. Schubert, M. Regier (Eds.), The microwave processing of foods. CRC Press LLC, Boca Raton, Boston, New York, Washington, DC, 22–40.
Torringa E., Esveld E., Scheewe I., van den Berg, R. Bartels P., 2001. Osmotic dehydration as a pretreatment before combined microwave-hot-air drying of mushrooms. Journal of Food Engineering, 49, 185–191.
Zenoozian M.S., Devahastin S., 2009. Application of wavelet transform coupled with artificial neural network for predicting physicochemical properties of osmotically dehydrated pumpkin. Journal of Food Engineering, 90, 219–227.
Terazowa Y., Ito K., 2001. Changes in carbohydrate composition in pumpkin (kabocha) during fruit growth. Journal of Japanese Society Horticultural Science, 70, 656–658.
USDA National Nutrient Database for Standard Reference, 2004. Nutritional Value of Pumpkin and Winter Squash. Realise 17.

CHAPTER 3

PRODUCT DEVELOPMENT

1

INFLUENCE OF HIGH CONTRIBUTION OF MILLED MAIZE PRODUCTS ON QUALITY OF WORTS

Introduction

Wort is an aqueous solution of malt components: carbohydrates, protein substances, enzymes, mineral. vitamins and several other substances [Kunze 1999]. It may be obtained from pilsner malts and a variety of specialty malts with or without the addition of adjuncts [Błażewicz 2004]. The traditional wort technology allows a maximum 20% supplementation with adjunct, due to hampered filtration and deteriorating extractivity of the mashed mixture.

Characteristics of wort can be modified by the selection of malts, mashing method or the type and proportion of adjuncts [Błażewicz et al. 2002]. The general principle is to reach the highest possible extractivity of the mashed mixture while maintaining proper wort filtration. The composition of wort may be very different from that found in typical brewing wort [Błażewicz 2002, Błażewicz, Rytel 2003, Zembold-Guła, Błażewicz 2007, Jurek et al. 2004].

Traditional unmalted materials used as adjuncts are cereal grains (barley, maize, wheat, tritical. oats and rice) which require many additional treatments before they are used during mashing:grain hulling, degermination and endosperm milling. At the brewery, adjuncts are gelatinized and mashed with the mal. usually with the addition of enzyme preparations.

In Poland, the most popular adjunct is degerminated maize [Błażewicz 2003, Błażewicz, Zembold-Guła 2007] or enzymatic hydrolysis products of wheat starch [Błażewicz, Musiał 2002]. Cereal hydrolysates obtained during the hydrolysis of whole cereal caryopses are not popular in Polish brewing [Błażewicz 2006].

The various techniques used for preparing adjuncts and the methods of mashing are responsible not only for differences in the quantities of extract substances in worts but also for the diverse quality of worts [Kunze 1999, Błażewicz 2004].

The use of adjuncts usually leads to a reduction in the products of protein hydrolysis in the wort and the deteriorated effects of amylolytic enzymes in malt. Technologically, it means a reduced number of amino acids necessary for the proper functioning of the yeast and a reduced amount of fermentable sugars. An insufficient saccharification abilities of malt can be corrected using amylolytic enzyme preparations. Commercially available complex preparations commonly contain the most characteristic malt enzymes. The appropriate addition of adjuncts and enzymatic preparations results in correct and effective hydrolysis of grain components [Błażewicz 2002].

The use of adjuncts in the production of malt concentrates less significantly affects technological suitability of the finished product than in beer production. Increased extraction of the components of cereal grains, undesirable in brewing, is often an advantage in the production of malt concentrates used in the food industry.Substitution of malt with unmalted material in the production of wort used for malt concentrates, allows a greater choice of adjuncts, as well as their greater share in the mash. The most important issues are then the efficiency of mash extraction and the impact of adjuncts and applied mashing techniques on wort filtration [Błażewicz, Zembold-Guła 2007].

The ever-increasing use of malt concentrates in various sections of the food industry creates a demand for a wide range of products, fulfilling the expectations of customers. In addition to quality requirements (increasingly regulated by different norms), it is inevitable that the choice is very much associated with the offered price, and raw adjuncts significantly reduce the price of finished malt concentrates.

The results of this paper will help clarify the opportunities and risks associated with the use of adjuncts in wort production with different shares of extractive ingredients coming from mal. maize grits or fine maize grits. The findings should have not only qualitative but also economic significance [Błażewicz 2004]. This is a continuation of our work published in "Food Technology Operations, New Vistas" [Błażewicz et al. 2009].

The aim of this study was to determine the influence of high shares of adjuncts in congress mashing (maize grits and fine maize grits) on selected technological properties of wort and malt concentrates.

Materials and methods

Experimental material:

- two malts: Pilsen type malt and light crystal mal.
- adjunct: maize grits 750–1250 μm and fine maize grits 250–750 μm. Grits and fine grits were obtained from the two manufacturers identified as A and B.

Congresswortswere produced at the Division of Fermentation Technology, Department of Food Storage and Technology at the Wrocław University of Environmental and Life Scien-ces, according to the method presented in diagram (Fig. 1). The shares of adjuncts were 0%, 40, 60 and 80%. Gelatinization and mashing were carried out using an LB12 Elektronic mashing apparatus (HB Labotech) in 12 repetitions. During mashing Novozymes enzyme preparations were used: Termamyl 120L Type L and Ceremix Plus MG.

The adjuncts were gelatinized in the presence of a Termamyl 120L enzyme preparation (the maximum dose recommended by the manufacturer). The purpose was to obtain gelatinized starch from adjuncts and reduce the viscosity of the suspension. The process was carried out at 75°C for 45 minutes with intense stirring. After cooling the gelatinized adjunct to 45°C, malt was added (0, 40, 60 and 80%) along with a Ceremix Plus preparation (the maximum dose recommended by the manufacturer).

The process of mashing malt with adjunct was performed in a standard manner, in accordance with EBC 4.5.1 (EBC, 1998) (solid line in the diagram (Fig. 2)). Mashing was carried out at 45°C for 30 minutes, then within 25 minutes the temperature was raised to 70°C (heating rate of 1°C per minute). Then 100 ml of distilled water was added (of the same temperature), and a temperature of 70°C was maintained for 60 minutes. The resulting mash

was cooled to a temperature of 20°C and supplemented with distilled water to a weight of 450 grams. Filtration was then performed with pleated filter papers (Whatman 597 ½), reversing the first 50 ml. The resulting filtrates constituted the worts that were used in further analysis.

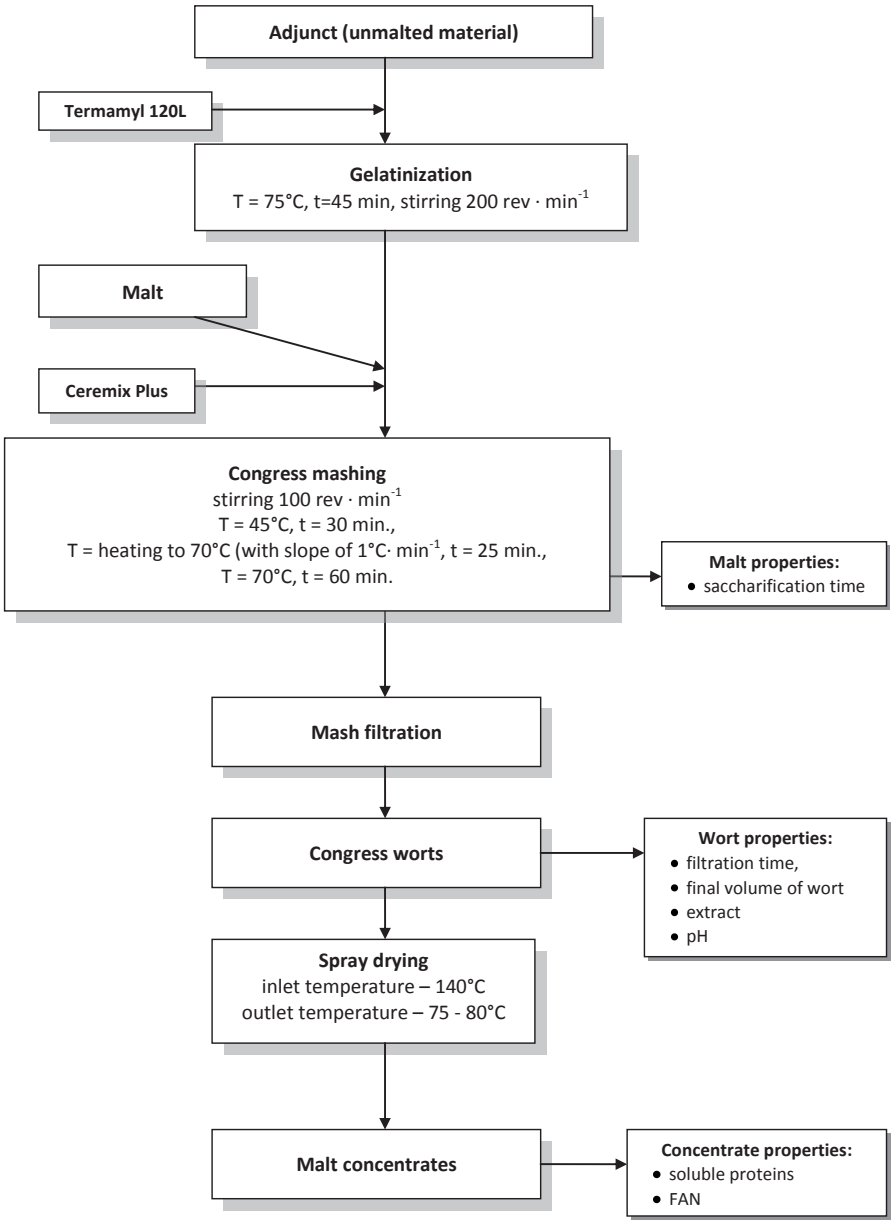

Fig. 1. Diagram of worts and malt concentrates obtainment

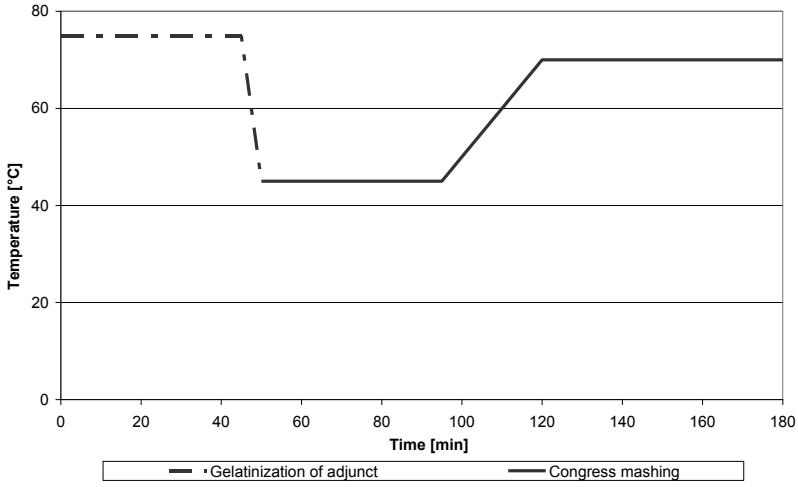

Fig. 2. Temperatures of gelatinization and mashing of malts with products of maize milling

The worts were used as intermediates in the production of malt concentrates. A spray drying method was used (Büchi Mini Spray Drier 190). The inlet temperature was 140°C and the outlet temperature was 75–80°C. The resulting concentrates had a form of powder, and had characteristic wort taste and smell, without caramelization and with a water content of several percent.

During mashing the following parameters were determined: mash saccharification time, wort filtration time, final volume of wort, extract content (according to the guidelines of EBC 4.5.1. [EBC 1998]) and the wort pH (EBC 8.17 [EBC 1998).

The dried concentrates were rehydrated in order to produce 12°BLG wort in which FAN content was determined (EBC 8.10 [EBC, 1998]), along with the content of soluble proteins,using a spectrophotometric method [Haslemore 1995]. The rehydration of malt concentrates is required in the methodology recommended by the EBC.

The obtained results of analysis of worts and concentrates obtained with the use of adjuncts were compared to control, which were worts and concentrates obtained from malts alone.

Results and discussion

In the technology of wort production, both with and without the use of unmalted material, granulation of the malt and adjunct is very important as it may affect the availability of extractive components to enzymes. In the tested material level of granulation was determined in range from 0,12 to 1,25 mm.

Table 1

Percent share of fractions in material

Material	Mesh size [mm]					
	1.25	0.63	0.32	0.27	0.12	< 0.12
Maize grits A	0.37	89.42	9.22	0.70	0.20	0.10
Maize grits B	0.21	86.93	12.26	0.38	0.19	0.04
Fine maize grits A	0.00	25.36	68.54	3.57	2.18	0.35
Fine maize grits B	0.00	0.90	16.50	25.69	51.22	5.70
Pilsner type malt	61.63	21.44	7.99	2.39	5.09	1.46
Light Crystal malt	59.07	20.77	9.40	2.77	5.33	2.68

The grits supplied by both manufacturers did not differ significantly in the degree of granulation (Tab. 1).

Significant differences were observed in the granulation of fine maize grits. Fine grit B had a higher share of small milling fractions than fine grit A and it significantly affected the extraction and some technological parametersof the examined laboratory worts.

The main parameter controlled during mashing of malt with adjuncts is saccharification time, often dependent on the level of granulation and activity of amylolytic enzymes.

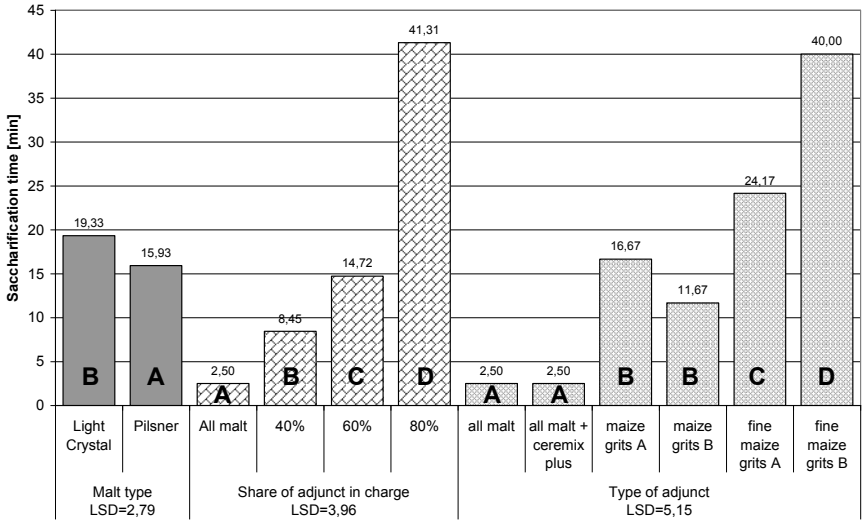

Fig. 3. Influence of malt type, share and kind of maize milling product used on saccharification time

Saccharification time allows determination of the rate of starch hydrolysis into short carbohydrate polymers and simple sugars. In industrial practice, it is assumed that mash saccharification time is correct when shorter than 20 minutes.

Both malts, although different in type and quality, complied with the formal technological requirements. The increasing share of adjuncts was accompanied by longer saccharification. Saccharification time in mashes containing 40 and 60% of the maize milling products was still normative, i.e. shorter than 20 minutes. Mashes with an 80% share of adjuncts, despite the addition of enzyme preparations, did not saccharify within the technologically acceptable time. There was a significant influence of granulation of maize products on the time of saccharification: saccharification of mashes with grits occurred within the technologically acceptable time, but the use of fine grits resulted in too long time of saccharification. It was found that statistically significant differences in the saccharification time between fine grits A and B resulted from the various shares of fine milling fractions. A greater percentage of fine grits fractions from the range 0,12–0,27 mm resulted in even 40 minute saccharification of fine grits and malt compositions.

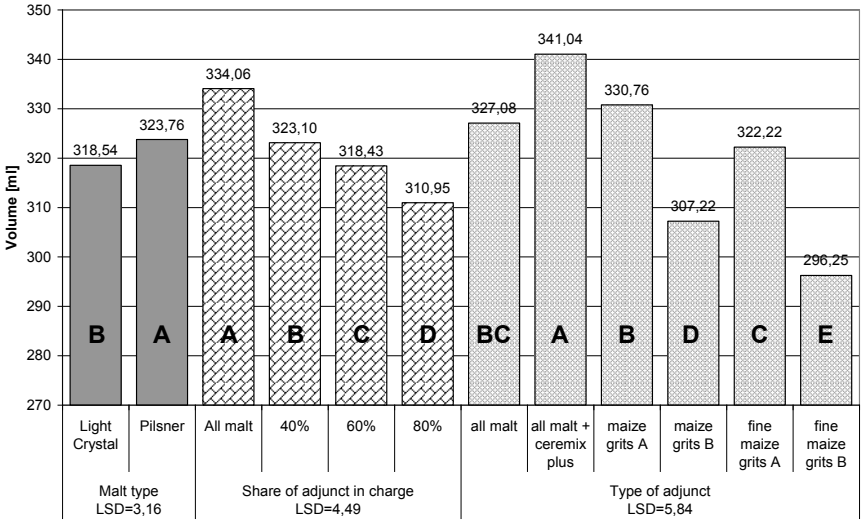

Fig. 4. Influence of malt type, share and kind of maize milling product used on final volume of wort

The filtration timeof laboratory wortis the time required for the complete filtration of mash. It should not take longer than 120 minutes. Filtration is "normal" when it is completed within 1 hour, and if it does take longer, it is referred to as "slow." Slow filtration may be caused by the presence of high molecular weight proteins in the mash; low amylolytic activity, a high content ofβ-glucans or low activity of β-glucanases.

The final volume of wort is determined after 120 minutes of filtration. In this study, statistically significant differences in the final volume of wort depended on the type of malt. With the increased share of milled maize products the final volume of obtained worts was decreased. The use of the Ceremix Plus preparation increased the final volume of wort, probably due to the improvement of enzymatic hydrolysis of the ingredients of the malt and adjunct. The volume of worts obtained with fine grits B and grits B was lower than the volume of worts for variants with product A.

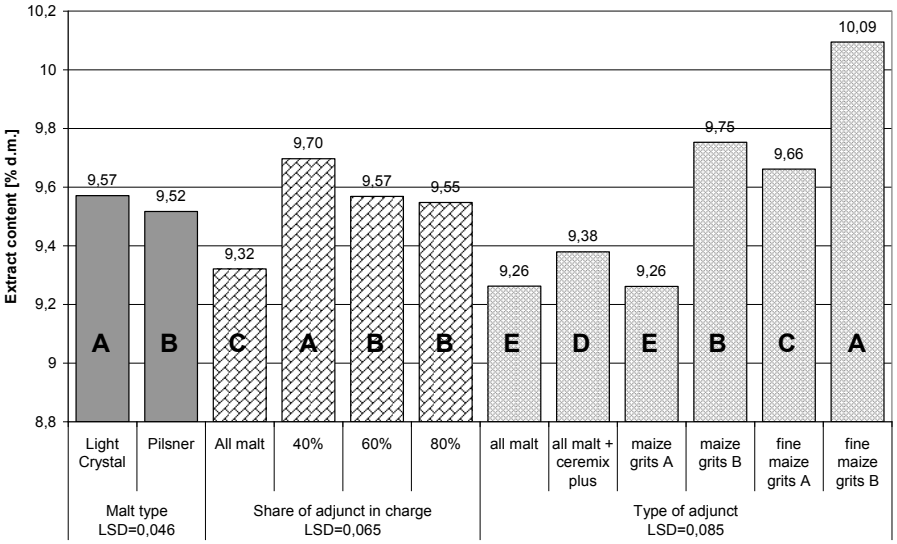

Fig. 5. Influence of malt type, share and kind of maize milling product used on extract content

The content of wort extract is a parameter used to estimate the efficiency of mashing. It is a measure of the amount of ingredientssolved in water during mashing.

In our study, it was observed, that differences in extract content in wort were associated with the type of malt. Wort obtained from pilsner malt had a lower content of extract compared to wort obtained from the light crystal malt. The lowest content of extract was noted for variants produced from malt alone. In the presence of adjuncts, all variants had a higher content of extract in comparison with control (wort from malt alone). A 40% addition of maize milling products caused the greatest increase in the content of extract. Increasing the share of adjuncts from 60 to 80% did not result in further increasesin extract content.

It was found that the content of extract depended on the granulation level of milled maize products.

The pH of wort was always at a similar level, ranging from 5,95 to 6,16, regardless of the examined variant. Despite the statistically significant differences, from a practical point of view it can be assumed that the use of adjuncts and enzymatic preparations did not significantly change pH.

Soluble wort proteinsare water-soluble small molecule polypeptides which are the product of protein hydrolysis during mashing, or proteins derived from the raw material. The solubility of proteins of higher molecular weight changes during the mashing process. Denaturation occurring during mash saccharification causes their precipitatation from solution. In this way, they are not transferred into the wort [Kunze 1999].

The differences in protein content of the wort, while depending on the type of mal. are associated not only with the specificity of the raw material but also with the activity of proteolytic enzymes in malt. Hence the significantly higher results for worts produced from pilsner type malt. The increase in the share of adjunct decreases the content of enzymatic hydrolysis products of proteins in wort. The reason for this is probably that maize grits and fine grits contain mainly starch.

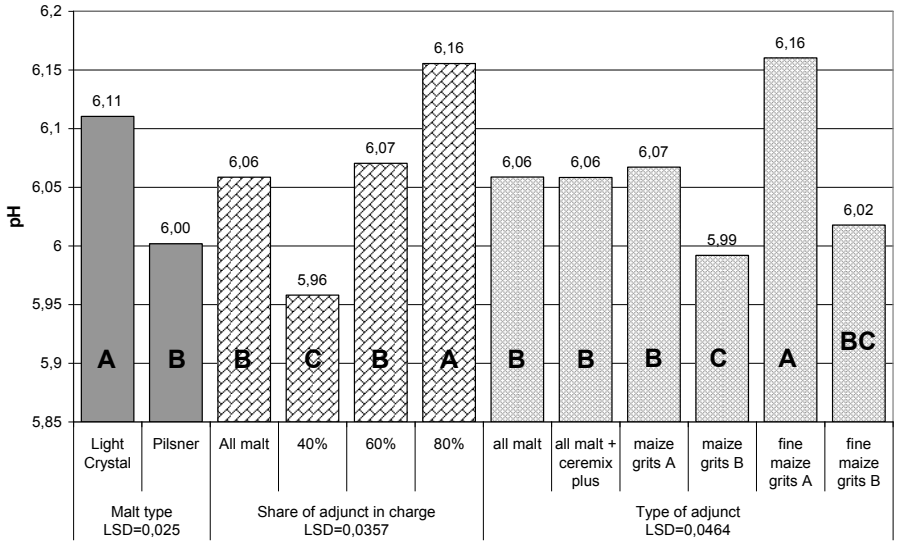

Fig. 6. Influence of malt type, share and kind of maize milling product used on pH

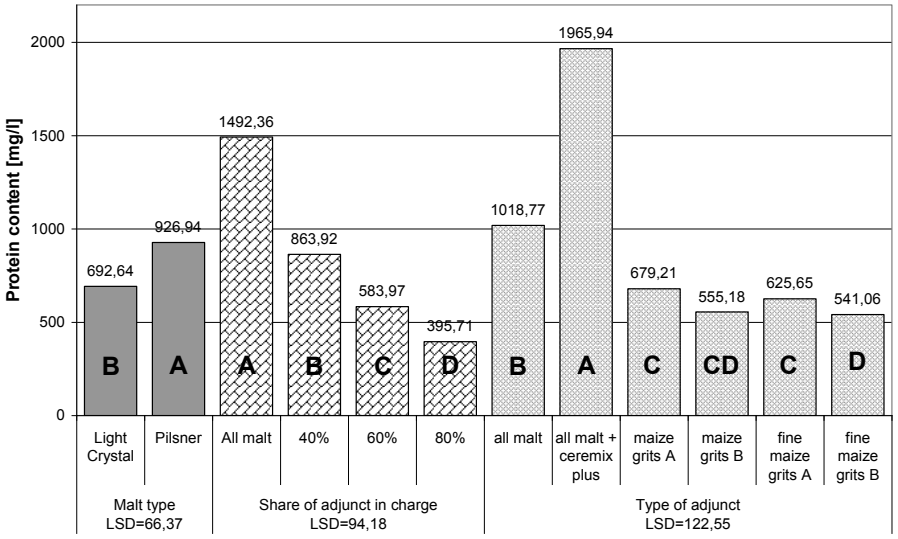

Fig. 7. Influence of malt type, share and kind of maize milling product used on soluble proteins content of 12ºBlg wort

The use of the preparation Ceremix Plus resulted in a twofold increase in soluble protein content in worts obtained from malt alone. The obtained data shows that Ceremix Plus increases the soluble protein content in the wort mainly by increased enzymatic hydrolysis of malt proteins. Wort obtained from mashing of milled maize products with malt in the presence of Ceremix Plus contained significantly less soluble proteins.

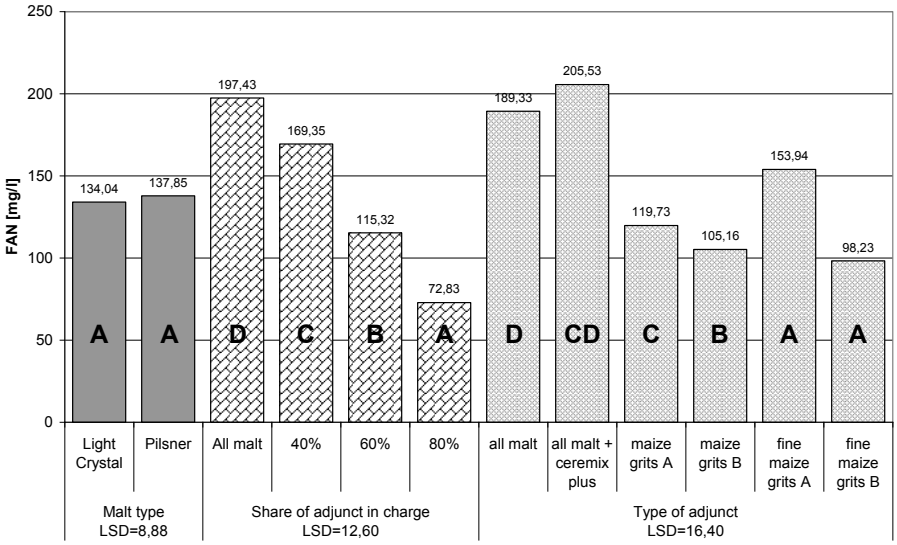

Fig. 8. Influence of malt type, share and kind of maize milling product used on FAN content of 12ºBlg wort

The content of free amino nitrogen (FAN) is an indicator of the amount of amino acids available for the yeast. Amino acids are essential building blocks of yeast cells. They are necessary for the growth of their biomass and they also influence their fermentation activity. Proper FAN content in wort should be higher than 200 mg/L. Wort made from a malt of good quality usually meets the aforementioned criteria.

In the examined worts, the type of malt did not significantly affect the content of FAN. However, reducing the share of malt resulted in a significant decrease in FAN. This was due to the lack of protein substances in the milled maize products. Using the Ceremix Plus preparation only slightly increased the content of FAN in the wort made from malt alone. Among the used maize milling products the highest FAN contents were observed in worts made using fine grit A.

The use of enzyme preparations opens up new possibilities for the production of worts with diverse contents of products of the enzymatic hydrolysis of carbohydrates, proteins and other components of malt and adjuncts exposed to the activity of malt enzymes and enzyme preparations. In brewing, it reduces the cost of wort production but makes it more difficult to produce beer. In the production of concentrates, the use of enzymatic preparations is more clearly positive.

Enzyme preparations are produced by various biotech companies, such as Amano, Genecor, Gist-Brocades, Megazymes, Novozymes, Pektowin and others. Bacterial or fungal enzymes are configured differently than the enzymes of barley grain or malt. They may need a different temperature and pH to act properly [Rodziewicz 2000]. Depending on the specific action of amylolytic enzymes, starch is broken down into various end products [Imam et al. 1991, Giraud et al. 1993]. There is a close relationship between the susceptibility of starch to the enzymes and its origin and surface structure. The process of total or partial gelatinization of starch can be found in most technological processes during the preparation of adjunct for mashing [Soral-Śmietana, Wronkowska1999].

The use of milled maize products and the selection of appropriate parameters of the preparation and mashing make it possible to produce wort and malt concentrates with acceptable technological traits and significantly reduced production costs. Such products can be widely used in the food industry, expanding the range of existing food products.

Conclusions

1. The use of adjuncts in the form of maize grits and fine maize grits (40, 60 and 80% in relation to malt) makes it possible to produce laboratory worts in brewhouse conditions, however only as an intermediate for the production of food concentrates. A reduction in the content of protein and free amino nitrogen as a result of such a large malt supplementation, prevents the use of these worts for brewing.
2. Gelatinization of adjunct (grits and fine grits) with the addition of enzyme preparation Termamyl 120L at 75°C for 45 minutes, allows proper preparation of adjuncts for the classical infusion method of wort production.
3. Enzyme supplementation of Pilsner malt and light crystal malt with Ceremix MG Plus makes it possible to obtain laboratory worts with adjuncts at 40% and 60% maize grits with a technologically acceptable time of mash saccharification, wort final volume and extract content in wort.
4. The usefulness of fine maize grits for malt substitution in the production of wort for malt concentrates depends mainly on their granulation. Excessive granulation hinders wort production and affects the wort quality.

Acknowledgements

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References

Analytica – EBC, 1998. Verlag Hans Carl Getraenke-Fachverlag, Nuernberg.

Błażewicz J., Figiel A., Stępień B., Peroń S., 2002. Influence of unmalted grain on the properties of thickened malt worts.; Acta Agrophysica, 77, 7–14.

Błażewicz J., Musiał D., 2002. Substytucja słodu przy produkcji brzeczki; Materiały: VII Szkoła Technologii Fermentacji, Łódź, 77–89.

Błażewicz J., Rytel E., 2003. Wpływ produktów hydrolizy enzymatycznej polisacharydów nieskrobiowych na cechy piwa pszenżytniego; Acta Sci. Pol., Technologia Alimentaria, 2(1), 75–82.

Błażewicz J., Zembold-Guła A., Szwed Ł., Pelak M., Kawa-Rygielska J., 2010. Unmalted adjuncts in malt extract production; Ogólnopolskie stowarzyszenie wspierania Inicjatyw NAUKA-PRZEMYSŁ, Kraków, 63–74

Błażewicz J., Zembold-Guła A., Szwed Ł., 2009. Food Technology Operations – New Vistas; Worts production with addition of milled corn products; Wydawnictwo UP we Wrocławiu, Ed. by Kopeć W., Korzeniowska M., 160–168.

Błażewicz J., Zembold-Guła A., 2007. Milled corn products in worts production. Pol. J. Food Nutr. Sci., Vol. 57, No. 4(A), 41–44.
Błażewicz J., Zembold-Guła A., 2007. Produkty przemiału ziarna kukurydzy w technologii otrzymywania brzeczek; Materiały: XII Szkoły Technologii Fermentacji. Wrocław Kliczków, 127–142.
Błażewicz J., 2002. Wpływ zastosowania w czasie zacierania preparatu enzymatycznego Ultraflo L na właściwości zagęszczonych i wysuszonych ekstraktów słodowych, Acta Sci. Pol.. Biotechnologia 1 (1–2), 19–28.
Błażewicz J., 2003. Możliwości zastosowania produktów przemiału polskiej kukurydzy w piwowarstwie. Materiały: VIII Szkoła Technologii Fermentacji; Jamrozowa Polana, 102–117.
Błażewicz J., 2004. Właściwości brzeczek i koncentratów słodowych otrzymanych z użyciem skrobi ziemniaczanej, ziarna pszenżyta i jęczmienia jako zamienników słodu; Zeszyty Naukowe AR we Wrocławiu, 491, Rozprawy CCXVII, 1–94.
Błażewicz J., 2006. Zastosowanie surowców niesłodowanych w produkcji piwa; Materiały: XI Szkoły Technologii Fermentacji; Łódź, 132–146.
Giraud E.L., Gosselin L., Marin B., Parada J.L., Raimbault M.; 1993; Purification and characterization of an external amylase activity from *Lactobacillus plantarum* strain A6. J. Bact., 75, 276–282.
Haslemore R.M., 1995. Rapid spectrophotometric measurment of soluble nitrogen in micromalts from barley breeding programme; J. Inst. Brew., Vol. 101, 469–472.
Imam S.H., Burgess-Cassler A., Cote S.L., Gordon S.H., 1991. A study of cornstarch granule digestion by an unusually high molecular weight alfa-amylase secreted by *Lactobacillus amylovorus*; Curr. Microb., 22, 365–370.
Jurek K., Błażewicz J., Petrów A., 2004. Właściwości piw wytwarzanych za dodatkiem produktów przemiału ziarna kukurydzy w warunkach uproszczonej technologii; Żywność, Nauka, Technologia, Jakość, 3 (40) Supl., 109–118.
Zembold-Guła A., Błażewicz J., 2007. Wpływ modyfikacji czasu słodowania ziarna jęczmienia na cechy brzeczek otrzymanych z udziałem grysu kukurydzianego, Żywność. Nauka. Technologia. Jakość. 5 (54), 75–81.
Zielińska K.J., Stecka K.M., Miecznikowski A.H., Suterska A.M., 2000. Degradacja surowej skrobi ziemniaczanej przez amylazy bakterii fermentacji mlekowej; Pr. Inst. Lab. Przem. Spoż., 55, 22–29.

2

THE EFFECT OF GENOTYPE ON PORK INTERMUSCULAR FAT AMOUNT AND CALORIC VALUE

Introduction

Meat is a source of amino acids, polyunsaturated fatty acids, fat and water soluble vitamins, minerals and trace elements. It is a high-calorific and well-digestible [Papadima, Bloukas 1999, Pettigrew, Esnaola 2001, Culioli et al. 2003, Cengiz, Gokoglu 2005, Jukna et al. 2007]. According consumption the quantity of pork is the second largest in the world [Drochner et al. 2000]. In the pork compared with other meat is a lot of fat, according to the category: from 27 percent to 49 percent. Pork meat under the fat content is divided into types: low in fat – up to 10 percent visible intramuscular fat, semi – 30–50 percent and fat meat – 50 to 85 percent visible intramuscular fat [Andersen 2000, Pettigrew, Esnaola 2001]. Meat fat – one of the main energy sources. Biological significance of fat depends on the available quantity of an irreplaceable polyunsaturated fatty acids (linoleic, linolenic, arachido). Of all the types of pork meat is the most indispensable of polyunsaturated fatty acids. Fat enhances the meat flavor and culinary qualities, and helps to absorb fat-soluble vitamins during digestion. Human daily intake should be no less than 50 grams of animal fat.Intramuscular fat accumulation and distribution of pork depends on the animal's genotype.The individual parts of the body fat is a different value.The most valuable are those fats that accumulate between bunch of muscle and fibers.They make the meat juicy and and improves taste [Lefaucher, Gerrar 2000, Purslow 2005, Jukna et al. 2007]. Too much fat inhibits gastric acids secretion and complicated protein digestibility, while the low intramuscular fat content of meat worsen the taste of meat [Valsta et al. 2005]. Many researchers found, that increasing marbled meat has a positive effect on meat quality [Fernandez et al. 2000, Fortin et al. 2004, Furman et al. 2007, Rincker et al. 2007]. In addition, quality of pork makes a significant impact on animal sex.M.A. Latorre with a group of researchers [2003] and H.K. Andersson, with co-workers [2005] pointed out that there are differences between the intramuscular fat content and fatty acid composition among geldings, gilts and boars uncastrated.

The aim of this study was to investigate genotype influence on pork intramuscular fat content and calorific value.

Materials and methods

To assess the genotype influence on pork intramuscular fat content and calorific value were selected and examined 96 offsprings of boars and sows reared in 2007 year. All ani-

mals had grown in the same keeping and feeding conditions in the state pig breeding station. Researches were performed with of English Large White, Yorkshire, Landrace and Lithuanian White pig breeds. The chemical composition of meat determined in Lithuanian University of Health Science, Veterinary academy, Meat Characteristics and Quality Assessment Laboratory in 2007.Pork chemical composition was determined by the following indicators: the dried materials (with automatic weighing instruments of the SM-1), fat (Soxhlet method), protein (Kjeldahl method), ash (incineration samples from 600 to 800°C). Carbohydrate content was calculated by difference.

The total value of meat calories (kcal) were calculated according to equation [Watt, Mersil 1975]: K=((Fp x P) + (FL x L) + (Fc x C)), where K is the conflicting calories, F multiplication factor for each component (Fp: 4.27 according to the protein, Fl: 9.02 according to fat, Fc: under carbohydrates), P protein (g/100 g), C carbohydrate content (g/100 g), fat content (g/100 g).

Statistical analysis

The R statistical package version 2.0.1. [Gentlemen, Ihaka 1997] was used to estimate data. The difference statistically reliable when $p < 0.05$.

Results and discussion

Studies have shown that on meat the intramuscular fat had been little from 1.76 to 1.49 percent of all tested breeds offsprings.According to this indicator, a statistically significant difference of 0.27 percent ($P < 0.05$) determined among the Large White and Yorkshire breeds (Tab. 1).

Table 1

Different pigs breeds of meat chemical composition and calorific value

Indicators	Breed			
	Lithuanian White	English Large White	Yorkshire	Landrace
n	24	24	24	24
Dry matter [%]	26.59±0.332	26.25±0.412	26.22±0.316	26.39±0.328
Intramuscular fat [%]	1.55±0.061	1.49±0.075*	1.76±0.121*	1.54±0.081
Ash [%]	1.16±0.008	1.17±0.013	1.16±0.009	1.17±0.016
Proteins [%]	23.88±0.333	23.61±0.402	23.3±0.332	23.69±0.300
Calorific values [kcal/100g]	120.10±1.487	118.93±1.984	120.68±1.511	119.80±1.620

* – $p < 0.05$

Pork calorific value ranged from 118.9 to 120.6 kcal/100 g. Meat calorific value decreased due to of the intramuscular fat content decreased of meat. A similar trend found and by other researchers [Cengiz, Gokoglu 2005, Gines et al. 2005]. The maximum amount of intramuscular fat in meat and meat calorific value were Yorkshire breed pigs.Meat calorific differences depending on genotype were statistically unreliable. The intramuscular fat

amount in meat was influenced of animals sex. Intramuscular fat was more in the castrates meat (P <0.05), however, according the calorific value did not differ from of gilts (Tab. 2).

Table 2

Meat chemical composition and calorific value according sex

Breed	Gilts	Castrates
n	46	50
Dry matter [%]	26.43±0.27	26.3±0.22
Intramuscular fat [%]	1.45±0.05*	1.71±0.07*
Ash [%]	1.17±0.01	1.16±0.01
Proteins [%]	23.81±0.25	23.43±0.22
Calorific values [kcal/100g]	119.51±1.27	120.22±1.07

* – p<0.05

Sex and genotype influence on meat quality investigated many scientists and found that on gilts meat intramuscular fat were less than castrates [Latorre et al. 2003, Fortin et al. 2004, Furman et al. 2007]. Calorific value of meat and meat chemical composition of the correlation coefficients are presented in Table 3.

Table 3

Calorific value of meat and meat chemical composition of the correlation coefficients

	Dry matter [%]	Intramuscular fat [%]	Ash [%]	Proteins [%]
All breeds	0.969***	0.508**	-0.168	0.876***
Lithuanian White	0.981***	0.426*	-0.451**	0.931***
English Large White	0.989***	0.685***	-0.328	0.952***
Yorkshire	0.925***	0.457*	-0.453*	0.724**
Landrace	0.978***	0.653**	-0.353	0.913***

* – p<0.05; ** – p<0.01; *** – p<0.001

Statistically significant high positive correlation coefficients between meat calorific value and the meat dry matter and protein were determined in the all analyzed pig breeds. The largest correlation connection on meat calorific value and on dry matter and on protein content (r=0.989 and r=0.952, p<0.001) was determined of the Large White pig breeds. Other breeds the correlation coefficients for these indicators were lower. English Large White pig breeds correlation coefficient between calorific value of meat and meat intramuscular fat were r=0.685 (p<0.001). Among the meat calorific value and ash content was established minor statistically significant negative correlation only in the Lithuanian White r=-0.451 (P <0.01) and Yorkshire pig breeds r=-0.453 (P<0.05). The correlation connection of these indicators were not statistically significant of other pig breeds.

Assessing the correlation coefficients by sex, we can assert that among both gilts and castrates the statistically significant high positives correlations coefficients were obtained between calorific value and meat dry matter and meat protein (Tab. 4).

Table 4

The correlation coefficients according sex among the meat calorific value and meat chemical composition

	Dry matter [%]	Intramuscular fat [%]	Ash [%]	Proteins [%]
Gilts	0.988***	0.575**	-0.116	0.953***
Castrates	0.954***	0.519***	-0.217	0.813***

* – p<0.05; ** – p<0.01; *** – p<0.001

Among the meat calorific value and intramuscular fat were established statistically reliable average positive correlation coefficients: of gilts r=0.575 (P <0.01) and castrates r=0.519 (P <0.001).

Conclusions

To sum up the research data can draw the following conclusions:

1. Pigs breed and sex had affected on the intramuscular fat content in the meat (P <0.05). Castrates meat had more intramuscular fat than gilts.
2. All investigated pig breeds of meat chemical composition differences were inconsiderable, therefore their of the meat calorific value was similar.
3. All tested pig breeds the highest correlation coefficients were determined between meat dry matter and protein content (p <0.001). Between the dry matter and meat fat content of the correlation coefficients were lower (P <0.05 - <0.001).
4. Meat intramuscular fat and protein content the most had influenced meat calorific value, when increasing of meat intramuscular fat content was noticed that meat calorific value increasing trend.

References

Andersson H.K., Andersson K., Zamaratskaja G., Rydhmer L., Chen G., Lundtrom K., 2005. Effect of single-sex or mixed rearing and live weight on performance, technological meat quality and sexual maturity in entire male and female pig fed raw potato starch. Animal Science. Vol. 55, 80–90.

Andersen H.J., 2000. What is pork quality? Quality of meat and fat in pigs as affected by genetics and nutrition (EAAP publication No.100). Wageningen, 15–26.

Cengiz E., Gokoglu N., 2005. Changes in energy and cholesterol contents of frankfurter-type sausages with fat reduction and fat replacer addition. Meat Science.Vol. 91, 443–447.

Culioli J., Berri C., Mourot J., 2003. Muscle foods: consumption, composition and quality. Science Aliments. Vol. 23, 13–34.

Drochner W., Mikulionienė S., Kulpys J., 2000. Kiaulių šėrimas. Kaunas, 5–9.

Fernandez X., Maurot J., Lebret B., Gilbert S., Monin G., 2000. Influence of intramuscular fat content on lipid composition, sensory qualities and consumer acceptability of cured cooked ham. Science Food Agric. Vol. 80, 705–710.

Fortin A.,Robertson W. M., Tong A. K.W., 2004. The eating quality of Canadian pork and its relationship with intramuscular fat. Meat Science. Vol. 69. 297−305.
Furman M., Malovrh Š., Sever S., Kovač M., 2007. The effects of genotype and sex on pork quality. Scientific and Professional Review.Vol. 13, 51–54.
Gentlemen R., Ihaka R., 1997. Notes on R: A programming environment for data analysis and graphics. Department of statistics university of Auckland.
Gines J. M. F., Lopez J. F., Barbera E. S., Alvarez J. A.P., 2005. Meat products as functional foods. Food science. Vol. 70. P. 37–43.
Jukna Č., Jukna V., Valaitienė V., Korsukovas A., 2007. Differentkinds ofmeatquality, comparative assessment.Vet Med Zoot. Vol. 37 (59). P. 24–27.
Jukna V., Jukna Č., Pečiulaitienė N. Genetic factors influence on pork quality. Vet Med Zoot., 2007. Vol. 40 (62). 35−38.
Latorre M. A., Lazaro R., Gracia M. I., Nieto M., Mateos G., 2003. Effect of sex and terminal sire genotype on performance, carcass characteristics and meat quality of pigs slaughtered at 177 kg body weight. Meat Science. Vol. 65. P. 1369–1377.
Lefaucher L., Gerrar D., 2000. Muscle fiber plasticity in farm mammaly. Animal Science. Vol. 80. 1550–1568.
Papadima S. N., Bloukas J.G., 1999. Effect of fat level and storage conditions on quality characteristics of traditional Greek sausages. Meat Science. Vol. 51. 103–113.
Pettigrew J. E., Esnaola M. A., 2001. Swine nutrition and pork quality. Animal Science. Vol. 79. 316–342.
Purslow P.P., 2005. Intramuscular connective tissue and its role in meat quality. A rewiew. Meat Science. Vol. 70. 435–447.
Rincker P.J., Killefer J., Ellis M., Brewer M. S., McKeith F.K., 2007. Intramuscular fat content has little influence on the eating quality of fresh pork loin chops. Animal Science. Vol.21. 490.
Valsta L.M., Tapanainen H., Mannisto S., 2005. Meat fats in nutrition. Meat Science. Vol. 70. 525–530.
Watt B.K., Mersil, A.L., 1975. Composition of foods-aw processed, prepared. Rev. USDA agriculture handbook. Washington. Vol. 8. 346–366.

3

POLISH DURUM WHEAT AS A RAW MATERIAL FOR PASTA PRODUCTION

Introduction

The best raw material for pasta production is semolina, obtained by milling of *Triticum durum* grain [Rachoń 2001]. The quality of the durum wheat can be defined based on the number of features, the choice of which depends on the way of its use [Troccoli et al. 2000]. Grain for milling should display physical properties that allow for obtaining high efficiency of semolina in milling. Producing semolina of suitable granulation, low ash and high protein and carotenoid content depends not only on appropriate grain quality, but also correct milling process.

The observed market deficit of *Triticum durum* grain was manifested by its higher price and variable quality [Jurga 2004, Zawadzki 2008]. The best quality raw material is produced in Canada and the USA. In Europe, one of the best hard wheat is produced in Germany and slightly worse raw material comes from the Mediterranean area [Bojarczuk 2006, Jurga 2004]. Grain of different quality is obtained in countries such as Austria, Hungary, Ital. Greece and France. Growing demand for durum wheat makes the farmers increase its acreage, which is associated with different yield quality. Pasta production in Poland is based largely on foreign hard wheat [Segit and Szwed-Urbaś 2008]. The necessity of importing this wheat increases the costs of pasta production, but also leads to growing interest in cultivation of Polish durum wheat [Rachoń 2001].

Breeding works on native hard wheat date back to the 1920s [Bojarczuk 2006, Gąsiorowski, Obuchowski 1978, Mazurek, Ruszkowski 1965]. The research started then resulted in obtaining the first Polish spring durum wheat variety called Puławska Twarda (Pulawy Hard). Subsequent breeding works allowed for obtaining another variety Hela. However, cultivation of both varieties was ceased in 1959 due to their low prolificacy. Sulewska et al. [2007] determined the degree of adaptation of hard wheat varieties from Germany, Austria and Italy to the conditions prevailing in the Wielkopolska region. Their yield was similar to common wheat, but low protein and carotenoid pigments content and low falling number influenced their negative evaluation. Other attempts to introduce foreign varieties in Poland did not bring the expected results either [Bojarczuk 2006].

The aim of this study was to assess the technological value of grain of new Polish lines and strains of spring durum wheat selected as a result of breeding research in Smolice Plant Breeding Centre.

Materials and Methods

The material consisted of grain from 19 lines and strains of spring durum wheat obtained as a result of breeding experiments in Smolice Plant Breeding Centre (IHAR Group) from the 2008 crop.

The grain was evaluated with regard to its physical characteristics: weight of 1 000 kernels, grain uniformity [Jakubczyk, Haber 1983], grain bulk density (PN-ISO 7971–2), grain vitreousity (PN-EN 15585), particle size index – 104 μm (Gąsiorowski et al. 1999), and milling properties including the yield and extraction rate of middlings and yield of passage flours and flour in total.

Then, the chemical properties of flour were determined (ash content according to PN--ISO 2171, total protein PN-75/A-04018, and carotenoid pigments AACC 14–50). Properties of the protein complex were evaluated on the basis of the wet gluten yield and its deliquescence (PN-77/A-74041) and farinographic curves (PN-ISO 5530–1). Zeleny (PN-ISO 5529) and SDS [Axford et al. 1979] sedimentation tests were also carried out. The properties of amylolytic-starch complex were evaluated by measuring starch content [Jakubczyk, Haber 1983], degree of its mechanical damage (AACC 76–30; AACC 80–60), the falling number (PN-ISO 3093) and the amylographic features (PN-ISO 7973). Flour colour was determined on the basis of L^* and b^* parameters in the CIE $L^*a^*b^*$ system.

The tested samples of flour were used for pasta production. The dough was prepared in the laboratory mixer Dolly Mini P3 La Monferrina by mixing the flour with water (30%) for 12–15 min. The dough was then pressed into 5–6 cm long vermicelli pasta and dried at room temperature for 24 h.

The pasta colour was assessed (using L^* and b^* parameters and the CIE $L^*a^*b^*$ system) and a three point bending test with Instron 5566 was performed. Pasta culinary assessment [Obuchowski 1997] included the estimation of minimum cooking time, weight increase coefficient and the loss of dry weight during cooking.

The statistical analysis of the results was performed with Statistica 9.0 programme. For each quality characteristics a mean value, standard deviation and variation coefficient were calculated. Moreover, relationships between selected parameters were determined on the basis of Pearson's correlation coefficients (P=0.95). They concerned the relationship between the quality characteristics of grain and flour and amylographic and farinographic parameters, flour colour and pasta cooking qualities.

Results and Discussion

The study showed that the assessed native lines of durum wheat were characterized by considerable diversity in terms of thousand kernels weight (V=8.5%), uniformity (V=9.2%), and the particle size index (V=10.4%) (Tab. 1). The lowest values of the variation coefficient were observed for grain bulk density (V=2.0%). The average weight of one thousand kernels for tested samples was 43.3 g and grain bulk density was 84.1 $kg \cdot hl^{-1}$. High vitreousity (90%) and uniformity (79.1%) of the grain was noted and grain hardness expressed as the particle size index was 16.4%. The grain of 177–24–5 line was found to have the best physical properties. The weight of one thousand kernels was 48.7 g, grain bulk density amounted to 85.6 $kg \cdot hl^{-1}$and vitreousity to 97%. This line of wheat also exhibited high grain uniformity (87.8%).

Vitreousity is one of the main indicators of durum wheat grain quality. It is claimed that hard wheat used for pasta production should have high, about 90-percent share of the vitreous grain [Ceglińska et al. 2004]. This feature is largely associated with grain hardness [Cacak-Pietrzak 2008]. Studying the effects of forecrop on yield and technological quality of grain of spring forms Woźniak [2005] obtained vitreousity results within the range 71.0–92.0%. The literature data on the Hungarian and German winter varieties of durum wheat show that their grain achieved lower vitreousity (60–90%) [Beke et al. 2000, Jurga 2004]. In the studies published by Rachoń and Szumiłła [2002] foreign and domestic varieties of spring lines were characterized by similar values of this trait (86.0–94.3%). Vitreousity of durum wheat from Polish cultivation assessed by Obuchowski [2007] and Rachoń et al. [2002] as well as Rachoń and Szumiłła [2009] was within the range of 50.0–94.3%. Hence, the vitreousity values presented in the present study should be considered high.

Among the milling properties the greatest variability was observed for the yield of breaking flour (V=18.4%) (Tab. 1). An average value of this trait was 8.6% and the lowest value was found for milled grain from the strains 264-R-1 (6.0%), 264-R-4 (6.4%) and 177–24–5 and 265 -R-5 (6.8%). The highest yield of breaking flour was recorded for the lines 213-R-2 (12.0%), 265-R-1 and 136–2R-3–2R-4 (10.8%). Values of the variation coefficient for the other milling properties were within the range from 1.3% for middlings reduction to 3.7% for middlings extraction. Average yield for reduction flour was 51.3% and for total flour it amounted to 59.9%. The highest yield of reduction flour was obtained in milling the grain from lines 177–24–5 (54.8%), 264-R-1 (53.6%) and 174–2R-2 (52.8%). In the case of total flour yield the highest values were observed in the lines: 174–2R-2, 213-R-2, 265-R-1 and 177–24–5 (62.0–62.4%). The highest middling yield (60.8%) was found in the line 264-R-1, which was also characterized by low particle size index (14.4%).

The effect of grain milling is determined by the flour yield and it mainly depends on the efficiency and capacity of reducing middlings and flour [Jurga 2002]. In our study the middlings extraction level was 53.6–60.8%. Similar results were obtained by Rachoń [2001 2004] (55.0–60.0%). The research involving Polish durum wheat variety Komnata show its higher semolina yield and higher ash content compared to the currently obtained results [Zych 2009]. Spring varieties analyzed by Rachoń et al. [2002] revealed higher yield of middlings at an average level 61.4%. It is assumed that wheat grain of good milling properties can yield rough middlings with the efficiency above 60% [Rachoń et al. 2002]. In the present study, such efficiency was achieved only for the lines: 264-R-1, and 177–24–5 (60.8%). Rachoń [2001] claims that low middlings extraction of *Triticum durum* is determined genetically.

Values of the variation coefficient for the flour quality parameters fluctuated over a wide range from 2.2% for starch content, to 32.0% for wet gluten deliquescence (Tab. 2). The tested material displayed high diversity in terms of SDS sedimentation rate (V=31.5%), whereas the results for protein content in flour (V=5.1%) and grain (V=4.2%) and flour ash content (V=3.9%) were more similar. The average protein content in grain was 11.9% and in flour 10.8%, while ash constituted 0.66%. The highest protein content in grain and flour (13.4 and 12.2% respectively) and wet gluten efficiency (36.2%) for deliquescence of 10 mm were found in the line 269-R-4. Low values of these characteristics were observed for lines 213-R-2 (28.2%) and 212-R-4 (26.3%). Deliquescence of gluten obtained from them was 7–9 mm. In the studies on Spanish varieties Rharrabti et al. [2003a] found that the protein content in grain is strongly affected by the environmental conditions, mainly water availability. The works of Polish authors demonstrated that the protein content in durum wheat

grain was higher in the spring varieties than in the winter ones [Rachoń et al. 2002, Rachoń and Szumiło 2002, Woźniak 2005]. In these studies, the content of the discussed component ranged widely from 13.9 to 18.2%. The wheat assessed in this study contained less protein (11–13.4%). The requirements of the pasta-making industry specify the minimum content of this component at the level of 13–15% [Obuchowski 1997]. Tests of the experimental material by means of Zeleny sedimentation rate showed its lower level and less variation of samples (14 cm^3, V=14.0%) than the SDS sedimentation test (25 cm^3, V=31.5%). In both tests the highest values were recorded for flour from the lines 129–4Rn-1 (18.5 cm^3; 40 cm^3), 177–24–5 (17 cm^3; 42 cm^3) and 269-R-4 (17.0 cm^3; 38 cm^3). The value of SDS sedimentation and Zeleny index depends on the protein quality. SDS test can be more widely applied and allows for more accurate assessment of the analyzed material [Axford et al. 1979]. Moreover Bojarczuk [2006] points out a positive correlation between protein content and SDS sedimentation rate. The average value of the SDS ratio obtained in this study corresponds to the value received by Abdel-Aal [1997] and Rachoń [2001].

Table 1

Physical features and milling properties of winter durum wheat grain

Lines	Weight of 1000 kernels [g]	Test weight [$kg \cdot hl^{-1}$]	Vitreousity of grain [%]	Uniformity of grain [%]	Particle size index [%]	Flour extraction [%]			Middlings extraction [%]	Middlings reduction [%]
						breaking	reduction	total		
129–4Rn-1	40.1	81.2	81	88.4	18.0	8.0	48.8	56.8	53.6	91.0
263-R-1	44.1	85.6	92	83.0	16.1	7.2	52.0	59.2	58.8	88.4
213-R-2	46.7	81.5	84	85.7	21.1	12.0	50.0	62.0	54.8	91.2
274-R-2	46.6	84.8	94	80.5	15.8	8.8	51.2	60.0	58.0	88.3
174–2R-2	45.7	85.4	96	82.4	16.5	9.6	52.8	62.4	59.2	89.2
213-R-5	49.9	81.5	81	88.5	15.7	9.2	51.2	60.4	58.0	88.3
264-R-1	44.6	85.2	94	84.2	14.4	6.0	53.6	59.6	60.8	88.2
104–4R-2	41.0	83.2	96	79.8	14.6	8.0	50.8	58.8	57.2	88.8
265-R-1	42.9	85.2	94	80.9	14.5	10.8	51.2	62.0	57.6	88.9
177–24–5	48.7	85.6	97	87.8	15.5	6.8	54.8	61.6	60.8	90.1
104–4R-5	38.8	81.4	81	65.2	16.9	8.8	52.0	60.8	57.6	90.3
264-R-4	43.0	85.4	93	80.7	14.1	6.4	51.6	58.0	59.2	87.2
136–2R-3–2R-4	41.1	83.8	91	79.1	17.7	10.8	48.4	59.2	53.6	90.3
212-R-4	44.4	83.4	83	78.0	18.8	9.2	51.6	60.8	58.0	89.0
264-R-6	38.0	83.9	86	66.3	16.6	8.4	51.6	60.0	58.0	89.0
265-R-5	41.5	85.6	94	76.0	15.9	6.8	52.0	58.8	58.4	89.0
270-R-2	44.2	86.0	93	78.7	16.0	8.0	51.2	59.2	58.4	87.7
269-R-4	42.8	83.4	89	64.1	18.1	9.2	50.0	59.2	54.8	91.2
177–2R-5	43.3	85.7	85	74.8	16.5	8.8	49.6	58.4	55.6	89.2
Minimal	38.0	81.2	81	64.1	14.1	6.0	48.4	58.0	53.6	87.2
Maximum	49.9	85.7	97	88.5	21.1	12.0	54.8	62.4	60.8	91.2
SD*	3.7	1.6	6	7.2	1.7	1.6	1.5	1.5	2.1	1.2
V [%]	8.5	2.0	6.7	9.2	10.4	18.4	3.0	2.5	3.7	1.3
Mean	43.3	84.1	90	79.1	16.4	8.6	51.3	59.9	57.5	89.2

* – standard deviation

Table 3

Chemicalparameters of winter durum wheat flour

Lines	Ash [%]	Total protein in: [%]		Wet gluten [%]	Deliquescence of wet gluten [mm]	Sedimentation test: [cm^3]		Falling number [s]	Starch [%]	Starch damage [%]	Carotenoids pigments [mg%]
		grain	flour			Zeleny	SDS				
129–4Rn-1	0.66	11.9	10.2	28.4	2	18.5	40	373	68.0	15.17	0.559
263-R-1	0.66	11.7	10.6	30.8	10	14.0	21	462	67.1	16.24	0.402
213-R-2	0.63	11.0	9.8	28.2	7	16.0	31	423	69.3	13.61	0.451
274-R-2	0.65	11.9	10.6	30.7	11	13.0	22	439	67.6	15.70	0.358
174–2R-2	0.64	11.8	11.0	32.2	11	13.0	21	454	67.1	15.99	0.343
213-R-5	0.70	11.5	11.0	25.1	8	13.5	24	451	69.2	15.42	0.473
264-R-1	0.65	11.8	10.6	31.9	10	13.0	22	433	68.7	16.48	0.382
104–4R-2	0.65	12.0	11.1	31.2	18	10.5	13	402	68.2	15.17	0.443
265-R-1	0.66	12.0	11.0	31.8	12	12.5	21	439	66.7	15.42	0.400
177–24–5	0.64	11.9	11.0	31.0	5	17.0	42	517	69.6	14.68	0.377
104–4R-5	0.70	12.0	10.9	31.5	13	12.0	19	436	65.6	13.00	0.424
264-R-4	0.67	12.1	11.0	30.6	11	13.5	20	453	66.6	15.70	0.359
136–2R-3–2R-4	0.64	12.1	10.2	30.6	10	15.5	32	513	67.1	12.79	0.475
212-R-4	0.65	11.1	9.9	26.3	9	14.0	32	453	69.5	14.02	0.432
264-R-6	0.71	12.2	11.2	29.4	10	13.0	21	444	67.5	15.42	0.425
265-R-5	0.70	12.4	11.2	31.8	12	13.0	21	474	68.2	14.68	0.383
270-R-2	0.66	11.8	11.0	32.4	14	13.5	21	451	68.6	14.92	0.368
269-R-4	0.65	13.4	12.2	36.2	10	17.0	38	480	65.0	12.38	0.531
177–2R-5	0.67	11.6	10.3	28.5	11	13.5	21	388	69.6	14.23	0.407
Minimal	0.63	11.1	9.8	25.3	2	10.5	10.5	373	65.0	12.79	0.343
Maximum	0.71	13.4	12.2	36.2	18	18.5	18.5	517	69.6	16.48	0.559
SD	0.03	0.5	0.5	2.5	3	2.0	2.0	36	1.5	1.18	0.058
V [%]	3.9	4.2	5.1	8.0	32.0	14.0	14.0	8.1	2.2	8.0	13.84
Mean	0.66	11.9	10.8	30.5	10	14.0	14.0	446	67.8	14.79	0.421

The tested flour was characterized by low activity of α-amylase expressed as the falling number of 373–517 s, and little differentiation in terms of starch content (V=2.2%). The average degree of starch damage was 14.79%. The least damaged starch granules were observed for the wheat lines: 269-R-4 (12.38%), 136–2R-3–2R-4 (12.79%), 104–4R-5 (13.00%) and 213-R-2 (13.61%). The highest level of this trait was found in flour from the lines: 174–2R-2 (15.99%), 263-R-1 (16.24%) and 264-R-1 (16.48%). Obuchowski (1997) reports that the falling number of good quality material for pasta production is 350–450 s, confirming good condition of the grain and products from milling thereof. The falling number for the native durum wheat investigated by Ceglińska et al. [2004] was 245–354 s. Similar values of this trait have also been published by Obuchowski [2007]. The wheat analyzed by the abovementioned authors was characterized by higher α-amylase activity than recommended. Hungarian and German winter hard wheat varieties assessed by Cseuza et al. [2000] and Jurga [2004] also demonstrated increased amylolytic activity (85–332 s). The falling number of

the material studied by Abde-Aal et al. [1997] was found to be at the appropriate level. The flours analysed in this study showed low and very low activity of α-amylase and a high starch resistance to its action.

The variation coefficient determined for the carotenoid pigments was 13.84% and their average content in flour was 0.421 mg%. The highest values of this parameter were found in flour from lines 129–4Rn-1 and 269-R-4 (0.559 mg% and 0.531 mg% respectively). Similar values of this factor (0.397–0.490 mg%) were noticed by Rharrabti et al. [2003a, 2003b] in the studies investigating the effect of abiotic factors on the technological value of Spanish durum wheat varieties. Lower value of this feature was found for Komnata variety (0.310 mg%) and foreign varieties of spring durum wheat (0.150–0.220 mg%) (Obuchowski et al. 2007, Makowska et al. 2008, Zych 2009). Low values of this parameter were also obtained in studies on national lines of durum wheat [Rachoń 2001, Rachoń et al. 2002]. The content of pigments in Hungarian winter wheat varieties amounted to 0.640–1.080 mg% [Beke et al. 2000, Cseuz et al. 2000]. The literature data indicate that the pigment content is influenced by genetic factors and climatic conditions [Rachoń 2001, Santra et al. 2003, 2005]. Another important factor considered during evaluation of raw material for the pasta production is low activity of redox enzymes that allows for limiting the negative changes in colour (Landi 2000, Makowska et al. 2008).

Considering amylographic features the research material showed the highest diversity of maximum gruel viscosity (V=29.9%) (Table 3). For the other amylographic parameters low variation coefficients were determined (2.1–5.2%). This shows the low variation of the studied flours, among which the line 177–24–5 characterized by the highest initial gelatinization temperature (57.0°C) and the maximum viscosity (1 400 AU), and the line 104–4R-5 characterized by highest final gelatinization temperature (91.5°C) and longest gelatinization time (41.0 min) should be noted. According to the studies conducted by Karolini-Skaradzińska [2001] and Subda et al. [2002] the flour of winter wheat varieties usually was characterized by high initial (70.0–82.0°C) and final gelatinization temperature (89.5–92.7°C). Żmijewski et al. [1999] observed lower initial gelatinization temperature (66.5–72.5°C) and similar final gelatinization temperature (90.5–91.5°C). In our study we obtained the lowest, among the cited literature data, values of the initial gelatinization temperature (44.9–57.0°C) and similar final temperature (82.5–91.5°C). Differences in the initial gelatinization temperature may be due to different properties of starch from common and hard wheat. Moreover, lower gelatinization temperature is typical for mechanically damaged starch granules [Gąsiorowski 1994], which are more abundant in the hard wheat flour. Numerous authors [Żmijewski et al. 1999, Karolini-Skaradzińska et al. 2001, Subda et al. 2002] described longer gelatinization time for starch from common wheat (43.0–45.1 min) than we found in our experiments (35.0–41.0 min). In the published studies on common wheat the maximum viscosity ranged from 210 to 420 AU. We reported higher values of this feature and their greater diversity (400–1400 AU). High falling numbers and maximum viscosity values confirm low amylolytic activity and considerable resistance of starch to enzyme action.

Table 3

Amylografic and farinographic traits of winter durum wheat flour

Lines	Temperature of gelatinization [ºC]		Maximal gruel viscosity [AU]	Gelatinization time [min]	Water absorption of flour [ml·100g^{-1}]	Dough development time [min]	Dough stability [min]	Softening of dough [FU]	Quality number [mm]
	initial	final							
129–4Rn-1	52.5	82.5	400	35.0	68.8	2.1	1.5	120	37
263-R-1	52.5	89.3	790	39.5	69.8	1.7	1.1	130	30
213-R-2	55.8	88.5	730	39.0	65.8	1.7	0.8	105	24
274-R-2	53.3	87.8	750	38.5	69.6	1.9	1.7	135	31
174–2R-2	51.0	88.8	720	39.2	71.2	1.5	1.0	130	29
213-R-5	54.0	87.6	615	38.4	69.8	1.6	1.1	120	23
264-R-1	54.0	88.8	620	39.2	70.0	2.3	1.6	130	30
104–4R-2	56.4	88.8	490	39.2	69.2	2.0	1.0	190	24
265-R-1	55.5	87.9	690	38.6	71.8	1.7	1.4	140	29
177–24–5	57.0	89.0	1400	39.4	67.4	5.0	6.3	70	82
104–4R-5	56.4	91.5	675	41.0	67.8	1.7	1.3	140	25
264-R-4	44.9	88.2	660	38.6	71.8	1.5	1.3	140	28
136–2R-3–2R-4	56.4	88.5	1000	39.0	66.8	1.7	1.3	110	30
212-R-4	54.9	90.0	840	40.0	68.7	2.3	1.6	95	34
264-R-6	55.2	87.9	635	38.6	72.0	1.8	1.4	130	29
265-R-5	54.9	88.2	795	38.8	73.4	2.1	1.4	115	33
270-R-2	54.9	88.5	775	39.0	73.0	1.6	1.4	140	27
269-R-4	54.3	87.6	890	38.4	67.8	2.3	2.4	110	35
177–2R-5	51.0	84.9	440	36.6	72.0	1.6	0.9	130	24
Minimal	44.9	82.5	400	35.0	65.8	1.5	0.8	70	23
Maximum	57.0	91.5	1400	41.0	73.4	5.0	6.3	190	82
SD	2.8	1.8	219	1.2	2.2	0.8	1.2	24	13
V [%]	5.2	2.1	29.9	3.2	3.1	38.6	74.2	19.1	40.2
Mean	53.9	88.1	732	38.7	69.8	2.0	1.6	125	32

Among the farinographic characteristics the smallest diversity was observed for flour water absorption (V=3.1%). The highest water absorption was found for the flour from the lines 265-R-5 (73.4 ml·100g^{-1}) and 270-R-2 (73.0 ml·100g^{-1}) and the smallest for the line 213-R-2 (65.8 ml·100g^{-1}). Large variation of wheat samples in terms of other farinographic features (V=19.1–74.2%) is explained by the values recorded for the line 177–24–5 that differ significantly from the results obtained for the other lines. Analysis of this line farinograph revealed that the obtained dough had the best rheological properties and despite not the highest flour water absorption (67.4%) it was characterized by the longest development time (5.0 min), and stability (6.3 min), the lowest softening (70 FU) and the highest quality number (82 mm).

Flour investigated in this study had higher water absorption than Komnata variety assessed by Zych [2009], and spring durum wheat evaluated by Rachoń and Kulpa [2004].

American winter wheat examined by Jurga [2004, 2010] showed lower water absorption than the lines investigated in this work. Similar values of this parameter were obtained by Ceglińska et al. [2004].

Statistical analysis showed low variation of the tested flour saturation with yellow pigment -*b** (V=5.0%) and the variation coefficient for *L** was only 0.4% (Tab. 4). The average value for colour factor *L** was 91.2% and 16.8% for *b**. The *L** factor values for the tested material ranged from 91.8 to 90.9%. The highest value of *b** factor was observed for flour from wheat of high content of carotenoid pigments, i.e.: 129–4Rn-1 (18.0%), 169-R-4 (19.2%) and 136–2R-3–2R-4 (-18.0%). The flour from 177–24–5 line showed the lowest level of yellow colour saturation (15.5%).

Table 4

Pasta properties from winter durum wheat

Lines	Flour colour [%]		Pasta colour [%]		Breaking force in three point bending test [N]	Cooking quality of pasta		
	*L**	*b**	*L**	*b**		minimal cooking time [s]	cooking index	cooking lost [%]
129–4Rn-1	90.9	18.0	88.0	12.8	5.80	480	3.2	11.2
263-R-1	91.3	16.2	89.0	10.0	5.70	480	3.2	11.1
213-R-2	91.8	16.3	87.7	12.1	5.71	420	3.0	11.9
274-R-2	91.3	16.2	87.2	11.2	5.98	420	3.1	9.8
174–2R-2	90.9	16.1	87.9	11.4	6.59	420	3.1	9.5
213-R-5	91.1	17.2	88.0	12.9	6.02	450	3.1	12.6
264-R-1	91.1	16.4	87.4	12.1	6.21	420	3.1	12.9
104–4R-2	91.3	16.9	87.7	12.3	6.02	450	3.3	10.3
265-R-1	91.1	16.6	86.3	12.3	5.95	420	3.1	9.2
177–24–5	91.4	15.5	88.5	11.0	6.72	480	2.8	11.4
104–4R-5	91.3	17.2	88.0	13.3	6.06	390	3.0	9.2
264-R-4	91.1	16.2	87.2	11.1	6.14	420	3.0	11.0
136–2R-3–2R-4	91.3	18.0	87.7	14.3	6.41	390	3.0	8.5
212-R-4	91.7	16.9	87.0	12.9	6.84	420	3.0	10.8
264-R-6	91.2	16.7	86.9	14.0	6.36	540	3.2	9.7
265-R-5	91.2	16.7	88.7	11.8	6.54	420	3.1	9.8
270-R-2	90.9	16.3	88.1	11.5	6.03	420	3.0	7.9
269-R-4	91.1	19.2	87.5	15.4	6.10	480	3.2	8.3
177–2R-5	91.3	16.8	88.4	12.4	6.26	390	3.0	11.4
Minimal	90.9	15.5	86.3	10.0	5.70	390	2.8	7.9
Maximum	91.8	19.2	89.0	15.4	6.84	540	3.3	12.9
SD	0.3	0.8	0.4	1.4	0.11	39	0.1	1.4
V [%]	0.4	5.0	0.5	11.6	1.8	8.9	4.2	13.8
Mean	91.2	16.8	87.7	12.4	6.18	437	3.1	10.4

In the case of pasta colour the value of variation coefficient for *L** was also very low (0.5%) and the b* factor was two times higher than for the flour (11.6%). The value of *L** factor for the pasta was within the range from 86.3% (265-R-1) to 89.0 (263-R-1) with an average 87.7%. The highest value of *b** factor for dried pasta was found for products from the wheat lines 264-R-6 (14.0%), 136–2R-3–2R-4 (14.3%), 269-R-4 (15.4%). High content of carotenoid pigments was also reported for lines 136–2R-3–2R-4 and 269-R-4. The lowest level of colour factor *b** was determined for dry pasta from lines 177–24–5 (11.0%), 263-R-1 (10.0%), with an average of 12.4%. Evaluation of bending strength in a three point bending test allows for determining the resistance of the material to external forces. This parameter had a low variation coefficient (V=1.8%). The observed bending strength ranged from 5.70 N for the 263-R-1 line to 6.84 N for the 212-R-4 line with an average of 6.18 N. Obuchowski [1997] maintains that the pasta weight growth factor is within the range of 2.5–3.5. In the work of Dziki et al. [2003] the values of this parameter for spaghetti pasta amounted to 2.2–2.6. In the present study, the pasta weight growth factor was on average 3.1. The values of this trait ranged from 2.8 for 177–24–5 line to 3.3 for 104–4R-2 line. Dry weight loss during cooking is an important factor in determining pasta functional characteristics. The lowest values of this parameter were observed for the pasta from wheat lines 270-R-2 (7.9%), 269-R-4 (8.3%) and 136–2R-3–2R-4 (8.5%) and the highest for lines 213-R-2 (11.9%), 213-R-5 (12.6%) and 264--R-1 (12.9%). The average loss of dry weight was 10.4%. It is believed that the smaller the dry weight loss the better the pasta quality. Obuchowski [1997] states that this value should not exceed 8%. According to other authors the maximum permissible loss of dry weight is 12% [Gallegos-Infante 2010]. In the pasta investigated by Gallegos-Infante et al. [2010] and Dziki et al. (2003) the loss of dry matter was 9.7–12.3%. In the work published by Vignaux [2005] the loss of dry weight was lower and ranged 4.7–6.2%. The average minimum pasta cooking time in this study was 437 s. The lowest values of this parameter were obtained for the lines 104–4R-5, 136–2R-3–2R-4 and 177–2R-5 (after 390 s), while the highest ones for the lines 264-R-6 (540s) and 129–4RNn-1, 263-R-1, 177–24–5, 269-R-4 (after 480 s).

Pasta culinary features depend both on the quality of raw material and the correctly chosen technological parameters, particularly at the stage of pressing and drying [Obuchowski 1997]. Cooked pasta should not stick and should be substantially flexible and have pleasant smell and taste [Jurga 2007]. In a study conducted by Dziki et al. [2003], the minimum cooking time varied, depending on the pasta type, from 90 s (vermicelli) to 780 s (spaghetti). Longer cooking times were observed for the pasta evaluated by Vignaux (2005) (528–612 s) and shorter in the study by Gallegos-Infante et al. [2010] (195–268 s).

The studies on durum wheat grain quality determined the correlation coefficients between grain quality characteristics and the basic parameters determining the quality of flour obtained from them (total protein, wet gluten yield and its deliquescence) [Szwed-Urbaś et al. 1996, 1997, Segit and Szwed-Urbaś 2006]. A few, mostly foreign, works focused on the correlation coefficients related to the relationship between the physical characteristics of durum wheat grain and carotenoid pigments content or sedimentation test results [Rharrabti et al. 2003a]. Few attempts were made to find the relationship between fractional protein composition of durum wheat and the farinographic features and quality of the resulting pasta [Dexter, Matsuo 1980].

Having vast amount of data we tried to find whether there was any correlation between grain, flour and pasta parameters for new strains and lines of durum wheat (Tab. 5). It was found that the grain bulk density was correlated with the flour water absorption (0.59), flour

colour factor b* (-0.47), and parameters L* (-0.47) and b* (-0.64) determined for the pasta. Factor b* values for flour and pasta, as well as the maximum viscosity values, correlated with the grain vitreousity (-0.48, -0.57; 0.47). This makes it possible to determine the suitability of raw pasta material from new strains and lines of durum wheat at the stage of assessing the physical characteristics of grain on the basis of grain vitreousity and bulk density.

Table 5

Significant values of Pearson`s correlation coefficient between features of grain, flour and pasta (P=0,95)

	Final temperature of gelatinization	Maximum gruel viscosity	Gelatinization time	Water absorption of flour	Dough development time	Dough stability	Softening of dough	Quality number	Flour colour		Pasta colour		Breaking force	Cooking index	Cooking lost
									L*	b*	L*	b*			
Test weight				0.59						-0.47	-0.47	-0.64			
Virtuosity of grain		0.47								-0.48		-0.57			
Uniformity of grain															0.58
Particle size index				-0.55			-0.49								
Reduction flour extraction	0.54		0.54		0.53	0.53		0.50		-0.62		-0.56		-0.47	
Total flour extraction	0.57		0.58							-0.48					
Middlings extraction	0.51		0.50							-0.69		-0.67			
Middlings reduction				-0.69						0.53		0.60			
Protein in flour															-0.49
Protein in grain										0.53					-0.56
Wet gluten															-0.59
Deliquescence of wet gluten	0.50		0.50				0.71								
Zeleny test				-0.47		0.47	-0.75	0.52							
SDS test		0.51		-0.56	0.61	0.61	-0.81	0.66		0.47					
Falling number	0.49	0.91	0.50		0.50	0.59	-0.57	0.57					0.50		
Starch															0.54
Starch damage				0.49					-0.60	-0.61		-0.62			0.48
Carotenoids pigments	-0.46			-0.51						0.85		0.78			

Correlation coefficient values within the range of 0.50–0.58 were found for total flour extraction and middlings extraction and final temperature and time of gelatinization. Reduction flour extraction was also correlated with farinographic parameters (dough development time and stability-0.53 and the quality number 0.50). In addition, middlings extraction was correlated with flour water absorption (-0.69). Numerous correlations between milling parameters and the flour and pasta colour were demonstrated by the values of the correlation coefficient revealing a broad range from -0.69 (factor b* for flour and middlings extraction) to 0.60 (factor b* for pasta and middlings reduction).

The most significant correlations were noted for farinographic parameters and sedimentation tests (Zeleny, SDS) and the falling number. The values of the correlation coefficient ranged widely from 0.47 (correlation between the dough stability and Zeleny's test) to -0.81 (correlation between SDS test and softening of dough). Correlation of amylographic features with discussed quality parameters was significantly lower, however, for the falling number and maximum viscosity the highest value of correlation coefficient (0.91) was recorded. The degree of starch granules damage and carotenoid pigments content were correlated with the flour water absorption (0.48, -0.51) and b* colour factor for the flour (-0.61, 0.85) and pasta (-0.62, 0.78).

Correlation between pasta culinary parameters and flour and grain characteristics was low and visible mainly for dry weight loss during cooking. This feature correlated with the grain uniformity (0.58), protein content in grain and flour (-0.49, -0.56) and wet gluten yield (-0.59). Values of this parameter were also correlated with the starch content (0.54) and the degree of starch granule damage (0.48).

Conclusions

1. The tested lines and strains of Polish winter durum wheat showed variation in the studied parameters.
2. The best physical parameters were observed for the grain from the lines 177–24–5 (highest weight of 1000 kernels, grain bulk density, vitreousity, and uniformity). Moreover, the strain 213-R-5 stood out in terms of weight of 1 000 kernels and uniformity. The line 177–2R-5 was characterized by high total flour extraction, reduction flour extraction and middlings extraction as well as low breaking flour extraction.
3. The analyzed material contained low amount of protein and the degree of starch damage was high. In terms of quality the best results were achieved for the flour 269-R-4 (the highest protein content, wet gluten yield and deliquescence, high carotenoid pigments content, low degree of starch granules damage). The line 177–24–5 was characterized by the highest values of Zeleny and SDS sedimentation test, falling number, the highest starch content and the lowest amylolytic activity.
4. The best farinographic properties were recorded for the dough made from flour of the 177–24–5 line. This line was marked by the longest development time and dough stability, the highest quality number and the lowest softening, while demonstrating one of the lowest flour water absorption values, which is advantageous from the pasta industry viewpoint.
5. The pasta with the best technological and culinary parameters was obtained from the wheat 264-R-6 and 269-R-4. The line 264-R-6 showed higher than average bending

strength, favourable value of weight gain coefficient and the minimum cooking time. The most advantageous cooking parameters were found in pasta from 269-R-4 flour.

6. Lines 177–24–5 and 269-R-4 exhibited the most favourable values of the analyzed features. These lines may serve as a valuable genetic source material for breeding of high-quality durum wheat varieties.

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References

Abdel- Aal E-S. M., Hucl P., Sosulski F. W., Bhirud P. R., 1997. Kernel, Milling and Baking Properties of Spring-Type Spelt and Einkorn Wheats. J. Cereal Sci. 26, 363–370.

American Association of Cereal Chemists, 2000. Approved Methods of the AACC. 10th Ed. Methods 14–50, 76–60, 80–60. The Association: St. Paul, MN.

Axford D.W.E., Mc Dermott E.E., Redman D.G., 1979. Note of the Sodium Dodecyl Sulfate Test of Breadmaking Quality: Comparsion with Polshenke and Zeleny Tests. Cereal Chem., 56 (6), 582–584.

Beke B, Matuz J., Cseuz L., 2000. Results of durum wheat (*Triticum turgidum L. var. durum*) breeding in Szeged. Hungary. Options Méditerranéennes. Serie A: Séminaires Méditerranéennes Numéro 40. Durum wheat improvement in the Mediterranean region: New challenges, 493–495.

Bojarczuk J., 2006. Genetyczno-metodyczne badania nad podstawami hodowli odmian pszenicy twardej ozimej w warunkach klimatycznych Polski, Wrocław

Cacak-Pietrzak G., 2008. Wykorzystanie pszenicy w różnych gałęziach przemysłu spożywczego- wymagania technologiczne. Przegl. Zboż.-Młyn., 11, 11–13.

Ceglińska A., Cacak-Pietrzak G., Romanowski H., Nita Z., 2004. Wartość technologiczna polskiej pszenicy twardej (*Triticum durum*). Przeg. Zboż.-Młyn., 8, 4–7.

Cseuz L., Matuz J., Beke B., 2000. Annual effect on grain quality of winter durum wheat (*Triticum turgidum L. var. durum*) in Szeged, Hungary. Options Méditerranéennes. Serie A : Séminaires Méditerranéennes Numéro 40. Durum wheat improvement in the Mediterranean region: New challenges, 133–135.

Czubaszek A., Subda H., Kowalska M., Korczak B., Żmijewski M., Karolini-Skaradzińska Z. 2001.Ocena chemiczna i biochemiczna mąki wybranychodmian pszenicy ozimej. Żywność: Nauka, Technologia, Jakość, 1(26) 76–83

Dexter J.E., Matsuo R.E., 1980. Relationship between durum wheat protein properties and pasta dough rheology and spaghetti quality. J. Agric. Food Chem. 28:899–902.

Dziki D., Laskowski J., Ziegler A., 2003. Wpływ wybranych czynników na cechy kulinarne makaronu. Żywność: Nauka, Technologia, Jakość: 2(35), 125–134.

Gallegos-Infante J.A., Rocha-Guzman N.E, Gonzalez-Laredo R.F., Ochoa-Martínez L.A., Corzo N., Bello-Perez L.A., Medina-Torres L., Peralta-Alvarez L.E., 2010. Quality of spaghetti pasta containing Mexican common bean flour (*Phaseolus vulgaris L.*).Food Chem. 119, 1544–1549.

Gąsiorowski H., Obuchowski W., 1978. Pszenica makaronowa durum. Postępy Nauk Rolniczych: 1/166, 35–52.

Gąsiorowski H., Kołodziejczyk P., Obuchowski W., 1999. Twardość ziarna pszenicy. Przegl. Zboż.--Młyn. 7, 6–8.
Jakubczyk T., Haber T., 1983. Analiza zbóż i przetworów zbożowych. Zakład Graficzny Politechniki Warszawskiej, Warszawa.
Jurga R., 2002. Przemiał ziarna pszenicy. Część 19. Zasady przemiału. Przegl. Zboż.-Młyn., 8, 39–40.
Jurga R., 2004. Produkcja pszenicy durum i jej jakość w Unii Europejskiej. Przegl. Zboż.-Młyn., 4,34–35.
Jurga R., 2007. Pszenica i semolina durum najlepszymi surowcami do produkcji makaronu. Przegl. Zboż.-Młyn., 5, 34–36.
Jurga R., 2010. Produkcja, podaż i popyt na ziarno pszenicy oraz jej jakość ze zbiorów 2009 roku w USA. Przegl. Zboż.-Młyn., 3, 32–33.
Karolini-Skaradzińska Z., Subda H., Korczak B., Kowalska M., Żmijewski M., Czubaszek A., 2001. Ocena technologiczna ziarna i mąki wybranych odmian pszenicy ozimej. Żywność. Nauka. Technologia. Jakość, 2 (27), 68–77.
Landi A., 2000. Durum wheat, semolina and pasta quality characteristics for an Italian food company. Options Méditerranéennes. Serie A : Séminaires Méditerranéennes Numéro 40. Durum wheat improvement in the Mediterranean region: New challenges, 33–42.
Makowska A., Obuchowski W., Sulewska H., Koziara W., Paschke H., 2008. Effect of nitrogen fertilization of durum wheat varieties on some characteristics important for pasta production. Acta Sci. Pol., 7(1), 29–39.
Mazurek J., Ruszkowski M., 1965. Badania nad pszenicą twardą (*Triticum durum* Desf.) . Pam. Puł., 19, 99–121.
Obuchowski W., 1997. Technologia przemysłowej produkcji makaronu. Wydawnictwo Akademii Rolniczej, Poznań.
Obuchowski W., Makowska A., Łuczak M., Sulewska H., 2007. Agrotechniczne i logistyczne aspekty uprawy pszenicy durum w Polsce. Przegl. Zboż.-Młyn., 10, 33–34.
PN-77/A-74041. Ziarno zbóż i przetwory zbożowe. Oznaczenie ilości i jakości glutenu.
PN-75/A-04018, 1975. Produkty rolniczo-żywnościowe – Oznaczanie azotu metodą Kjeldahla i przeliczanie na białko.
PN-EN 15585, 2008. Ziarno zbóż i przetwory zbożowe – Pszenica durum (*T. durum* Desf.) – Oznaczanie procentowego udziału ziaren, które utraciły szklistość i obliczanie procentowego udziału ziaren szklistych
PN-ISO 2171, 1994. Ziarno zbóż i przetwory zbożowe. Oznaczenie popiołu całkowitego.
PN-ISO 3093, 2007. Pszenica, żyto i mąki z nich uzyskane, pszenica durum i semolina – Oznaczanie liczby opadania metodą Hagberga-Pertena.
PN-ISO 5529, 1998. Pszenica. Oznaczenie wskaźnika sedymentacyjnego. Test Zeleny'ego.
PN-ISO 5530–1, 1999. Mąka pszenna. Fizyczne właściwości ciasta. Oznaczenie wodochłonności i właściwości reologicznych za pomocą farinografu.
PN- ISO 7971–2, 1998. Ziarno zbóż – Oznaczanie gęstości w stanie zsypnym, zwanej "masą hektolitra" – Metoda rutynowa.
PN-ISO 7973, 2001. Ziarno zbóż i przetwory zbożowe. Oznaczanie lepkości mąki. Metoda z zastosowaniem amylografu.
Rachoń L., 2001. Studia nad plonowaniem i jakością pszenicy twardej (*Triticum durum* desf.).Wydawnictwo Akademii Rolniczej w Lublinie. Lublin.
Rachoń L., Dziamba Sz., Obuchowski W., Kołodziejczyk P., 2002. Ocena przydatności ziarna odmian pszenicy twardej (Triticum durum) i zwyczajnej (*Triticum aestivum ssp. vulgare*) do produkcji makaronu. Annales UMCS Lublin . Polonia. Sectio E, 57, 77–86.
Rachoń L., 1999. Plonowanie i jakość pszenicy twardej (*Triticum durum* desf.). Pam. Puł., 118, 349–355.

Rachoń L., 2004. Ocena przydatności ziarna krajowych i zagranicznych linii i odmian jarej pszenicy twardej (*Triticum durum* Desf.) do produkcji makaronu. Biuletyn IHAR, 231, 129–137.
Rachoń L., Szumiło G., 2002. Plonowanie i jakość niektórych polskich i zagranicznych odmian i linii pszenicy twardej (*Triticum durum* desf.*)*. Pam. Puł., 130, 619–624.
Rachoń L., Szumiło G., 2009. Yield of winter durum wheat (*Triticum durum* desf.*),* lines in condition of different protection level of plants. Acta Sci. Pol. Agric., 8(3), 15–22.
Rharrabti Y., Villegas D., Royo C, Aparicio N., Garcia del Moral L.F., 2003a. Durum wheat quality in Mediterranean environments I. Quality expression under different zones, latitudes and water regimes across Spain. Field Crops R, 80, 123–131.
Rharrabti Y., Royo C., Villegas D., Garcia del Moral L.F., 2003b. Durum wheat quality in Mediterranean environments II. Influence of climatic variables and relationships between quality parameters. Field Crops Research, 80, 133–140.
Santra M., Rao V.S., Tamhankar S.A., 2003. Modification of AACC Procedure for Measuring ß-Carotene in Early Generation Durum Wheat. Cereal Chemistry, 2, 130–131.
Santra M., Santra D. K., Rao V. S., Taware S. P. ,Tamhankar S. A., 2005. Inheritance of β-carotene concentration in durum wheat (*Triticum turgidum* L. ssp. *durum*). Euphytica, 144, 215–221.
Segit Z., Szwed-Urbaś K., 2006. Ocena cech jakościowych ziarna wybranych linii pszenicy twardej. Biuletyn IHAR, 240/41, 75–82.
Segit Z., Szwed-Urbaś K., 2008. Zróżnicowanie genetyczne cech użytkowych pszenicy twardej. Biuletyn IHAR, 250, 117–124.
Subda H., Jarosławska A., Unton A., Karolini-Skaradzińska Z., 2002. Ocena wpływu wybranych cech chemicznych pszenicy ozimej na jakość ciasta i chleba. Biuletyn IHAR, 232/243, 111–119.
Sulewska H., Koziara W., Bojarczuk J., 2007. Kształtowanie plonu i jakości ziarna wybranych genotypów *Triticum durum* Desf. w zależności od nawożenia azotem i gęstości siewu. Biuletyn IHAR, 245, 17–28.
Szwed-Urbaś K., Grundas S., Segit Z., 1996. Wartość ważniejszych cech technologicznych pszenicy twardej. Biuletyn IHAR, 200, 299–305.
Szwed-Urbaś K., Segit Z., Mazurek H., 1997. Parametry jakościowe ziarna krajowych linii pszenicy twardej. Biuletyn IHAR, 204, 129–139.
Troccoli A., Borrelli G.M., De Vita P., Fares C., Di Fanzo N., 2000. Durum Wheat Quality: A Multidisciplinary Concept. J. Cereal Sci., 32, 99–113.
Woźniak A., 2005. Wpływ przedplonów na plon i jakość technologiczną ziarna pszenicy twardej (*Triticum durum* Desf.). Annales UMCS Lublin . Polonia. Sectio E, 60, 103–110.
Vignaux N., Doehlert D.C., Elias E. M., McMullen M.S., Grant L. A., Kianian S. F., 2005. Quality of Spaghetti Made from Full and Partial Waxy Durum Wheat. Cereal Chem., 82 (1), 93–100.
Zawadzki K., 2008. Niepokojąca sytuacja na rynku pszenicy durum. Przegl. Zboż.-Młyn. 10, 12.
Zych J., 2009. Wartość technologiczna odmian pszenicy. Przeg. Zboż.-Młyn. 8, 2–8.
Żmijewski M., Subda H., Kowalska M., Korczak B., Czubaszek A., Karolini-Skaradziński Z., 1999. Skład chemiczny i wartość wypiekowa ziarna oraz mąki odmian pszenicy jarej. Część II. Wartość wypiekowa. Biuletyn IHAR, 212, 71–77.

4

PHYSICAL CHARACTERISTICS OF EGGS PRODUCED BY ORGANIC METHODS

Introduction

Organic farming is unquestionably one of the most rapidly developing sectors of agricultural production in recent years, becoming increasingly popular both in Europe and in other parts of the world. The main reason is the growing demand from consumers, who are looking for safer and more controlled food products while showing concern for a wholesome environment, and thus for a health-promoting lifestyle [Hirt 2002, Koreleska 2006]. Organic farming is defined as an alternative farming system to conventional agriculture which aims to improve the quality and healthiness of food products and other farm produce, is ecologically balanced, and limits human interference in the farm ecosystem, thus inhibiting the degradation of the agricultural habitat. In wealthy European countries, this farming system began to develop intensively in the 1980s. The rapidly developing organic food and farming system in Europe already focused the attention of public offices in the mid-1980s. The higher prices and assurances of the many benefits of organic farming led the European Commission to consider what type of control is needed to ensure consumer protection and what rewards these benefits deserve [Kowalkowska, Falkowska 2008].

For the first time in the world, organic food production and organic cultivation became subject to legal definition and control in January 1993, when Council Regulation (EEC) No 2092/91 of 24 June 1991 *onorganic production of agricultural products and indications referring thereto on agricultural products and foodstuffs* came into force. These regulations were in force for eighteen years, during which period they were amended more than 40 times (most recently in the autumn of 2008), thus becoming inconsistent and burdensome. There was a need to simplify, improve, streamline and update the old legislation. In addition, it was important to create a legal framework to maximize the potential of organic food and farming as a key element in the EU agricultural and rural development policy, thus enabling this sector to grow and develop in the future [Mikkelsen, Schlűter 2009].

The next significant developments for the organic production sector took place on 1 January 2009, when the following regulations came into force:

a) Council Regulation (EC) No 834/2007 of 28 June 2007 *on organic production and labelling of organic products*(OJ L of 189/1 of 20.07.2007), repealing Regulation (EEC) No 2092/91
b) Commission Regulation (EC) No 889/2008 of 5 September 2008 *laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control*(OJ L of 250/1 of 18.09.2008).

This set a new legal framework for the organic farming sector in the EU. The regulations mentioned above were amended over the years and will continue to be amended in different aspects for the purpose of maintaining high standards in organic farming [Metera, Sakowski 2008].

In Poland, these regulations were enforced by the Law on Organic Farming of 25 June 2009 (Journal of Laws No 116, item 975) and the Regulation of the Minister of Agriculture and Rural Development concerning some conditions of organic production of 18 March 2010 (Journal of Laws No 56, item 348).

In line with expectations of organic farmers, rearing of poultry, including laying hens, is based on respect for high bird welfare standards. Detailed requirements in this area are laid down in the regulations cited above, such as Council Regulation No 834/2007, Commission Regulation (EC) No 889/2008, Law on Organic Farming of 25 June 2009, and Regulation of the Minister of Agriculture and Rural Development concerning some conditions of organic production of 18 March 2010.

When choosing layer breeds or hybrids for organic production, account should be taken of their adaptability to local environmental conditions, vitality and resistance to disease. These traits are inherent to conservation breeds of birds characterized by multicoloured feathers, such as Greenleg Partridge (Z-11), Yellowleg Partridge (Ż-33), Rhode Island Red (R-11 and K-22) and Polbar (Pb), ermine feathers such as Sussex (S-66), or white feathers such as Rhode Island White (A-33) and Leghorns (G-99 and H-22).

Of the commercial hybrids of laying hens, birds intended for semi-intensive egg production (in particular, domestic commercial lines such as Rosa 1, Rosa 3, Rosa 4, Rosa 5, Messa 443 and Experimental Astra) are suited for this type of rearing. Use can also be made of foreign Dominant stock (Sussex D-104, Blue D-107, Black D-109, Black D-149, Brown D-192, Amber D-843, Barred D-959 and Partridge D-300).

Because most eggs from organically raised laying hens are marketed to individual consumers, it is not recommended to use white-feathered hens that lay white-shelled eggs. Such eggs are least desired by consumers. Differences in egg shell colour depending on origin of hens are shown in Figure 1.

Fig. 1. Differences in egg shell colour according to hen's origin (nos. 1 to 4) and differences in size of eggs from Rhode Island Red hens (R-11) reared under organic (no. 3) and conventional conditions (no. 5)

When choosing the type of chickens for organic production, it is also necessary to account for their basic performance parameters, which show considerable differences. In conventional free-range farming during 44 weeks of egg production, production per housed hen averages 168–169 eggs weighing 52–58 g for Greenleg Partridge (Z-11) and Yellowleg Partridge (Ż-33), and 183–186 eggs weighing 53–60 g for Rhode Island Red (R-11) and Sussex (S-66) [Calik 2009]. For multipurpose hybrid chickens, about 250–300 eggs weighing 60–65 g are to be expected [Lewko, Gornowicz 2010]. Values exceeding the above performance parameters of hens are achieved with a very well balanced feed mixture whose nutritive value meets the living and production requirements of the layers, especially in terms of the quantity and quality of protein, including the content of essential amino acids lysine, methionine, cystine, tryptophan and threonine [Smulikowska and Rutkowski 2005]. When feeding layers in accordance with organic farming requirements, which in this case are rather restrictive, it is very difficult to prepare a feed mixture containing 15–17% crude protein and appropriate amounts of the amino acids referred to above. This is one of the reasons why almost 30% lower egg production and 5% lower egg weight are to be expected in organic layer farming compared to conventional farming [Koreleski, Herbut 2004, Pomykała 2009].

The research objective of the study carried out at the National Research Institute of Animal Production in 2010 was to evaluate the physical characteristics of eggs from four conservation breeds of laying hens: Sussex (S-66), Rhode Island Red (R-11), Yellowleg Partridge (Ż-33) and Greenleg Partridge (Z-11), reared under organic conditions. The principles of organic livestock production were followed when selecting birds, taking into account their adaptability to local conditions, viability and resistance to disease; four breeds were chosen to promote large biological diversity (Commission Regulation (EC) No 889/2008 of 5 September 2008).

Materials and Methods

Birds were kept at the Jaworze Organic Farm belonging to the Grodziec Śląski Experimental Station of the National Research Institute of Animal Production. Each year since 2007, the farm has received a certificate of conformity of the agricultural production with organic farming principles, based on inspections by the certification body (Centre of Quality AgroEko Ltd.).

A total of 400 hens were assigned to four experimental groups with 100 birds per group. Each group was kept on chopped straw bedding in a separate container (3m x 4m x 10m). Birds had free access to the outside run, part of which was roofed to protect them from adverse atmospheric conditions such as excessive solar radiation or rain. The outside run was a 2 ha pasture characterized by high biodiversity.

At the end of the rearing period when hens were 19 weeks old, because of the need to provide adequate living conditions, birds were moved in the autumn-winter period into a brick building with access to free range, in which a certain amount of manure was stored. The division of birds into four experimental groups according to conservation breed was maintained.

The facilities in which chickens were housed in the spring-summer period (containers), and in the autumn-winter period (brick building) were equipped with appropriate perches and nests, the number of which conformed with Commission Regulation (EC) No 889/2008 of

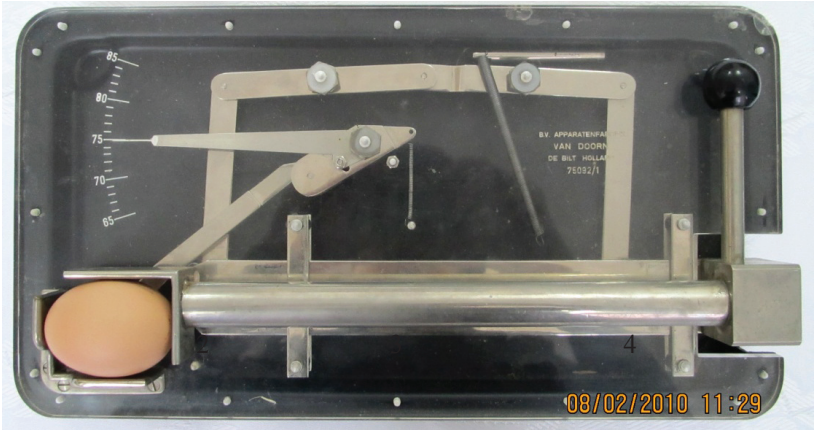
5 September 2008, Annex III p.2. This document lays down the minimum perch area per layer to be 18 cm long, with one nest for a maximum of seven layers.

Birds received feeds whose nutritive value was suitable for a given growth period and which were composed of agricultural ingredients from organic farming and of natural non-agricultural substances. The feeds contained no genetically modified organisms (GMOs) and products produced from or by GMOs.

Feeding was based on organic feeds produced at the Jaworze farm as well as purchased wheat, minerals and limestone grit for hens. Feed was prepared in the Jaworze organic farm, which has its own organic feed mixing plant. Chickens were provided with constant access to feed and water.

At 26 weeks of age, out of all eggs laid, 20 eggs per group were collected every morning. The collected eggs were transported to a laboratory. Egg quality analysis at the laboratory (National Research Institute of Animal Production, Department of Animal Genetic Resources Conservation, Zakrzewo, Poznańska 18, 62–070 Dopiewo) was performed immediately on delivery from the farm. It is estimated that the number of days between egg laying and quality analysis never exceeded 7 days.

Physical characteristics of the eggs were determined using a model EQM egg quality management system (Technical Services and Supplies Limited, UK), and the following parameters were evaluated: weight of egg and its fractions (g), height of thick albumen (mm), Haugh units (HU), yolk colour (Roche scale), shell colour (% light reflectance) and shell density (mg/cm^2). Air space height was measured using a handheld egg candling lamp (ovolux) and a specialist millimeter-scale ruler. Egg shape was determined with percentage shape index (ratio of egg width to egg length). Measurements were made accurate to 0.5% with a shape index instrument (B.V. Apparatenfabreik Van Doorn, De Bilt, Holland), scaled from 65 to 85% (Fig. 2). Egg shell deformation was measured with a deformation apparatus (Marius N.V., Utrecht, Holland), accurate to 1 µm. Shell thickness without inner and outer shell membranes was measured with a micrometer (1 µm, Mitutoyo, Japan). A Mettler Toledo pH meter (Switzerland) was used to determine the concentration of albumen and yolk hydrogen ions (pH) (Fig. 3).



1 4 5

Fig. 2. Measurement of egg shape index

Fig. 3. Measurement of the hydrogen ion concentration in egg albumen and yolk

The egg quality traits in the experimental populations of birds were analysed statistically by analysis of variance (means, standard deviation and coefficient of variation), and Duncan's test was used to determine significance of differences ($p \leq 0.05$) between them. Statistica 6.0 package was used.

Results and Discussion

Egg weight is the main physical characteristic of hen eggs perceived by the potential buyer. It is also the principal quality attribute included in egg marketing regulations and dividing eggs into four weight grades (Commission Regulation (EC) 589/2008). For these reasons, egg weight is the primary selection trait in layer breeding and one of the major traits in multipurpose hen breeding.

In the experiment (Tables 1 and 2), heaviest eggs were laid by S-66 hens (48.37 g) and this value was significantly ($p \leq 0.05$) higher compared to the weight of eggs from Z-11 hens (45.41 g). Mean egg weight (47.07 g) was comparable to the weight of eggs obtained from the analysed conservation breeds raised under the conventional system. When compared to consumable eggs produced under standard conditions, this weight is lower by 25%. According to the Commission Regulation (EC) 589/2008 mentioned above, organic eggs shall be graded as small (S), weighing less than 53 g.

Egg shape is crucial for egg breaking strength during marketing, packing into package sets, and further distribution. The mean egg shape index ranged from 75.35% (Z-11) to 77.60% (S-66) for the conventional system, and was 76.75% for the organic population. Consumable eggs from the conventional system were less oval with a 0.99% lower shape index.

When comparing the weight of individual components of eggs from the four conservation breeds, it is worth noting the lack of significant differences between yolk weights. The difference between the mean value of these and the weight of yolk from standard consum-

able eggs was 3.57 g in favour of eggs from the conventional system. However, organic eggs had a higher shell weight by 0.65 g. Particularly notable among these were the shells of eggs from R-11 and S-66 hens, which weighed 5.78 g and 5.88 g, respectively, with a significant ($p \leq 0.05$) difference in relation to group Z-11 (5.41 g).

Table 1

Physical characteristics of eggs from four conservation breeds of organically raised hens

Parameter	N	Greenleg Partridge Z-11	Yellowleg Partridge Ż-33	Rhode Island Red R-11	Sussex S-66
Egg weight [g]	20	45.41^{b}±3.43	46.67^{ab} ±2.42	47.85^{a}±4.34	48.37^{a}±4.34
Egg shape index [%]	20	75.35^{b}±2.98	76.95^{ab}±2.82	77.11^{a}±3.30	77.60^{a}±1.57
Air space height [mm]	20	2.15± 0.37	2.10±0.31	2.21±0.42	2.15±0.37
Egg albumen weight [g]	20	26.66^{c} ±2.31	27.28^{bc} ±2.19	28.62^{ab} ±2.86	29.42^{a}±3.26
Egg yolk weight [g]	20	12.94±1.31	13.07±0.73	12.70±1.57	12.56±1.14
Egg shell weight [g]	20	5.41^{b}±0.44	5.64^{ab}±0.53	5.78^{a}±0.60	5.88^{a}±0.63

Note:, ^{ab} – different letters in rows denote a statistically significant difference at $p \leq 0.05$

Table 2

Comparison of physical characteristics of eggs from organically raised hens and of consumable eggs from conventionally raised hens*

Parameter	N	Organically raised hens	N	Conventionally raised hens
Egg weight [g]	80	47.07±3.71	50	61.98±4.35
Egg shape index [%]	80	76.75±2.74	50	75.76±3.72
Air space height [mm]	80	2.15±0.37	50	6.81±9.49
Egg albumen weight [g]	80	28.00±2.69	50	37.59±3.37
Egg yolk weight [g]	80	12.82±1.22	50	16.39±1.54
Egg shell weight [g]	80	5.68±0.55	50	5.03±0.47

Note: * – own study (2007), means for five breeding lines: Lohmann Brown Classic, HY-Line Brown, ISA Brown, Astra S and Dominant

Above al. the physical composition of eggs (Tab. 3) showed no differences in shell percentage in eggs from hens of the four conservation breeds. Percentage of yolk (by 0.85%) and shell (by 3.9%) was higher for organic eggs compared to eggs from the conventional system.

Table 3

Basic physical composition of eggs from the experimental organic system

Parameter	N	Greenleg Partridge Z-11	Yellowleg Partridge Ż-33	Rhode Island Red R-11	Sussex S-66
Percentage egg albumen	20	58.70^{b}±1.93	58.42^{b}±2.81	59.81^{ab}±2.50	60.74^{a}±2.66
Percentage egg yolk	20	28.47^{a}±1.49	28.04^{a}±1.58	26.54^{b}±2.05	26.02^{b}±1.79
Percentage egg shell	20	11.94±0.87	12.09±1.08	12.09±0.87	12.17±0.90

For explanations, see Table 1

The main quality characteristic of consumable eggs is freshness, which is determined, among others, from air cell size, albumen thinning expressed as albumen height and Haugh units, and pH value. Of these traits, air cell size is the easiest to evaluate quickly. For this reason, this trait has for many years been the main criterion of egg freshness in the market. Also today, according to many international standards and the EU regulations in force in Poland concerning egg marketing standards, air space height is the parameter used to divide eggs into different quality classes. Class A eggs have an air space height of less than 6 mm; however, for eggs to be marketed as "extra", it may not exceed 4 mm (Commission Regulation (EC) No 589/2008).

From the moment an egg is laid, as a result of biophysical and chemical changes known as egg aging, the shell loses its natural protective capacity while water and gases move both within the egg and between the internal and external environment of the egg. The water evaporation of eggs is determined by physiological factors such as shell permeability, shell pore diameter, and the rate at which mucin covering dries and cracks. It was also found that water evaporation is quicker in small eggs with high surface to volume ratios [Calik et al. 2003].

By design, fresh eggs were analysed in the present experiment. The evaluation was performed within 7 days of egg laying. It was assumed that changes in the above parameters associated with the movement of water and gases within the egg were determined by environmental factors related to the avian production system. Based on the results obtained for air space height (2.10 to 2.21 mm), all analysed eggs were graded as class A "extra".

As noted above, the next important characteristics indicative of egg freshness (egg quality) are albumen parameters. The better the albumen quality, the greater its height and the smaller its area after breaking open the egg. Haugh units are calculated based on egg weight and height of thick albumen. Values above 60 Haugh units are considered desirable. For the highest quality egg albumen, Haugh units range from 79 to 100 [Haugh 1937]. Values obtained for this parameter in our study (Tab. 4) were very high, in excess of 90 units, ranging from 91.83 (Z-11) to 97.40 (R-11). The latter value was significantly ($p \leq 0.05$) higher compared to the other values. The albumen of eggs from organically raised hens met the high value expected of this parameter (93.55 on average).

Albumen pH value was high and similar for organically raised hens of the same breed, ranging from 9.01 (S-66) to 9.94 (Z-11).

The high concentration of hydrogen ions found in albumen in our study and confirmed by other authors [Scott, Silversides 2000, Silversides, Scott 2001, Silversides, Budgell 2004] may favour the growth of microorganisms in case they penetrate the egg. Of crucial importance, therefore, is the quality of eggshell, which protects the egg content.

The yolks of eggs from all experimental groups (Tab. 4 and 5) had intensive colour (from 12.00 to 12.55 Roche scale points). Significantly ($p \leq 0.05$) better results in this respect were obtained for eggs from Ż-33 hens. Poorer yolk colour intensity (by about 3.0 points) was observed for the eggs from conventionally raised layers which were unable to use the free range and its varied vegetation. It should be noted that the organic feed given to the experimental hens had no synthetic colouring agents, which means that layers from this group owed the good and natural yolk colour intensity to xanthophylls ingested from free-range plants. Literature suggests that free-range layers additionally consume about 30–35 g dry matter in the form of grasses and herbs. Yolk colour intensity depends on the botanical composition and growth phase of the plants, in particular the xanthophyll content of the green material obtained [Zielińska 1965, Nys 2000].

Table 4

Physical characteristics of albumen and yolk of eggs from four breeds of organically raised hens

Parameter	N	Greenleg Partridge Z-11	Yellowleg Partridge Ż-33	Rhode Island Red R-11	Sussex S-66
Albumen height [mm]	20	7.74 ^{b}±1.12	7.80 ^{b}±1.10	9.03 ^{a}±1.47	8.14 ^{b}±1.22
Haugh units	20	91.83 ^{b}±6.75	91.85 ^{b}±5.48	97.40 ^{a}±6.71	93.11 ^{b}±5.48
Albumen pH	20	9.04±0.16	9.03±0.08	9.02±0.07	9.01±0.07
Yolk colour, Roche scale	20	12.35 ^{ab}5±0.67	12.55 ^{a}5±0.76	12.00 ^{b}5±1.15	12.00 ^{b}5±0.79
Yolk pH	20	6.28 ^{b}5±0.02	6.28 ^{b}5±0.02	6.34 ^{a}5±0.06	6.32 ^{a}5±0.09

For explanations, see Table 1

Table 5

Comparison of quality characteristics of yolks of eggs from organically raised hens and of consumable eggs from conventionally raised hens*

Parameter	N	Organically raised hens	N	Conventionally raised hens
Yolk colour, Roche scale	80	12.235±0.86	50	9.265±0.54
Yolk pH	80	6.31±0.06	50	6.78±0.10

For explanations, see Table 1

The shells of eggs from all experimental groups (Tab. 6) had light brown colour desired by the individual consumer. In the experimental groups of hens, shell colour values ranged from 38.05 (S-66) to 57.50 (Z-11), with statistically significant differences ($p \leq 0.05$). Our results support the hypothesis of Scholtyssek [1988] that egg shell colour is most correlated to hen genotype, a fact accounted for when developing commercial lines of laying hens.

Table 6

Physical characteristics of shells of eggs from organically raised hens

Parameter	N	Greenleg Partridge Z-11	Yellowleg Partridge Ż-33	Rhode Island Red R-11	Sussex S-66
Shell colour [pts]	20	57.60 ^{a}±5.73	44.25 ^{b}±5.36	41.95 ^{b}±4.16	38.05 ^{c}±3.35
Shell density [mg/cm^2]	20	89.58±6.03	91.62±8.06	92.35±6.86	93.25±7.12
Shell deformation* [µm]	20	21.53±4.66	21.05±3.98	21.16±3.90	20.65±3.90
Shell thickness*, [µm]	20	339.70±23.99	341.40±26.13	350.70±30.31	355.47±30.31

For explanations, see Table 1, * – arithmetic mean for measurements at three locations

It is well known that the other shell quality traits are determined by both genotype and non-genetic factors that include layer age and nutrition, in particular the amount, form and availability of calcium.

The shells of eggs from organically raised hens were characterized by greater density (by 23.74 mg/cm^2) and thickness (by 24.84 µm) and smaller deformation (by 7.98 µm) in relation to the eggs from commercial lines of layers from the conventional system. The present shell quality tests thus indicate that organically raised layers produced eggs having thick

and dense shells with low breaking strength. A similar tendency for poorer shell strength in eggs from free-range hens was reported by Krawczyk et al. [2005], Mertens et al. [2006] and Krawczyk and Gornowicz [2010]. However, the small differences found for the shell traits of eggs from different experimental groups of organically raised hens were not significant.

The differences in the physical characteristics of eggs obtained using conventional and organic methods are presented in Figure 4. The eggs of hens raised according to organic farming requirements (B) are characterized by smaller yolk with good colour intensity as well as high albumen, with a noticeable division into thick and thin albumen.

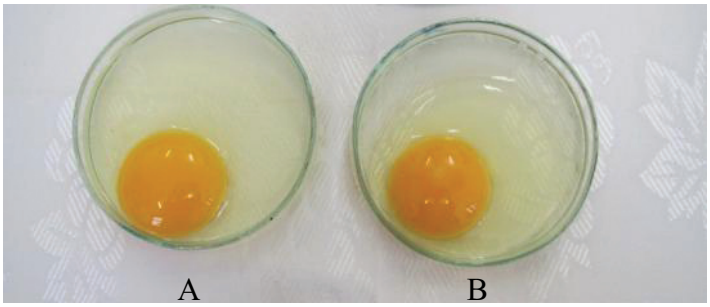


Fig. 4. Differences in physical traits of eggs from conventional (A) and organic systems (B)

Conclusions

To sum up the results of physical characteristics of eggs obtained in accordance with organic farming requirements, we may conclude that:

1. The eggs from organically raised hens are smaller and 25% lighter compared to the eggs from conventionally raised layers.
2. The shells of eggs from organically raised hens are thick and dense.
3. The albumen of eggs from organically raised hens is characterized by very high parameters desired by the consumers.
4. The yolk of eggs from organically raised hens has intensive and uniform colour, exceeding 12 units on the Roche scale.

References

Calik J., Połtowicz K., Wężyk S., 2003. Wpływ systemu utrzymania kur nieśnych oraz warunków przechowywania jaj spożywczych na ich jakość. Wyniki Oceny Użytkowości Drobiu, Zeszyt 31, Kraków, 57–62.

Calik J., 2009. Charakterystyka kur nieśnych objętych programem ochrony zasobów genetycznych w Polsce. Zesz. Nauk. Południowo-Wschodni Oddział Polskiego Towarzystwa Inżynierii Ekologicznej, PTG, Rzeszów, nr 11, 21–26.

Haugh R.R., 1937. The Haugh Unit for measuring egg quality. U.S. Egg Poultry Magazine, 43, 552–555, 572–573.

Hirt H., 2002. Organic poultry production in Switzerland. Arch. Geflügelk., t. 66, 33, 21–22;
Koreleska E., 2006. Rolnictwo ekologiczne w Polsce i innych krajach Unii Europejskiej. Zesz. Nauk. AR Wroc. Rol. LXXXVII, nr 540, 241–246.
Koreleski J., Herbut E., 2004. Produkcja jaj metodami ekologicznymi. KCRE-RCDRRiOW, Radom, 29.
Kowalkowska B., Falkowska A., 2008. ABC rolnictwa ekologicznego – przewodnik. WSŚ, Bydgoszcz, 56.
Krawczyk J., Wężyk S., Połtowicz K., Cywa-Benko K., Calik J., Fijał J., 2005. Wpływ utrzymania kur rodzimych ras na zielonych wybiegach na jakość jaj w początkowym okresie nieśności. Rocz. Nauk. Zoot., T. 32., z.1, 129–140.
Krawczyk J., Gornowicz E., 2010. Quality of eggs from hens kept in two different free-range systems in comparison with a barn system. Arch. Geflügelk. 74 (3), 151–157.
Lewko L., Gornowicz E., 2010. Wyniki badań jakości jaj wybranych krajowych rodów hodowlanych kur nieśnych. Wyniki oceny wartości użytkowej drobiu w 2009 roku, Warszawa, 99–111.
Mertens K., Bamelis F., Kemps B., Kamers B., Verhoelst, De Ketelaere B., Bain M., Decuypere E., De Baerdemaeker J., 2006. Monitoring of eggshell breakage and eggshell strength in different production chains of consumption eggs. Poult. Sci., 85 (9), 1670–1677.
Metera D., Sakowski T., 2008. Podręcznik rolnictwa ekologicznego. CDR w Brwinowie, Radom, 258.
Mikkelsen C., Schlűter M., 2009. Nowe rozporządzenie UE w sprawie żywności ekologicznej i rolnictwa: (WE) nr 834/2007 – kontekst, ocena, interpretacja. IFOAM EU Group, Bruksela, 65.
Nys Y., 2000. Dietary carotenoids and egg yolk coloration – a review.Arch. Geflügelk., 2000, 64 (2), 45–54.
Pomykała D., 2009. Praktyczny przewodnik ekologicznej produkcji zwierzęcej. CDR w Brwinowie, Radom, 28;
Rozporządzenie Rady (WE) nr 834/2007 z dnia 28 czerwca 2007 r. w sprawie produkcji ekologicznej i znakowania produktów ekologicznych (Dz. U. L 189 z 20.07.2007 r. s. 1).
Rozporządzenie Komisji (WE) nr 589/2008 z dnia 23 czerwca 2008 r. ustanawiające szczegółowe zasady wykonywania rozporządzenia rady (WE) nr 1234/2007 w sprawie norm handlowych w odniesieniu do jaj.
Rozporządzenie Komisji (WE) nr 889/2008 z dnia 5 września 2008 r. ustanawiające szczegółowe zasady wdrażania rozporządzenia Rady (WE) nr 834/2007 w sprawie produkcji ekologicznej i znakowania produktów ekologicznych w odniesieniu do produkcji ekologicznej, znakowania i kontroli (Dz. U. L 250/I z 18.09.2008 r., s. 1).
Rozporządzeniem Ministra Rolnictwa i Rozwoju Wsi w sprawie niektórych warunków produkcji ekologicznej z dnia 18 marca 2010 r. (Dz. U. Nr 56, poz. 348).
Ustawa o rolnictwie ekologicznym z dnia 25 czerwca 2009 r. (Dz. U. Nr 116, poz. 975).
Scholtyssek S., 1988. Futterung und innere Eiqualität. Deutsch. Geflügel und Schweine, 5, 131–135.
Scott T.A., Silversides F.G., 2000. The effect of storage and strain of hen on egg quality. Poult. Sci., 79, 1725–1729;
Silversides F.G., Scott T.A., 2001. Effect of storage and layer age on quality of eggs from two lines of hens. Poult. Sci., 80, 1240–1245.
Silversides F.G., Budgell K.L., 2004. The relationship among measures of egg albumen height, pH and whipping volume. Poult. Sci., 83, 1619–1623.
Smulikowska S., Rutkowski A. redakcja, 2005. Zalecenia żywieniowe i wartość pokarmowa pasz - normy żywienia drobiu. Wyd. IV, IFiŻZ PAN, Jabłonna, 156.
Zielińska B., 1965. Studies on the estimation of the quantity and quality of the natural food consumer by chickens on free range (in Polish). Rocz. Nauk. Rol. 86 B-4, 640–656.

5

THE EFFECT OF RESISTANT STARCH ON THE QUALITY OF WHEAT BREAD

Introduction

In the recent years there has been a significant change in general nutrition patterns, resulting from the increasingly popularized achievements of technological development, informatization and robotization, as well as the changes in people's eating habits and lifestyle [Diowksz 2006, Dziugan et al. 2006]. Civilizational transformations have led to larger consumption of highly processed foods. This in turn caused impoverishing the diet in dietary fiber, which is essential for proper functioning of the human body. A change of economic conditions has been followed by a change in views on nutrition. These days a tendency to attempt to reduce the energy content of meal. especially in developed countries, is being observed [Bartnikowska 1997, Leszczyński 2004, Mielcarz 2004a].

In the last fives decades there is a trend to find new sources of dietary fiber. Dietary fibers from different sources have been used to replace wheat flour in the preparation of bakery products [Ayadi *et al*. 2009]. In the recent years physiologists, nutritionists and technologists have been increasingly interestedin starch resistant to the hydrolytic influence of the human body's digestive enzymes. Resistant starch (RS) is thus the sum of starch and its breakdown products which are not absorbed in the small intestine of a healthy human being [Champ 1994]. Different forms of resistant starch can be distinguished. Resistant starch type 1 (RS 1) is the kind of starch found in plant cells with intact cell walls, for example in whole wheat grains. Resistant starch type 2 (RS 2) is the starch found in raw (ungelatinized) granules of some plant species, like potato or banana, and type 3 (RS 3) is retrograded starch. Resistant starch type 4 (RS 4) is chemically or physically modified starch [Englyst, Cummings 1987, Haralampu 2000]. Resistant starch has been attributed numerous health benefits. Therefore, it is regarded as a component of dietary fiber [Ohr 2004, Englyst, Hudson 1997]. The beneficial influence of resistant starch on human digesting process is revealed in better glucose tolerance (glycaemic index reduction), lowering lipids level in blood and the increase of chyme mass. Indigested resistant starch is fermented in the large intestine, as a result of which short chain fatty acids are created (acetate, propionate and butyrate). This in turn results in significantly reducing pH in the bowel, and consequently a selection of microorganisms takes place in the large intestine (thus providing its antineoplastic protection) [Leszczyński 2004, Soral-Śmietana, Wronkowska 1999]. Because of their high consumption, baked food products are potential carriers of dietary fiber. Cereal products and bread are perhaps the most important item in our daily diet [Mielcarz 2004b, 2005]. Both the nutritional value and technological properties of resistant starch are important in the potential development of a wide range of fiber-enriched

food (e.g. bakery products, snacks, sauces, drinks, cereal. biscuits, dairy products, meat products) [Ayadi et al. 2009].

The aim of the present work was to evaluate the impact of resistant starch content on the quality properties of wheat bread.

Materials and methods

Materials

The research material was wheat flour type 750 incorporated with retrograded acetylated starch (resistant starch RS 4) (a degree of substitution 0,16; moisture 10,9%, digestibility 30,03%). The starch had been obtained according to the methodology guidelines developed by the Department of Food Storage and Technology at the Wrocław University Of Environmental And Life Sciences. The starch preparations had been obtained according to the P-382126 patent application [Zięba 2007]. Potato starch had been retrograded and then acetylated. The acetylating process had been carried out analogically to the way it is done in Polish starch production plants [Mężyński 1972]. The obtained resistant starch preparations had been crumbled and sifted with a sieve with meshes of 265 μm. The content of resistant starch in the achieved flour samples was 10 and 20%. The control sample was wheat flour without the addition of resistant starch.

The bread was baked according to the method developed by the Cereal Technology Institute at the Wrocław University Of Environmental And Life Sciences, described by Karolini-Skaradzińską et al. [2001] and in patent number P-384873 [Wojciechowicz et al. 2008a] and based on the following recipe: wheat flour – 250 grams, yeasts – 7,5 grams, salt – 3,8 grams, water in amounts allowing to obtain 300 FU consistency. The single-phase method was used when preparing the dough. Blending time was 3 minutes. After that the dough was placed in a baking tin and fermented in a temperature of 30–35°C for 1 hour. After this one-hour fermentation period the dough was again kneaded and placed back in the fermentation chamber. After about 30 minutes the dough was kneaded once more and left to final fermentation. The bread was baked in the laboratory stove for 30 minutes in a temperature of about 240°C.

Methods

The bread samples have been marked with the following designations:

- volume of bread baked of 100 grams of flour measured using a loaf volumeter *Sa-Wy*;
- overbake;
- porosity of the crumb according to 8-points Dallmann scale;
- energy value by Rozental [Gawęcki, Jeszka 1986];
- total dietary fiber content [AOAC 985.29. 1997];
- starch digestibility [Digestibility of the obtained starch samples was evaluated by the amount of glucose formed after 16 h of hydrolysis with the mixture of pancreatic alpha-amylase and glucoamylase];
- sensory evaluation, using a 9-point verbal hedonic scale [Świderski 1999], where 9 points shall be given to a sample of the most desirable features, and 1 point to sample, which features strongly dislikes; we evaluated the appearance, color of crust and crumb, texture, taste and flavor of breads; the evaluation group consisted of 6 persons;

- and indices of crust and crumb color (L*, a*, b*) using a Minolta Chroma Meter CR-200b.

Statistical analysis

In order to compare the average values, one factor analysisofvariance has been performed, with the significance level of $\alpha \leq 0{,}05$. The average values have been estimated by means of Duncan test. Statistical analysis of the results has been carried out with the use of the Statistica 9.0 pack. All mean results are shown in Tables.

Results and discussion

According to Eerlingen et al. [1994], adding components containing an artificially increased content of resistant starch in the process of bread baking does not lower the quality of the resulting products, and what is more, it results in reducing the caloric value of the goods [Leszczyński 2004].

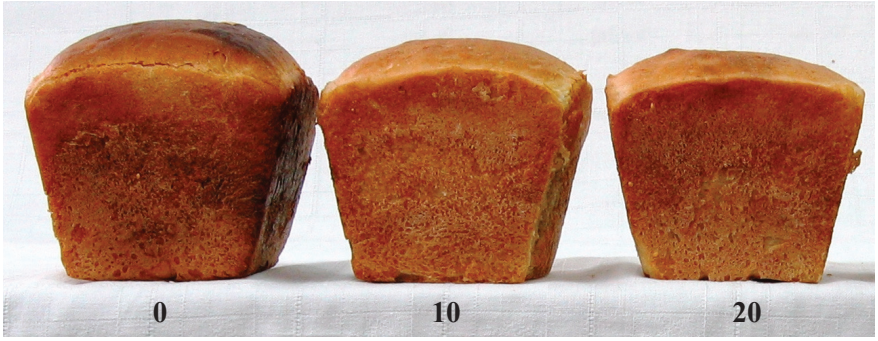
Enriching wheat flour with resistant starch, as it has been done in this experiment, has caused change in quality properties of wheat breads (Tab. 1). With the increase of the quantity of resistant starch, a significant increase of bread overbake and total dietary fiber content has been observed – respectively from 42,3% and 2,9% (control sample) to 63,8% and 4,8% in the samples with 20% content of resistant starch (Tab. 1).

Table 1

Means values of quality properties of wheat bread depending on the content level of resistant starch

Content level of resistant starch [%]	Bread volume [$cm^3100^{-1}g$ flour]	Overbake [%]	Porosity of the crumb acc. to Dallmann scale	Total dietary fiber content [%]	Energy value by Rozental [$kcal100^{-1}g$]	Starch digestibility [%]
0	574 a	42.3 c	5.0 a	2.9 b	184 a	25.4 a
10	550 b	52.6 b	5.0 a	4.8 a	170 ab	22.0 b
20	524 c	63.8 a	5.0 a	4.8 a	155 b	20.7 c

Explanatory notes:
a, b, c, d, e – mean values in the columns, denoted by different letters, differ statistically significant at level of $\alpha \leq 0{,}05$



Cotent level of resistant starch [%]

Fig. 1. Whole breads enriched with resistant starch

Low substitution acetylated starch used in the food industry is characterized by an increased water absorption properties [Golachowski 1998, Zięba et al. 2007]. Growth of the overbake of bread results from a larger water absorption of the mixtures containing RS4. Wojciechowicz and Gil [2009] and Wojciechowicz et al. [2008b] have noted a similar tendency in their research. Becuase of fact that resistant starch is regarded as a component of dietary fiber, its increasing participation in breads causes increase of total dietary fiber content. With the increase of resistant starch content in the samples, the volume of the bread has decreased from 574 cm^3 in the control sample to 524 cm^3 (20% of RS4) (Tab. 1, Fig. 1), which has been caused by weakening gluten by the addition of resistant starch, being a source of dietary fiber, to the flour. A similar dependence has also been observed by Ayadi et al. [2009]; Korus and Achremowicz [2004]; Korus et al. [2009]; Masoodi and Chauhan [1998]; Wang et al. [2002], Wojciechowicz and Gil [2009]; Wojciechowicz et al. [2008b]. According to the research carried out by Wepner et al. [1999], the addition of 10% of potato starch esterified with citric acid has not resulted in lowering the volume of bread, compared with breads not incorporated with resistant starch. The decrease in bread volume is a sign of lowering its quality, which may result in decreasing the attractiveness of the bread to consumers. Starch digestibility and energy value have gradually decreased from 25,4 to 20,7% and from 184 to 155 kcal 100^{-1}g with the increase of retrograded acetylated starch content in the samples, which has been caused by increase resistance to enzymatic degradation of chemically modified starches [Le Thanh et al. 2007, Zięba et al. 2007]. Angioloni and Collar [2011] have obtained significantly higher values of starch digestibility in wheat and high fibre breads.

The increase in the content of resistant starch has had a significant influence on the sensory evaluation of wheat bread (Tab. 2). The worst color and texture of the crumb has been noted in the control sample (6,8 and 7,0) (Fig. 2). For the sample with 10% content of resistant starch the highest values of crust color (7,6) and taste of bread has been obtained (7,4).

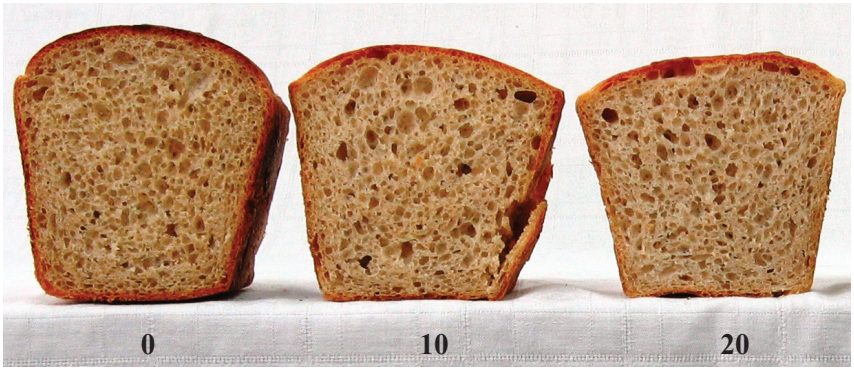
Table 2

Means values of sensory evaluation of wheat bread depending on the content level of resistant starch

Content level of resistant starch [%]	Appearance	Crust color	Crumb color	Texture	Taste	Flavor
0	7.6 a	7.2 b	6.8 b	7.0 b	7.0 ab	7.6 a
10	7.6 a	7.6 a	7.2 a	7.4 a	7.4 a	7.6 a
20	7.6 a	7.4 ab	7.2 a	7.6 a	6.6 b	7.4 a

Explanatory notes:
a, b, c, d, e – mean values in the columns, denoted by different letters, differ statistically significant at level of $\alpha \leq 0,05$

Table 3 presents the results of color traits analyses of bread. It was observed that with the increase of resistant starch content in the samples, crust color was more light, more redness and yellow (Fig. 1). Crumb color was lighter than color of the crust and the lightest was crumb of bread enriched with 10% of resistant starch (Fig. 2). Crumb of bread with 20% of modified starch was the least yellow from the others.



Cotent level of resistant starch [%]

Fig. 2. Cross-section of breads enriched with resistant starch

Table 3

Means values of color parameters of wheat bread depending on the content level of resistant starch

Content level of resistant starch [%]	Crust color			Crumb color		
	L*	a*	b*	L*	a*	b*
0	35.8 c	12.0 b	13.2 c	63.8 b	-1.6 a	13.9 a
10	46.5 b	12.5 ab	24.2 b	66.1 a	-1.3 a	13.0 a
20	49.2 a	13.2 a	28.1 a	62.9 c	-1.3 a	11.2 b

Explanatory notes:
a, b, c, d, e – mean values in the columns, denoted by different letters, differ statistically significant at level of $\alpha \leq 0,05$

Conclusions

The increasing content of resistant starch in the mixtures has resulted in the rise of the bread overbake and dietary fiber content. It was found that the increasing content of resistant starch caused bread volume, starch digestibility and energy value to decrease. Wheat flour supplementation by resistant starch only slightly affected on the sensory quality of obtained bread, independently on a dose used. Therefore, it can be said only about a lack of distinct, negative or positive effect of resistant starch on bread quality.

References

Angioloni A., Collar C., 2011. Physicochemical and nutritional properties of reduced-caloric density high-fibre breads. LWT-Food Science and Technology, 44, 747–758.

AOAC Official Method 985.29, 1997. Total Dietary Fiber in Foods-Enzymatic-Gravimetric Method in Official Methods of Analysis 16th Ed., AOAC International, Arlington, VA.

Ayadi M.A., Abdelmaksoud W., Ennouri M., Attia H., 2009. Cladodes from Opuntia ficus indica as a source of dietary fiber: Effect on dough characteristics and cake making. Industrial Crops and Products, 30, 40–47.
Bartnikowska E., 1997. Włókno pokarmowe w żywieniu człowieka. Część I. Przem. Spoż., 5, 43–48.
Champ M., 1994. Definition, analysis, physical and chemical characterization and intake of RS.EURESTA Working Group I. Proceedings of the concluding plenary meeting of EURESTA. Eds. Asp N.-G., Amelsvoort J.M.M., Hautvast J.G.A.J., Wageningen, The Netherlands.
Diowksz A., 2006. Pieczywo hipoalergiczne – poszukiwanie nowych rozwiązań dla szybko rosnącego rynku produktów dietetycznych. Przegl. Piek., 8, 2–4.
Dziugan P., Dziedziczak K., Ambroziak W., 2006. Błonnik w pieczywie. Cuk., 5, 60–62.
Eerlingen R.C., Van Haesedonck I.P., De Paepe G., Delcour J.A., 1994. Enzyme-resistant starch. III. Thequality of straight-dough bread containing varying levels of enzyme-resistant starch. Cereal Chem., 71, 165–170.
Englyst H.N., Cummings. J.H., 1987. Digestion of polysaccharides of potato in the small intestine of man. Am. J. Clin.Nutr., 45, 423–431.
Englyst H.N., Hudson G.J., 1997. Starch and heath. Starch structure and functionality (eds. P.J. Frazier, P. Richmond, A.M. Donald). The Royal Society of Chemistry, Cambridge, 9–21.
Gawęcki J., Jeszka J., 1986. Żywienie człowieka. Ćwiczenia. Wydawnictwo Naukowe PWN, Warszawa.
Golachowski A., 1998. Stosowanie skrobi i jej przetworów w przemyśle spożywczym. Zesz. Nauk. AR Wroc., Technol. Żyw., 12/ 328, 117–124.
Haralampu S.G., 2000. Resistant starch-a review of the physical properties and biological impact of RS3. Carbohydr. Polymers, 41, 285–292.
Karolini-Skaradzińska Z., Subda H., Korczak B., Kowalska M., Żmijewski M., Czubaszek A., 2001. Ocena technologiczna ziarna i mąki wybranych odmian pszenicy ozimej. Żywność. Nauka. Technologia. Jakość, 2 (87), 68–77.
Korus J., Achremowicz B., 2004. Zastosowanie preparatów błonnikowych różnego pochodzenia jako dodatków do wypieku chlebów bezglutenowych. Żywność. Nauka. Technologia. Jakość, 1(38), 65–73.
Korus J., Witczak M., Ziobro R., Juszczak L., 2009. The impact of resistant starch on characteristics of gluten-free dough and bread. Food Hydrocoll., 23,988–995.
Leszczyński W., 2004. Skrobia oporna i jej znaczenie. Przegl. Piek., 7, 2–5.
Le Thanh J., Błaszczak W., Lewandowicz G., 2007. Digestibility vs structure of food grade modified starches. EJPAU, 10(3), s. 10.
Mężyński L. 1972. Acetylacja skrobi. Przem. Chem., 51/5, 289–290.
Masoodi F.A., Chauhan G.S., 1998. Use of apple pomace as a source of dietary fiber in wheat bread. J. Food Proc. Pres., 22 (4), 255–263.
Mielcarz M., 2004a. Żywieniowe i technologiczne aspekty zastosowania błonników pokarmowych do produkcji wyrobów piekarskich i ciastkarskich. Przegl. Piek., 8, 7–9.
Mielcarz M., 2004b. Wartość odżywcza pieczywa i jego przeznaczenie dla konsumentów wymagających określonych diet (cz. I). Przegl. Piek., 10, 12–13.
Mielcarz M., 2005. Wartość odżywcza pieczywa i jego przeznaczenie dla konsumentów wymagających określonych diet (cz.III). Przegl. Piek., 6, 2–3.
Ohr L.M., 2004. Fortyfying with fiber. NutraceuticalsandFunctional Foods, 58 (2), 71–75.
Soral-Śmietana M., Wronkowska M., 1999. Czy skrobia odporna na hydrolizę enzymatyczną może zastąpić błonnik pokarmowy? Przem. Spoż., 7,22–24.
Świderski F. (pod red.), 1999. Towaroznawstwo żywności przetworzonej. Wyd. SGGW, Warszawa.
Wang J., Rosell C.M., Benedito de Barber C., 2002. Effect of the addition of different fibres on wheat dough performance and bread quality. Food Chem., 79, 221–226.

Wepner B., Berghofer E., Miesenberger E., Tiefenbacher K., Ng P.N.K., 1999. Citrate starch-applicationas resistant starch in different food systems. Starch/Stärke, 10, 354–361.
Wojciechowicz A., Gil Z., 2009. Influence of resistant starch on wheat dough and bread quality, Food Technology Operations. New Vistas, 29, 257–263.
Wojciechowicz A., Gil Z., Kapelko M., Zięba T., 2008a. Pieczywo o podwyższonej wartości odżywczej. BUP, 20 (907), 2.
Wojciechowicz A., Gil Z., Kapelko M., Zięba T., 2008b. Wpływ dodatku skrobi opornej na właściwości ciasta i jakość pieczywa pszennego. Żywność. Nauka. Technologia. Jakość., 5 (60), 24–33.
Zięba T., 2007. Sposób otrzymywania skrobi o zmniejszonej podatności na działanie enzymów amylolitycznych.BUP, 20 (881),16.
Zięba T., Kapelko M., Gryszkin A., 2007. Selected properties of potarto starch subjected to multiple physical and chemical modifications. Pol. J. Food Nutr. Sci., 57 (4C), 639–645.

6

EVALUATION OF PHYSICOCHEMICAL TRAITS OF EGGSFROM SELECTED POLISH BREEDING STRAINS OF LAYING HENS

Introduction

The hen egg demonstrates most valuable and nutritious components among the basic food products consumed [Mine, Nolan 2004]. Despite the average egg weight around 60 grams, it is an unusual energy source accompanied by biologically highest protein quality, vitamins and minerals content [Li-Chan et al. 1995, Suginoet al. 1997]. The egg due to its valuable functional properties plays more and more the role of a nutraceutical [Stadelman 1999, Hartmann, Wilhelmson 2001].

Numerous reports have shown that the physicochemical egg traits are dependent to great extent upon the genotype, apart from many other factors such as: environmental conditions, age, nutrition, management hygiene and veterinary prophylaxis [Sáinzet al. 1983, Reynard, Savory 1999, Danilov 2000, Suk, Park 2001, Leduret al. 2002, Wall, Tauson 2002; Roberts 2004, Basmacioglu, Ergűl 2005, Dottavioet al. 2005, Wu et al. 2005a, Wu et al. 2005b].

Due to the observed globalization and concentration of poultry breeding, the scale of Polish breeding units of laying hen strains has been reduced and at the present moment there are only three pedigree farms, i.e.: Rszew Laying Hen Breeding Farm Ltd. Co., Experimental Station Rossocha Ltd. Co. – National Research Institute of Animal Production and Messa Poultry Breeding Station Ltd. Co, located in Mienia. In the year 2005 in the poultry units specified above there were 15 breeding strains and gene pools used as a basis for the development of breeding stock and commercial hybrids distributed throughout Poland. It was been estimated that the domestic breeding strains of laying hens account only for 7 to 10% of the total commercial farm population of layers producing table eggs in Poland [Koźleckaet al. 2006, Koźlecka, Wencek 2007].

The recent achievements in the various fields of science and the dynamic changes in the egg industry over the recent years, demonstrate that eggs are used more and more frequently not only in the food, pharmaceutics and cosmetic industries but also in the human and veterinary medicine [Davis, Reeves 2002, Sheppard 2002]. That trend has been developed due to certain egg components having important functional properties and biological activity, first of all the egg white lysozyme [Johson 1994, Kijowski, Leśnierowski 1995, Kijowskiet al. 2000, Losso 2000]. Apart from the numerous functions and properties, lysozyme is responsible for egg albumen gelous structure which witness its quality [Gutierrez et al.1997, Hansen et al. 1998].

Consumers are more and more interested in egg quality thus that feature is of basic importance. In the civilised countries people pay great attention to the health standards, thus the

quality traits of food are a main issue both for consumers and producers but also a challenge for scientists. Hence, in the time of high competition among egg producers there is a need to develop brand products offered on the market and representing high quality and wholesomeness [Trziszka 2000].

A diversified gene pool being available in a country can facilitate the implementation of an own breeding programme for the laying stock without the necessity of importing foreign material. For that reason the study was aimed at determination of differences in the physical and chemical traits of eggs from various breeding strains of laying type birds. It was anticipated that the experimental results will be utilised by local breeding farms in the selection of their populations of layers to stimulate production of table eggs demonstrating quality traits expected by the consumers.

Materials and methods

Eggs from the specified below five layer breeding strains being used in Poland were taken as experimental material, *i.e.*: A-22 (Rhode Island White) and K-44 (Rhode Island Red) from DusznikiWlkp. Laying Hen Farm; M-55 (Rhode Island White) and V-44 (Rhode Island Red) from Mienia Layer Breeding Centre and S-55 (Sussex) from Rszew Layer Breeding Farm. Each strain consisted of 500 birds. For the experiment randomly selected 100 birds. Birds used in the experiment were kept in three separate poultry houses on the litter (I – A-22 strain and K-44 strain; II – M-55 strain and V-44 strain ; III – S-55 strain) under the same environmental conditions and fed on the same compound feeds. Individual bird was the replicate unit – 100 eggs came from 100 individual birds and each bird used in the experiment has been individually caged in the trap-nest unit. Afterwards each egg was collected, marked and transmitted for analysis. Eggs were taken at random on the same day from each strain of birds to standardise the experimental conditions. Physical and chemical examination was carried out on eggs from hens at 36 weeks of age.The physical examination comprised (a) in whole eggs: egg total weight, index and chamber height; (b) in egg white: weight, height, pH and Haugh value; (c) in egg yolk: weight and pH (d) in egg shell: weigh, colour, thickness, density and elastic strain. The examination of the above egg traits was conducted in the electronic apparatus of Egg Quality Micro-Technical Services and Suppliers Ltd (U.K). The resulting egg content was divided into egg white and yolk and placed separately into sterile plastic containers, sealed and frozen. The prepared egg content samples were subjected to chemical examination. Percentage content of crude protein, water and ash content in the egg white and yolk, and of lipids in the egg yolk were determined. The content of crude protein was determined by Kjeldahl method [PN-75/A-04018/Az3:2002 Standard]; of water by PN-A-86509:1994 Standard, while the ash content acc. to Krełowska-Kułas [1993]. Lipid content in the egg yolk was examined by Soxhlet method acc. to PN-A-86509:1994 Standard. The concentration and hydrolytic activity of lysozyme was determined acc. to Kijowski and Leśnierowski [1999].

The results of physical and chemical examinations were subjected to the analysis to variance to find differences in the traits of eggs from the five studied groups of layers. Statistic value F-Snedecor for one-way analysis of variance was determinedas well as Duncan test was used to compare mean values of groups. Simple correlations were calculated to estimate

relationships among egg traits within each group of birds. All the results were statistically analysed using Statistica 6.0 programme [Anon. 2002].

Results and discussion

The results of experiments are presented in Tables 1 to 5 and on diagrams 1 to 3, whereas the selected correlations among the determined egg traits are shown in Table 6.

Eggs laid by S-55 breeding strain demonstrated a significantly highest 68.36 g ($p \leq 0.05$) total egg weight (tab. 1). The highest egg index was shown by eggs from M-55 strain (78.64%). In the case of egg chamber height a considerable variation was observed among eggs in the range from 3.38 mm (V-44 strain) to 10.88 mm (K-44 strain). That egg trait also demonstrated an extremely high coefficient of variation which reached 234.6% in the eggs from V-44 strain. In the case of egg weight trait this coefficient ranged from 4.4% (M-55 strain) to 7.8% (K-44 strain) and in the case of egg index does not exceed 6.6%. Moreover the greatest variation between groups was demonstrated for the egg weight (F=80.25) and lowest for egg chamber height (F=9.28). For all above-mentioned traits the statistic values F were statistically significant ($p \leq 0.05$).

Table 1

Egg weight, egg index, and egg chamber height in the A-22 (Rhode Island White), K-44 (Rhode Island Red), M-55 (Rhode Island White), V-44 (Rhode Island Red), and S-55 (Sussex) selected Polish breeding strains of layers

Trait	Strain							
	A-22	K-44	M-55	V-44	S-55	Total	SEM	F
N	100	100	100	100	100	500		
Egg weight [g]								
x	61.57^{c}	59.64^{d}	66.01^{b}	62.53^{c}	68.36^{a}	63.62	0.39	80.25*
sd	3.79	4.67	2.90	4.77	3.08	3.92		
v	6.2	7.8	4.4	7.6	4.5	6.2		
Egg index [%]								
x	77.44^{b}	75.61^{c}	78.64^{a}	77.47^{b}	76.09^{c}	77.05	0.33	13.36*
sd	2.76	3.03	1.89	3.07	4.99	3.31		
v	3.6	4.0	2.4	4.0	6.6	4.3		
Egg chamber height [mm]								
x	8.41^{ab}	10.88^{a}	8.50^{ab}	3.38^{c}	6.03^{b}	7.44	0.93	9.28*
sd	7.97	9.15	11.07	7.94	10.14	9.33		
v	94.7	84.0	130.3	234.6	168.2	125.5		

Explanations:
x – mean value for the experimental group
n – number of eggs in the group
sd – standard deviation
v – variation coefficient [%]
SEM – standard error mean
F – statistic value F-Snedecor for variation between groups
^{ab} – means statistically significant difference at $p \leq 0.05$
*– significance on a level at $p \leq 0.05$

The analysis of experimental findings pertaining to the quality of egg white (tab. 2) from the examined bird strains showed that the best characteristics were noted in the eggs from M-55 birds *i.e.* the highest ($p \leq 0.05$) albumen height (9.01mm) and the Haugh unit (92.80). As far as the egg albumen weight is concerned the significantly ($p \leq 0.05$) highest (41.14 g) was found in S-55 layer strains. In the egg albumen from V-44 strain the highest pH value (8.01) was noted. Albumen height demonstrated the highest coefficient of variation from among discussed traits of egg white which reached from 14.8% (S-55 strain) to 20.3% (V-44 strain). For the other traits of egg white its average value does not exceed 9.8%.Variability between analyzed groups of egg white traits was statistically significant ($p \leq 0.05$). The highest variation between groups was noted in albumen weight (F=65.92).

Table 2

Albumen weight, albumen height, Haugh units, and albumen pH in the A-22 (Rhode Island White), K-44 (Rhode Island Red), M-55 (Rhode Island White), V-44 (Rhode Island Red), and S-55 (Sussex) selected Polish breeding strains of layers

Trait	Strain							
	A-22	K-44	M-55	V-44	S-55	Total	SEM	F
N	100	100	100	100	100	500		
Albumen weight [g]								
x	36.92^{c}	34.46^{d}	40.19^{b}	37.46^{c}	41.14^{a}	38.03	0.33	65.92*
sd	3.12	3.49	2.81	3.45	3.54	3.29		
v	8.5	10.1	7.0	9.2	8.06	8.7		
Albumen height [mm]								
x	8.36^{b}	7.99^{b}	9.01^{a}	7.99^{b}	6.91^{c}	8.05	0.14	29.86*
sd	1.36	1.44	1.45	1.62	1.03	1.39		
v	16.3	18.0	16.1	20.3	14.8	17.3		
Haughunits								
x	90.53^{ab}	88.66^{bc}	92.80^{a}	87.88^{c}	80.04^{d}	87.98	0.86	31.17*
sd	7.77	10.62	7.64	9.48	7.23	8.64		
v	8.6	12.0	8.2	10.8	9.0	9.8		
Albumen pH								
x	7.45^{c}	7.08^{d}	7.85^{b}	8.01^{a}	7.78^{b}	7.63	0.06	42.83*
sd	0.66	0.60	0.57	0.54	0.44	0.57		
v	8.9	8.5	7.2	6.8	5.7	7.4		

Explanations: see Table 1

As it is shown in Table 3 the eggs yolk from S-55 hen strain demonstrated significantly ($p \leq 0.05$) highest weight which reached 18.16 g. The highest pH value 6.97 was noted in the eggs yolk from V-44 strain. In addition was observed that yolks from eggs laid by S-55 breeding strain were characterized by the lowest coefficient of variation of weight (6.8%) and pH value (5.6%) and the value of F-statistic shows that the variability between the groups for these two traits was significant($p \leq 0.05$).

Table 3

Yolk weight and yolk pH in the A-22 (Rhode Island White), K-44 (Rhode Island Red), M-55 (Rhode Island White), V-44 (Rhode Island Red), and S-55 (Sussex) selected Polish breeding strains of layers

Trait	Strain							
	A-22	K-44	M-55	V-44	S-55	Total	SEM	F
N	100	100	100	100	100	500		
Yolk weight [g]								
x	16.25^{d}	16.84^{c}	17.46^{b}	16.85^{c}	18.16^{a}	17.11	0.13	31.83*
sd	1.40	1.30	1.20	1.27	1.24	1.28		
v	8.6	7.7	6.9	7.5	6.8	7.5		
Yolk pH								
x	6.58^{b}	6.55^{b}	6.93^{a}	6.97^{a}	6.89^{a}	6.78	0.05	18.84*
sd	0.44	0.49	0.48	0.52	0.38	0.47		
v	6.7	7.5	7.0	7.5	5.6	6.9		

Explanations: see Table 1

The examination of egg shell traits (Tab. 4) revealed that the eggs from S-55 birds exhibited significantly ($p \leq 0.05$) highest shell weight (6.16g), shell thickness (372.17µm) and the lightest shell color (63.51). Significantly highest ($p \leq 0.05$) shell density (80.06 $cm^{-2} \cdot mg$) was found in eggs laid by K-44 layers. Shell deformation level was noted in the range from 22.31µm (A-22) to 27.85 µm (M-55) and was accompanied by high variation coefficient ranging from 12.3% (V-44) to 20.7% (A-22). In that trait statistically significant differences were found at $p \leq 0.05$. Furthermore F-statistic value for the shell colour was much higher than other egg shell traits (F=289.16). This is due to the fact that the average value of shell colour from S-55 hen (x=63.51) significantly differed from the values of the remaining layer strains.

Statistically significant differences at $p \leq 0.05$ in albumen lysozyme content were observed (Tab. 5) among the investigated eggs from five hen strains thus indicating the effect of bird genotype on that egg trait. Egg white from A-22 strain was found to have not only the highest percentage content (0.51%) but also the greatest activity of that enzyme which reached 108746 $U \cdot ml^{-1}$. An opposite situation was observed in the egg white from V-44 laying strain *i.e.* the lowest percentage content (0.39%) of lysozyme followed by the lowest enzyme activity at the level of 83243 $U \cdot ml^{-1}$. Moreover, the value of F-statistic shows that the differences between the groups developed similarly in showed traits of lysozyme and were statistically significant ($p \leq 0.05$).

The percentage of egg constituents *i.e.* yolk, white and shell in the eggs from the five examined hen strains is presented in figure 1 and demonstrates statistically significant differences at $p \leq 0.05$. The content of egg white ranged from 57.79% (K-44) to 60.87% (M-55); of the egg yolk from 26.41% (A-22) to 28.30% (K-44) whereas of the egg shell from 8.47% (M-55) to 9.74% (K-44).

Table 4

Shell weight, shell color, shell thickness, shell density, and shell elastic strain in the A-22 (Rhode Island White), K-44 (Rhode Island Red), M-55 (Rhode Island White), V-44 (Rhode Island Red), and S-55 (Sussex) selected Polish breeding strains of layers

Trait	Strain							
	A-22	K-44	M-55	V-44	S-55	Total	SEM	F
N	100	100	100	100	100	500		
Shell weight [g]								
x	5.74^{b}	5.79^{b}	5.58^{c}	5.66^{bc}	6.16^{a}	5.79	0.05	19.43*
sd	0.47	0.56	0.36	0.58	0.51	0.50		
v	8.2	9.7	6.5	10.2	8.3	8.7		
Shell color								
x	42.21^{cd}	43.44^{bc}	44.35^{b}	41.03^{d}	63.51^{a}	46.91	0.55	289.16*
sd	6.06	5.96	4.65	5.44	5.31	5.51		
v	14.4	13.7	10.5	13.3	8.4	11.7		
Shell thickness [µm]								
x	357.10^{b}	369.17^{a}	356.49^{b}	356.62^{b}	372.17^{a}	362.31	2.67	8.32*
sd	31.28	26.81	22.73	24.68	27.29	26.71		
v	8.8	7.3	6.4	6.9	7.3	7.4		
Shell density [cm^{-2}·mg]								
x	77.69^{b}	80.06^{a}	72.15^{d}	75.84^{c}	77.74^{b}	76.70	0.61	23.58*
sd	5.49	6.98	4.39	6.93	6.19	6.10		
v	7.1	8.7	6.1	9.1	8.0	7.9		
Shell elastic strain [µm]								
x	22.31^{d}	22.53^{d}	27.85^{a}	25.83^{b}	24.06^{c}	24.52	0.41	32.10*
sd	4.61	4.58	3.52	3.17	4.50	4.12		
v	20.7	20.3	12.6	12.3	18.7	16.8		

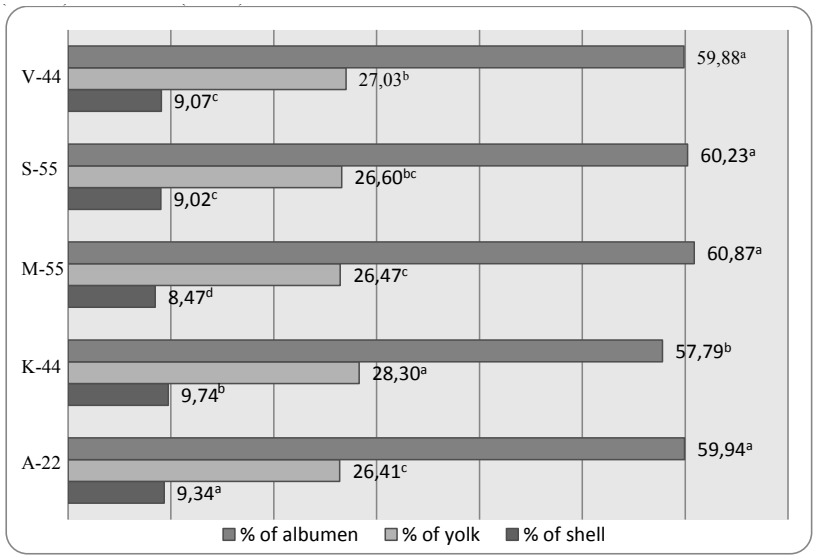
Explanations: see Table 1

Table 5

Lysozyme concentration, percentage content of lysozyme, and activity of lysozyme in the A-22 (Rhode Island White), K-44 (Rhode Island Red), M-55 (Rhode Island White), V-44 (Rhode Island Red), and S-55 (Sussex) selected Polish breeding strains of layers

Trait	Strain							
	A-22	K-44	M-55	V-44	S-55	Total	SEM	F
N	100	100	100	100	100	500		
Percentage content of lysozyme								
x	0.51^{a}	0.43^{d}	0.46^{c}	0.39^{e}	0.49^{b}	0.46	0.01	43.29*
sd	0.06	0.06	0.05	0.06	0.07	0.06		
v	12.3	14.7	11.4	15.6	13.9	13.2		
Activity of lysozyme [U·ml^{-1}]								
x	108746^{a}	91523^{c}	96610^{b}	83243^{d}	104313^{a}	96887	1793.63	44.24*
sd	13237	13300	11022	12964	13976	12683		
v	12.2	14.5	11.4	15.6	13.4	13.1		

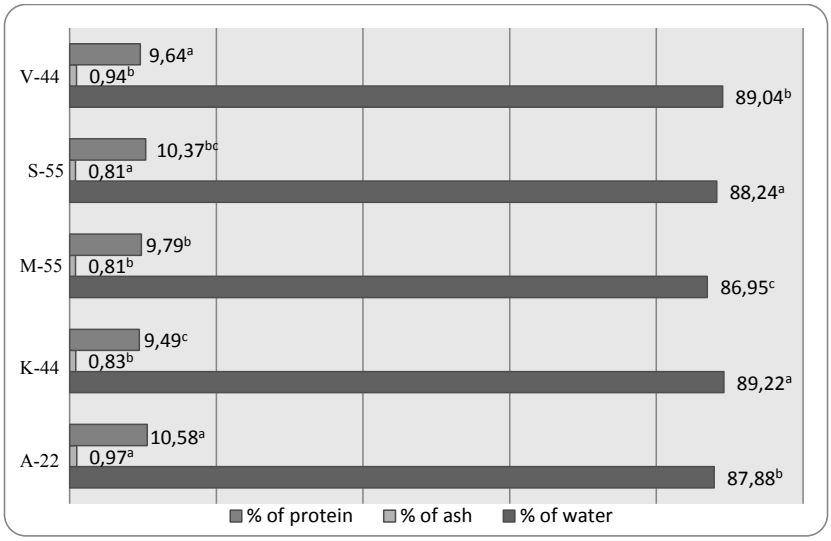
Explanations: see Table 1



ab – means statistically significant difference at p≤0.05

Fig. 1. Percentage content of albumen, yolk, and shell in the A-22 (Rhode Island White), K-44 (Rhode Island Red), M-55 (Rhode Island White), V-44 (Rhode Island Red), and S-55 (Sussex) selected Polish breeding strains of layers

The analytical results of the basic chemical components of the egg white (Fig. 2) from five breeding strains revealed the highest water content (89.22%) in the eggs from layers of K-44 strain. The other examined chemical components of the egg white were found at the highest level in the eggs from A-22 strain (10.58% of protein; 0.97% of ash) and the differences statistically significant at p≤0.05.



ab – means statistically significant difference at p≤0.05

Fig. 2. Basic chemical composition of albumen in the A-22 (Rhode Island White), K-44 (Rhode Island Red), M-55 (Rhode Island White), V-44 (Rhode Island Red), and S-55 (Sussex) selected Polish breeding strains of layers

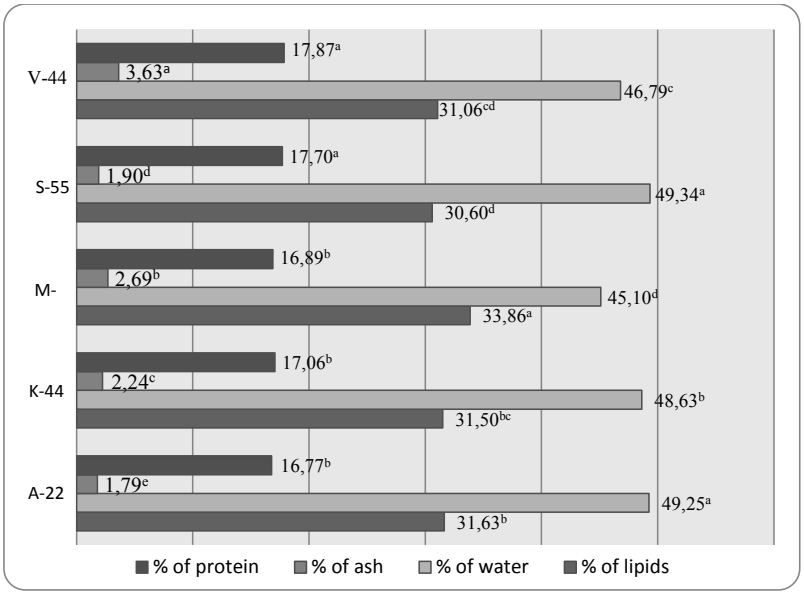
The chemical composition of the egg yolk given in Figure 3, also showed statistically significant differences at p≤0.05. The yolk of eggs from V-44 strain demonstrated the highest content of both crude protein (17.87%) and ash (3.63%). The water content in the egg yolk ranged from 45.10% in the M-55 strain to 49.34% in the S-55 strain. The content of egg yolk lipids was noted in the range from 30.60% in the S-55 strain to 33.86% in the M-55 strain of birds.

Many significant correlations at p≤0.05 were found among the examined egg traits (Tab. 6) whereas they were most numerous in the eggs from S-55 strain and least numerous in the eggs from V-44 strain.

In the available scientific literature there is only a small number of references dealing with the physicochemical traits of eggs from particular breeding strains of laying hens. The known studies pertain primarily to quality evaluation of table eggs delivered by commercial lying stock farms.

Considerable differences in the examined physical traits of eggs from three strains ISA--Brown, Babcock B-300 and Brown Leghorn line hens were reported by Silversides et al. (2006). Eggs from ISA Brown birds demonstrated the largest total weight (66.86 g), albumen (43.34 g) and egg shell (6.66 g) weight. The difference in the egg shell weight amounted to nearly 2 g, in the albumen it exceeded 10 g whereas in the total egg weight it reached nearly 15g. The lowest quality traits of eggs were reported in Brown Leghorn line, *i.e.* the lowest egg total weight (52.45 g), yolk weight (15.44 g) and albumen weight (33.15 g) and its height (5.97 mm).

In our study such marked differences were not observed among the examined traits, except the egg and albumen weight when the difference was at the level 8.72g and 6.69g, respectively.



[ab] – means statistically significant difference at $p \leq 0.05$

Fig. 3. Basic chemical composition of yolk in the A-22 (Rhode Island White), K-44 (Rhode Island Red), M-55 (Rhode Island White), V-44 (Rhode Island Red), and S-55 (Sussex) selected Polish breeding strains of layers

Table 6

Certain correlations among the examined physicochemical traits in the A-22 (Rhode Island White), K-44 (Rhode Island Red), M-55 (Rhode Island White), V-44 (Rhode Island Red), and S-55 (Sussex) selected Polish breeding strains of layers

Traits	Strain					
	A-22	K-44	M-55	V-44	S-55	Total
N	100	100	100	100	100	500
1	2	3	4	5	6	7
Egg weight x albumen weight	0.767*	0.772*	0.668*	0.834*	0.341*	0.690*
Egg weight x yolk weight	0.574*	0.648*	0.427*	0.400*	0.223*	0.467*
Egg weight x shell weight	0.492*	0.435*	0.345*	0.467*	0.316*	0.423*
Egg weight x chamber height	0.093	0.109	0.112	0.067	0.153	0.100*
Egg weight x shell elastic strain	0.207*	0.181	-0.101	0.086	0.046	0.104*
Egg weight x albumen height	0.155	0.028	0.145	0.147	0.105	0.112*
Egg index x shell weight	0.040	-0.070	0.018	-0.059	-0.281*	-0.106*
Egg index x shell density	-0.023	-0.133	0.080	-0.015	-0.233*	-0.100*
Egg index x Haugh units	0.043	0.122	0.247*	0.085	0.049	0.089*
Albumen weight x chamber height	-0.029	0.076	0.146	0.060	0.208*	0.100*

Table 6 cont.

1	2	3	4	5	6	7
Albumen weight x shell weight	0.253*	0.268*	0.192	0.417*	0.128	0.260*
Albumen weight x Haughunits	0.106	0.019	0.168	0.073	0.263*	0.113*
% of albumen x% of yolk	-0.512*	-0.102	-0.371*	-0.267*	-0.046	-0.226*
% of albumen x albumen height	0.103	0.206*	0.168	0.160	0.263*	0.173*
% of albumen x Haugh units	0.098	0.213*	0,169	0.164	0.283*	0.187*
% of yolk x Haugh units	-0.039	-0.204*	-0.141	0.023	-0.253*	-0.116*
Chamber height x shell thickness	-0.249*	-0.021	-0.110	-0.130	-0.204*	-0.142*
Chamber height x shell elastic strain	0.186	0.136	0.142	0.004	0.187	0.139*
Haugh units x% water (albumen)	-0.219	0.096	-0.227*	0.006	0.001	-0.109*
Water (albumen) x water (yolk)	0.070	0.008	-0.214*	0.086	0.025	-0.144*
Protein (yolk) x lipids (yolk)	-0.135	0.119	-0.286*	-0.218*	0.085	-0.171*
Protein (yolk) x water (yolk)	-0.421*	-0.596*	0.099	-0.021	-0.570*	-0.129*
% of lysozyme x activity of lysozyme	0.973*	0.999*	1.000*	1.000*	0.992*	0.994*

Explanations:
* – statistically significant difference at $p \leq 0.05$
n – number of eggs in the group

Freshness of egg content is measured by albumen height and pH value. The study by Silversides and Budgell [2004] demonstrated that albumen quality is affected by genetic factors.Authors examined albumen quality in eggs from three lines of laying hens *i.e.* Brown Leghorn, ISA Brown and Babcock and reported the highest pH value (8.84) in Brown Leghorn eggs. In the other lines of laying hens the pH value of albumen was at much lower level *i.e.* from 4.81 (Brown Leghorn) to 6.77 (Babcock).

In our study the pH values of egg albumen were found markedly lower than those reported by Silversides and Budgell [2004] and amounted from 7.08 (K-44 strain) to 8.01 (V-44 strain). On the other hand, the egg albumen height in our study was lower from 2.10mm to 4.20mm.

Tharrington et al. [1999] investigated the solids content in the eggs from birds of various genotype and observed significant differences among the four lines of layers i.e. CS5, CS7, CS10 and CC5. The eggs from CS5 hens exhibited not only the highest crude protein content in the albumen (11.90%) but also the highest crude protein (51.53%) and lipids (33.08%) in the egg yolk. In our study similar traits were noted in eggs from M-55 strain which similarly as in the eggs of CS5 line, showed the highest albumen (60.87%) and lipid content in the yolk (33.86%) accompanied by a relatively high crude protein in the yolk (16.89%). Tharrington et al. (1999) also reported that CS10 eggs were found to have the highest crude protein content (10.60%) in the albumen and the lowest lipid content (32.40%) in the yolk. Their study confirmed the considerable effect of bird genome on the solids content in the chicken egg.

The results of our study on the chemical traits of eggs from five breeding strains of laying hens demonstrated an appreciable differentiation among the examined birds. The highest crude protein content (10.58%) and ash content (0.97%) was noted in the albumen of A-22

eggs. The above traits were on the highest level in the yolk of V-44 eggs and accounted for 17.87 and 3.63%, respectively.

Apart from the composition of the basic solids content in the chicken egg its important trait is the quantity of lysozyme in the albumen. As early as in 1956 Wilcox examined lysozyme level in the albumen of White Leghorn (WL) and Rhode Island Red (RIR) and reported a significant effect of genome on that trait. He found that WL eggs contained a higher concentration of lysozyme than RIR eggs. Similar investigations carried out by Bzdak [1997] on RIR breed birds and Messa 245, Astra W and Astra S hybrids revealed that lysozyme activity was significantly dependent on bird genome, whereas the highest one was noted in Astra S and the lowest in Messa 24 egg albumen. The difference between lysozyme in Astra S eggs and in eggs from the other bird groups was statistically significant at $p \leq 0.05$. Noworyta-Głowacka [2005] reported the effect of genotype of Hy-Line and Tetra birds at 50 weeks of age on lysozyme activity in their eggs. Statistically significant differences at $p \leq 0.05$ were also noted in our study since the highest enzyme activity was observed in egg albumen from A-22 (108746 $U \cdot ml^{-1}$) and S-55 (104313 $U \cdot ml^{-1}$) layers and those differences were statistically significant in comparison with the three other examined strains. In this study the highest lysozyme activity found in A-22 egg albumen is in line with the results of studies by Bzdak [1997] and Noworyta-Głowacka [2005]. Both authors reported a high lysozyme activity of Astra S egg albumen. Astra S is a commercial hybrid resulting from the cross ♂K–64 x ♀A-82 also with the use of A-22 strain. That finding confirms that bird genotype affects egg quality traits.

Considerable differentiation was observed among the physicochemical traits of egg constituents. In the eggs from the examined five Polish breeding strains of layers the egg weight was significantly correlated with the weight of main egg constituents. The main correlation value calculated for the total experimental material was in the range from 0.423 (egg weight x shell weight) to 0.690 (egg weight x albumen weight). It is worth mentioning that, in the case of S-55 only, the correlation values were lower than the mean for the total population. It was an appreciable difference which amounted to nearly 50%. On the other hand, in the A-22 and K-44 strains very high correlations were noted between egg weight and yolk weight, the latter one being the most valuable egg constituent. The physical traits of eggs from S-55 strain demonstrated the highest number of significantly correlated traits which ranged from -0.281 (egg index x shell weight) to 0.341 (egg weight x albumen weight). In the case of chemical traits, the M-55 strain was found to have the highest number of significantly correlated egg traits from -0.286 (yolk protein x yolk lipids) to 1.000 (% of lysozyme x its activity).

The thorough characteristics of quality in the eggs from the examined breeding strains of layers (A-22, K-44, M-55, V-44 and S-55) and the calculated correlations among the physicochemical egg traits point to the differences affected by bird strain. In many cases the observed differences were statistically significant at $p \leq 0.05$. The S-55 strain eggs showed the most desirable traits, from the consumer point of view, *i.e.* the highest weight of egg (68.36 g), albumen (41.15 g) and yolk (18.16 g) and accompanied by the greatest shell weight (6.16 g) having the highest thickness (372.17 μm). In the egg albumen from A-22 layers the highest crude protein (10.58%) and ash (0.97%) were determined whereas the egg yolk from S-55 layers demonstrated the highest water content (49.34%) and the lowest lipid content (30.60%).

Conclusions

The results of this study have been distributed among the laying stock breeders in Poland. They can take them into consideration in their work aimed at improvement of the desirable egg traits to meet the needs of the commercial laying hen farms producing table eggs.

At the present time certain poultry breeds threatened by extinction are kept as a valuable gene pool to be used in the future to reach a better genetic variability or to change the current trends of selection in the existing poultry populations.

References

Anon., 2002. Statistica 6.0 for Windows 6.0 StatSoft Inc., Tulsa, OK, USA.

Basmacioglu H., Ergűl M., 2005. Characteristic of egg in laying hens. The effect of genotype and rearing system. Turk J Vet Anim Sci. 29,157–164.

Bzdak S., 1997. Differences in albumen lysozyme activity in eggs from various strains of laying hens kept with and without access to the range.Master's Thesis, Faculty of Animal Sciences, SGGW, Warszawa, 1–28.

Danilov R.V., 2000. Effect of hen's age on quality of hatching eggs and embryonic development. Proc. of 21th World's Poultry Congress WPSA in Montreal, Canada. CD-ROM.

Davis C., Reeves R., 2002. High value opportunities from the chicken egg (collective work), RIRDC Publication No 02/094, RIRDC Project No DAQ-275A.

Dottavio A.M., Canet Z.E., Faletti C., Alvarez M., Font M.T., Di Masso R.J., 2005. Yolk:albumen ratio in experimental hybrid layers with different paternal genotype. Arch. Zootec., 54, 87–95.

Gutierrez M.A., Takahashi H., Juneja L.R., 1997. Nutritive value of hen eggs. in: Hen Eggs. Yamamoto T., Juneja L.R., Hatta H., Kim M., Ed., Boca Raton: CRC Press Inc., 25–35.

Hansen J.B., Grimsgaard S., Nielsen H., Nordoy A., Bonaa K.H., 1998. Effects of highly purified eicosapentaenoic acid and docosahexaenoic acid on fatty acid absorption, incorporation into serum phospolipids and postprandial triglicerydemia. Lipids, 33, 131–138.

Hartmann C., Wilhelmson M., 2001. The hen's egg yolk: a source of biologically active substances. WPS, 57,13–28.

Johson E.A., 1994. Egg-white lysozyme as a preservative for use in foods. in: Eggs Uses and Processing Technologies, New Developments. Edited by Sim J.S. and Nakai S. International CAB, Wallingford, 177–191.

Kijowski J., Leśnierowski G., 1995. Utilization of lysozyme to food preservation, in medical diagnostics and pharmacology. Biotechnologia, 2 (29),130–139,

Kijowski J., Leśnierowski G., 1999. Separation, polimer formation and antibacterial activity of lysozyme. PJFNS 8/49 (3), 3–16,

Kijowski J., Leśnierowski G., Fabisz-Kijowska A., 2000. Lysozyme polymer formation and functionality of residuals after lysozyme extraction. [in:] Egg Nutrition and Biotechnology. Sim J.S., Nakai S. and Guenter W. eds. CAB Int. Oxon, 269–285.

Koźlecka M., Szukalski G., Wencek E., 2006. Results of the estimation of poultry productive in the year 2005. Warszawa, 5–14.

Kożlecka M., Wencek E., 2007. Results of the estimation of poultry productive in the year 2006. Warszawa, 5–17.

Krełowska-Kułas M., 1993. The examination of the quality of food products, PWE, Warszawa, 97.

Ledur M.C., Liljedhal L.E., McMillan I., Asselstine L., Fairfull R.W., 2002. Genetic effects of aging on egg quality traits in the first laying cycle of White Leghorn Strains and Strain Crosses. Poult. Sci., 81, 1439–1447,

Li-Chan E.C.Y., Powrie W.D., Nakai S., 1995. The chemistry of eggs and egg product. in: Egg Science and Technology, 4th Edition Stadelman W.J. and Cotterill O.J. eds. The Haworth Press, Inc., New York, 105–175.

Losso J.N., Nakai S., Charter E.A., 2000. Lysozyme. Pain: Natural food Antimicrobial Systems. Naidu A.S. ed. CRC Press, Inc. New York, 185–210.

Mine Y., Kovacs-Nolan J., 2004. Biologically active hen egg components in human health and disease. JPS, 41, 1–29.

Noworyta-Głowacka J., 2005. The influence of from of management system, feeding, origin and age of hens of the level of biological active proteins of egg white. PhD Diss. Faculty of Animal Sciences, SGGW, Warszawa.

Polish standard: PN-75/A-0418/Az3, 2002. Agri-food products. Determination of nitrogen by Kjeldahl method and the conversion of protein, 2.

Polish standard: PN-A-86509, 1994. Egg products. Physicochemical researches, 7.

Reynard M., Savary C.J., 1999 Stress-induced oviposition delays in laying hens: duration and consequences for egg shell quality. BrPoult Sci., 40, 585–591.

Roberts J.R., 2004. Factors affecting egg internal quality and egg shell quality in laying hens. JPS 41, 161–177.

Sáinz F., Gonzalez M., Roca P., Alemany M., 1983. Physical and chemical nature of eggs from six breeds of domestic fowls. Br Poult Sci. 24, 301–309.

Sheppard E.H., 2002. Specialty eggs: n-3 fatty acid-enriched eggs. [in:] Eggs and Health Promotion Eggs and Health Promotion (Watson R.R. ed.). Iowa State Press. Ames, 37–44.

Silversides F.G., Budgell K.L., 2004. The relationship among measures of egg albumen height, pH and whipping volume. Poult. Sci., 83, 1619–1623.

Silversides F.G., Korver D.R., Budgell K.L., 2006. Effect of strain of layer and age at photostimulation on egg production, egg quality and bone strength. Poult. Sci., 85, 1136–1144.

Stadelman W.J., 1999. The incredibly functional egg. Poult. Sci., 78, 807–811.

Suk Y.O., Park C., 2001. Effect of breed and age of hens on the yolk to albumen ratio in two different genetic stocks. Poult. Sci. 80, 855–858.

Sugino H., Nitoda T. Juneja L.R., 1997. General chemical composition of hen eggs. in: Hen Eggs, Their Basic and Applied Science (Yamamoto T., Juneja L.R., Hatta H and Kim M eds.). CRC Press, Inc, New York, 13–24.

Tharrington J.B., Curtis P.A., Jones F.T., Anderson K.E., 1999. Comparison of physical quality and composition of eggs from historic strains of Single Comb White Leghorn Chickens. Poult. Sci. 78, 591–594.

Trziszka T., 2000. Egg products. Univ. Agric., Wrocław, Poland. 9–17.

Wall H., Tauson R., 2002. Egg quality in furnished cages for laying hens-Effect of crack reduction measures and hybrid. Poult. Sci., 81, 340–348.

Wilcox F., 1956. Factors influencing the lysozyme level of hens egg white. Poult. Sci., 35, 278–284.

Wu G., Bryant M.M., Voitle R.A., Roland D., 2005a. Performance comparison and nutritional requirements of five commercial layer strains in chase IV. Int. J. Poult. Sci., 4, 182–186.

Wu G., Bryant M.M., Voitle R.A., Roland D., 2005b. Effect of dietary energy on performance and egg composition of Bovans White and Dekalb White hens during phase 1. Poult. Sci., 84, 1610–1615.

7

THE QUALITY OF SMOKED PRODUCTS FROM BOAR MEAT

Introduction

Considerable profits resulting from boar meat production encourage producers as well as researchers to try to utilize this material for culinary and processing purposes [Smih et al. 1983, Rzęsa 1998] Fattening of boars carries a risk of the appearance of the so-called sex odour [Babol, Sqiures 1995]. Intensity of the a/m undesirable smell is affected, among others, by breed, rearing conditions, feeding system, age of animals at slaughtering and processing technologies applied [Mos et al. 1992, Wood et al. 1993, Blanchard 1995, Babol, Squires 1995, Babol et al. 1996, Godt et al. 1996, Szmańko et al. 2002, 2009].

Boar meat can be utilized in numerous ways of which the most often quoted technologies are: smoking or processing with proper seasoning or subjecting to intensive thermal treatment [Mateńko, Horszczaruk 1990, Chen et al. 1993].

Positive results discussed in the quoted literature encouraged the authors to undertake a study aimed at determining how boar meat could be utilized in production of smoked products which are traditionally made from pork, i.e.: pork loin, collar and smoked backfat.

Materials and methods

In the study was used meat of boars from wbp x pbz crossbred sows and wbp, pbz and Duroc boars. Fatteners were slaughtered at the age of 170–175 days and 85–100 kg body weight. The experimental population was divided into 2 groups: boars castrated on the second day of life (I) and boars (II).

The primal cuts used in experimental production were: pork loin (*muscles longissimus dorsi*), collar and backfat. The production was carried out in laboratory conditions according to traditional low-efficiency technologies.

The following indicators were taken into account:

– colour /pork loin, collar/ determined in L^*,a^*,b^* system measurements were carried out with the use of CR – 200b Minolta reflectance colorimeter,
– organoleptic evaluation was carried out by a team of six persons, according to 5 – degree scal. with the use of principles given by Tilguer [Baryłko-Pikielna 1975]. Moreover, all products were evaluated with regard to intensity of sex odour and taste. Three levels of the a/m indicators were adopted: B – no boar taint (taste); N – boar taint (taste) at non-disqualifying intensity; D – boar taint (taste) at disqualifying intensity.

– histological slices were obtained from the loins. The samples was fixed in 4% buffered formalin and embedded in paraffin. Then the sections were cut lengthwise and crosswise. Deparaffinized sections were stained with Delafield hematoxylin and methyl blue [Zawistowski 1986]. Measurements were done in 100 fields of view.

Statistical analysis of the results was carried out using STATISTICA 9.0 software where averages, standard deviations, least significant differences and estimation of differences between mean values at $p<0.05$ were calculated.

Results and discussion

No colour differences between pork loins and collars made from boars and hogs meat were found (Tab. 1). Products made from hog loins tended to be darker in colour (L^*), whereas collars exhibited contrary tendency, a lower L^* value was determined in products made from boar meat. It was observed that reflectance spectrum showed higher levels of red colour (a^*) and yellow (b^*) in loins and collars made from boar meat.

Organoleptic evaluation of smoked products gave higher colour notes in loin, collar and backfat products from boar meat (Tab. 2). In the same way juiciness and tenderness were evaluated higher when pork loin and collar were made from boar meat.

Tastiness of pork loin and collar made from meat of castrated and uncastrated boars was evaluated with similar results, whereas smoked backfat made from boar cuts was classified slightly higher. Saltiness of pork loins, collars and smoked backfat made from boar and hog meat was evaluated with similar results.

Table 1

Effect of gelding in boars on colour of smoked products

Tested indicators		Pork loin		Collar	
		hogs	boars	hogs	boars
Colour L^*	$\bar{x}$	56.56^a	59.28^b	59.45^b	55.08^a
	sd	5.45	7.97	4.79	3.76
	n	12	12	13	11
Colour a^*	$\bar{x}$	7.02	7.93	13.60^a	14.87^b
	sd	2.05	2.58	2.83	1.72
	n	12	12	13	11
Colour b^*	$\bar{x}$	3.93	4.35	5.85	5.89
	sd	2.20	2.47	1.13	0.89
	n	12	12	13	11

$\bar{x}$ – mean value for the experimental group
sd – standard deviation
a, b, c – mean values in the same columns denoted by different capital letters are significantly differ at level of $p\leq0.05$

Table 2

Effect of gelding in boars on organoleptic indicators in smoked products, n=12

Tested indicators		Pork loin		Collar		Smoked backfat	
		hogs	boars	hogs	boars	hogs	boars
Colour	$\bar{x}$	4.64	4.65	4.52	4.62	–	–
	sd	0.53	0.54	0.62	0.51	–	–
Smell	$\bar{x}$	4.47	4.53	4.43	4.48	4.90	4.93
	sd	0.73	0.59	0.85	0.65	1.34	1.27
Juiciness	$\bar{x}$	4.62	4.54	4.48	4.66	–	–
	sd	0.59	0.60	0.66	0.54	–	–
Texture (points)	$\bar{x}$	4.56	4.44	4.50	4.61	–	–
	sd	0.54	0.63	0.70	0.55	–	–
Tastines	$\bar{x}$	4.42	4.40	4.28	4.28	4.34	4.51
	sd	0.76	0.69	1.06	0.88	0.53	0.45
Saltiness	$\bar{x}$	4.28	4.35	4.32	4.21	4.43	4.44
	sd	0.89	0.71	0.80	0.91	0.55	0.59
General sensory evaluation	$\bar{x}$	4.53	4.46	4.42	4.52	4.56	4.73
	sd	0.64	0.64	0.83	0.69	0.92	1.44

$\bar{x}$ – mean value for the experimental group
sd – standard deviation

Castrations of pigs did not affected general organoleptic evaluation of pork loin. It was noted, however, that other products (collar and smoked backfat) made from primal cuts of boars tended to score higher (Tab. 3)

Boar taint of non-disqualifying intensity in products made from boar cuts was found in about 2% of pork loins and smoked backfat in about 13% of collars (Pict. 1–3). It was also found that the odour was detectable in collars and smoked backfat made of meat from gelded animals. In case of smoked products made of hog backfat, its presence was found in over 2 times higher number of products (7.32%).

ll as boar collars.

The sex taste at disqualifying levels was found in products made from cuts of gelded animals as well as boars. Over two-fold higher number of smoked products had it in pork loins made from hog muscles (Pict. 4–6). It was also found at almost two times higher number of tests on collars made from hog cuts. In case of smoked backfat, it concerned almost identical number of products (4.35, 4.55%) made from boar and hog backfat, irrespective of gelding.

Sex taste at disqualifying intensity was found for collars made from hog meat only and it was characteristic for about 4% of products.

Table 3

Effect of gelding in boars on appearance of sex odour and tast in smoked products, n=12

Tested indicators		Pork loin		Collar		Smoked backfat	
		hogs	boars	hogs	boars	hogs	boars
Sex odour [%]	B	100	97.73	91.58	82.89	92.68	97.44
	N	0	2.27	3.16	13.16	7.32	2.56
	D	0	0	5.26	3.95	0	0
Sex taste [%]	B	92.86	96.43	88.89	86.25	95.65	95.45
	N	7.14	3.57	7.07	13.75	4.35	4.55
	D	0	0	4.04	0	0	0

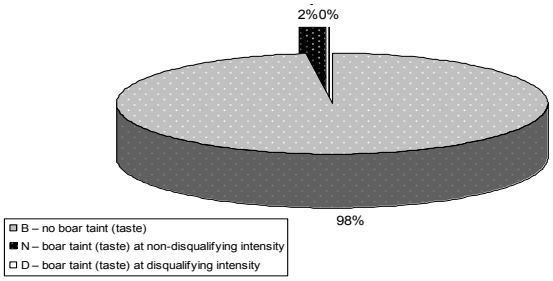
Table 4

The overall histological assessment of pork loin

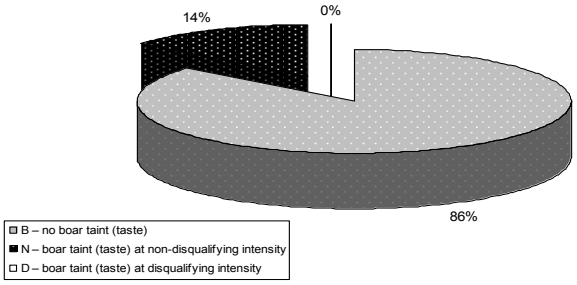
Parameters		Pork loin	
		Hogs	Boars
Surface bundles of muscle fibers [μm^2]	$\bar{x}$	468.86	522.96
	sd	112.14	90.22
	n	100	100
Distance between the muscle bundles [μm]	$\bar{x}$	35.4	31.8
	sd	6.35	4.67
	n	100	100
Thickness of muscle fibers [μm]	$\bar{x}$	42.28	44.1
	sd	8.15	7.34
	n	100	100

$\bar{x}$ – mean value for the experimental group
sd – standard deviation

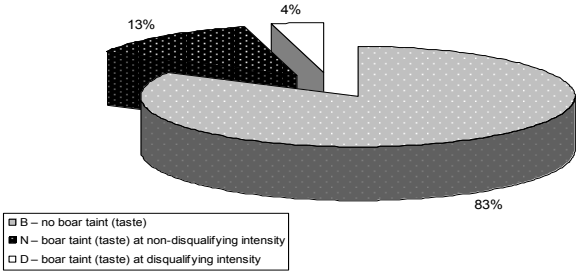
A disqualifying intensity of boar taint was identified in smoked collars made from hog as we the characteristic feature of the structure of the pork loin produced from boar meat was more compact bundles of muscle fibers (Tab. 4). Compared with the construction of the muscle tissue of these preparations to the loins produced from hogs muscle fibers in transverse cross-section resembled the polygons. While in the case of hogs were rather round. It was also significantly wider, open spaces between bunches in the processed of meat hogs and the increase in intramuscular connective tissue. In addition, these spaces often observed the presence of adipose tissue. There were no differences between the compared groups in the thickness of the muscle fibers and bundles of cross-sectional area (Photo 1–8).



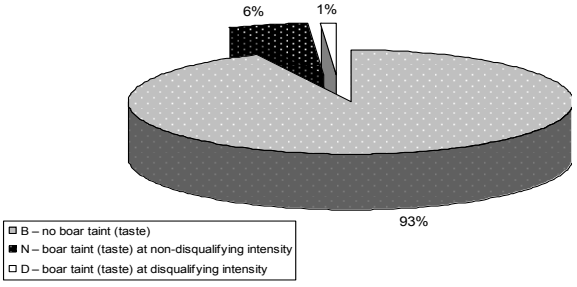
Pict. 1. Sex odor of pork loin made from boars meat



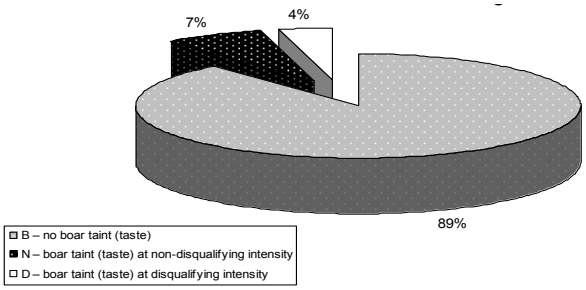
Pict. 2. Sex odor of collar made from boars meat



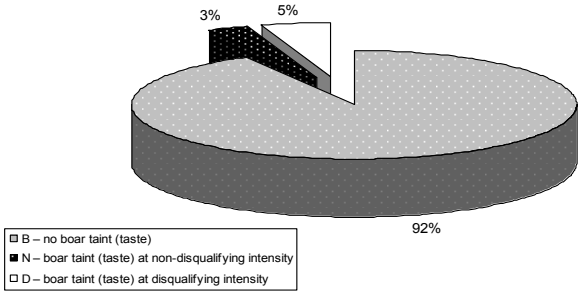
Pict. 3. Sex odor of smoked backfat made from boars meat



Pict. 4. Sex odor of pork loin made from hogs meat



Pict. 5. Sex odor of collar made from hogs meat



Pict. 6. Sex odor of smoked backfat made from boars meat

Photo 1. Histological picture of pork loin from boar meat, x 300

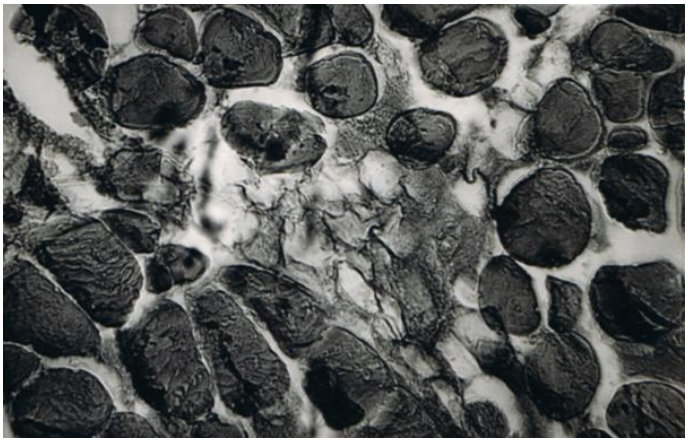


Photo 2. Histological picture of pork loin from hogs meat, x 300

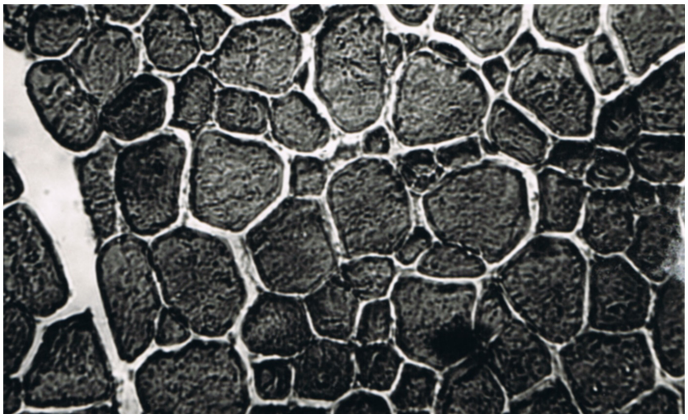


Photo 3. Histological picture of pork loin from boar meat, x 300

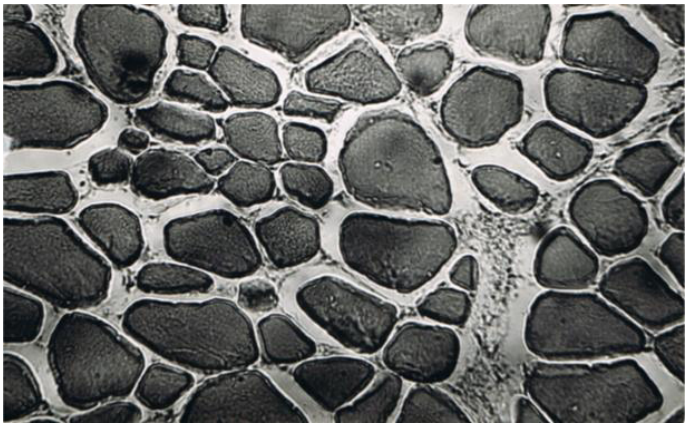


Photo 4. Histological picture of pork loin from hogs meat, x 300

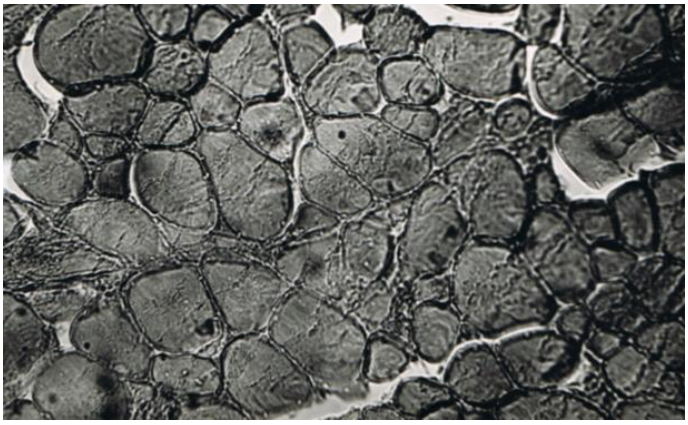


Photo 5. Histological picture of pork loin from boar meat, x 300

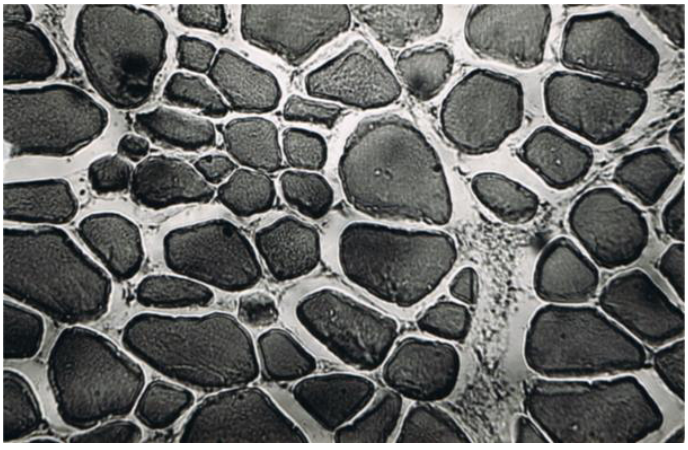


Photo 6. Histological picture of pork loin from hogs meat, x 300

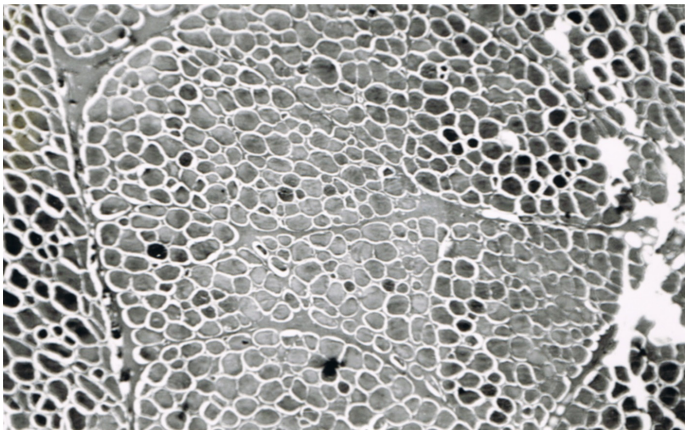


Photo 7. Histological picture of pork loin from boar meat, x 5

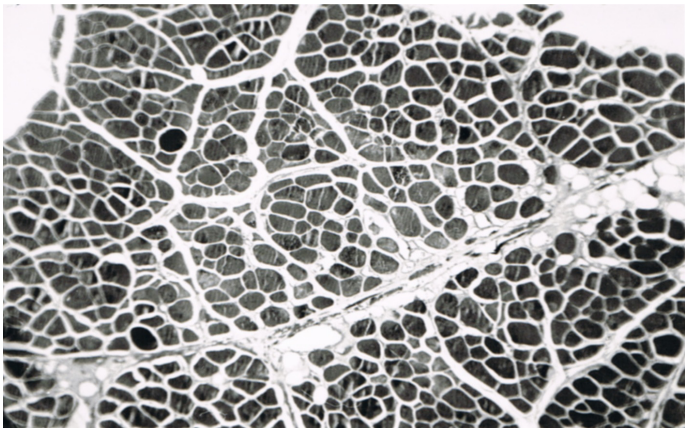


Photo 8. Histological picture of pork loin from hogs meat, x 10

Conclusions

Sex odour and taste had non-disqualifying intensity appeared in similar number of products made from hog and boar meat, in some product groups it was more characteristic for smoked products made from hog cuts, for the others it was faster identified in products made from boar meat. Sex odour and taste of disqualifying intensity was found in collars. In smoked products made from hog collar these determinant was found in a higher number of products.

Smoked products (pork loin, collar, smoked backfat) made from hog and boar cuts are characterized by similar results of organoleptic evaluation.

The structure of pork loins from boars meat compared to these from hogs was much more dense with narrower spaces between the muscle fiber bunches and lover amount of an intramuscular connective tissue.

References

Babol J., Squires E.J., Bonneau M., 1996. Factors Regulating the concentrations of 16 androstene steroids in submaxillary salivary glands of pigs. Journal Animal Science, 74, 413–419.

Babol J., Squires E.J., 1995. Quality of meat from entire male pigs. Food Research International, 3:201–212.

Baryłko-Pikielna N., 1975. Zarys analizy sensorycznej. WNT, Warszawa.

Blanchard P. 1995. Pork quality. Meat Focus International, 4 (10), 409–413.

Chen W., Forrest J.C., Peng I.C., Pratt D.E., Judge M.D., 1993. Palatability of prerigor cooked boar meat. Jornal Animal. Science. 71, 645–650.

Godt I., Kristensen K., Poulsen C.S., Iuhl H.J., Bech A.C., 1996. Aconsumer study of Danish entire male pigs. Fleischwirtschaft. 5, 518–520.

Mateńko K., Horszczaruk F., 1990. Organoleptyczna ocena jakości mięsa tuczonych knurków. Zeszyty Problemowe Postępów Nauk Rolniczych. 384, 103–106

Moss B.W., Have M., Walker N., 1992. Boar taint – The role of skatole. Meat Focus, 10, 289–292.

Ryszkowski J., Żebrowski Z., 1986. Badania nad tuczem i oceną tusz knurków. Roczniki Naukowe Zootechniki. Monografie i Rozprawy, 24, 180–190.

Rząsa A., 1998. Ustalenie optymalnego terminu kastracji knurków oraz wpływ tego zabiegu na użytkowość tuczną i rzeźną. Praca doktorska, Wrocław.

Smith W.C., Ellis M., Clark J.B.K., Innes N., 1983. A comparison of boars, gilts and castrates for bacon manufacture.a.Curing characteristics, bacon yield and qualty. Animal Production. 37 11–16.

Szmańko T., Górecka J., Bronkowski R., 2009. Wpływ trzebienia knurków na jakość mięsa. Prace Instytutu Zarządzania i Inżynierii Rolnej Państwowej Wyższej Szkoły Zawodowej w Sulechowie. Technologia Żywności i Żywienie Człowieka, 3, 55–60.

Szmańko T., Rząsa A., Świątkowska D., 2002, Wpływ trzebienia knurków na właściwości organoleptyczne mięsa i tłuszczu tuczników, Prace i Materiały Zootechnika, Zeszyt Specjalny 13: 167–175.

Wood I.D., Nute G.R., Fursey G.A.J., Cuthberson A., 1993. Effects of final cooking temperature on the eating quality of pork loin steaks. Animal Production. 56, 422–432.

Zawistowski S., 1986. Technika histologiczna. PZWL, Warszawa.

8

USES OF COLOUR DISPERSION PRODUCED WITH CARBOXYHEMOGLOBIN ADDITION

Introduction

Colour is the most widely used measure of durability and acceptability of fresh meat. On the meat purchasing decisions are influenced by colour more than any other quality factor because consumers consider discolouration as an indicator of freshness and wholesomeness. As a result, nearly 15% of retail beef in USA is discounted in price due to surface discolouration, which corresponds to annual revenue losses of $1 billion [Mancini, Hunt 2005]. Smith [2000] analysed the economic significance of discolouration of meat and meat products and have found that, discolouration of meat is 5.4% in sales of retail fresh meat and 3.7% of meat products. Prevention of deterioration of meat colour can limit return of products and greatly increase the profits of producers.

Myoglobin and hemoglobin are the proteins mainly responsible for meat colour. Hemoglobin is a watersoluble protein containing four globular protein subunits. Each subunit is composed of 8 a-helices linked by short no helical sections and non-protein heme group located in hydrophobic pocket of protein [Stryer 1996]. Iron atom is centrally located in the heme ring and can form six bonds. Four of these bonds are with pyrrole nitrogens while the 5 coordinates with the proximal histidine. A 6th site is available to reversibly bind ligands. A distal histidine also influences colour dynamics by affecting space relations within the hydrophobic heme pocket [Stryer 1996]. The ligand present and the valence of iron may dictate muscle colour (Fig. 1). Therefore, four major chemical forms of myoglobin are primarily responsible for meat colour [Livingston, Brown 1981, Mancini, Hunt 2005].

Deoxyhemooglobin (DeoHb) occurs when the heme iron is ferrous and no ligand is present at the 6th coordination site. Then meat change a colour on purplish-pink or purplish-red, what is typically for muscle after cutting and for products packaged in vacuum. Oxyhemoglobin (OxyHb) is made by oxygenation of hemoglobin or deoksyhemoglobin, what can happen when protein is exposed to oxygen, so the 6th coordination site is occupied by diatomic oxygen. The colour of oxyhemoglobin is discribed as bright cherry-red [Wallace 1982]. When derivatives of ferrous hemoglobin come to ferric form (methemoglobin, MetHb) by oxidation, no ligand can bind to 6th coordination site. Therefore discolouration is often referred to as the amount of surface area covered by metmyoglobin, what can be seen as brown-grey colour. Carboxyhemoglobin (COHb) occurs, when carbon monoxide binds to the vacant on 6th position [Livingston, Brown 1981]. Both deoxyhemoglobin and oxyhemoglobin can be converted to carboxy form. Carboxyhemoglobin presents intensive, bright cherry-red colour of meat, which is stable during the storage, [Lanier et al. 1978, Grant et al.

2002, Luño et al. 2000]. Until now CO has been used in Modified Atmosphere Packaging to maintain an attractive and stable cherry-red colour throughout retail life [Luño et al. 1998, Sorheim et al. 1999, Wilkinson et al. 2006, Jayasingh et al. 2001]. Based on stochiometric calculations Sorheim et al. [1997, 2001] reported that the use of low CO levels in modified atmosphere meat packaging does not present toxic risks for consumers.

Porcine blood (liquid and dry) treated with carbon monoxide, was used as alternative sources of food proteins [Fontes 2004]. The results indicate that blood saturation of CO give a product having greater potential for use in meat products without compromising its visual appearance.

A possibility for solving the negative aspects of meat discolouration may be the chemical modification of the hemoglobin molecule to the more stable and sensory accepted carboxyhemoglobin through the addition of carbon monoxide to the hemolysed erythrocytes from collected animal blood, taking advantage of the greater affinity of the heme group for the CO (Stryer, 1996). Formation of biocomposite, for example emulsion, contained carboxyhemoglobin, to obtain structured colour of meat seems to be promising in future.

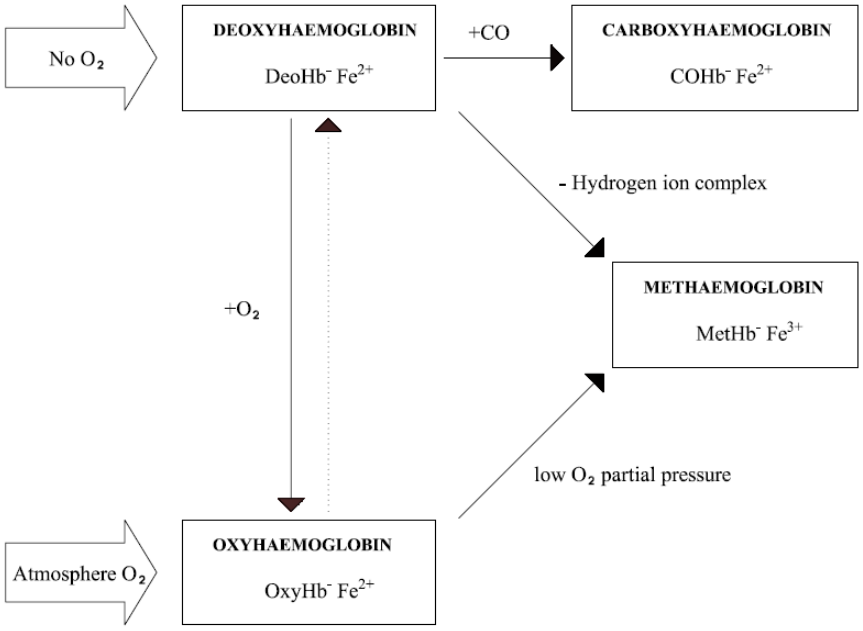


Fig. 1. Visible myoglobin redox interconversions on the surface of meat [Mancini 2005]

The stability of meat colour is strongly correlated with the oxidation of fats [Sanchéz-Escalante et al. 2001]. Antioxidants may be also used to protect lipids from oxidation and to stabilise oxymioglobin or oxyhemoglobin. Both natural and synthetic antioxidants, could increase the shelf life of biocomposite and meat covered by emulsion [Sebranek et al. 2005, Formanek et al. 2003, Ahn et al. 2002].

The aim of this study was to determine the possibility of increasing the colour stability of meat stored in refrigeration as a result of surface coating of meat by emulsion, which contains carboxyhemoglobin and antioxidants.

Materials and methods

This study includes two experiments. In first part of experiment the chemical composition was optimised. In second experiment piece of meat was covered by biocomposite, wich were produced in first part.

Porcine blood and longest dorsal muscle (musculus longissimus thoracis) was collected from Meat Plant "Dworeccy" in Golejewo. Materials was chilled to 4°C and purchased 48 hour post mortem.

First experiment

Box-Menken fractional model with three variables was used in this experiment. Rosemary extract addition on three levels: 250, 500 and 1000 ppm, was first variable. Three levels of BHA: 100, 150 and 200 ppm and time of storage were another two variables (Tab.1). Biocomposite without antioxidants was used as the controls sample.

To prepare emulsions were used: rapeseed oil "Kujawski" (ZT Kruszwica S.A.), dL-α-tocopherol acetate (HORTIMEX Sp. z o.o.), potassium sorbate (POCH S. A.), lysozyme chloride (OVOPOL Sp. z o.o.), heksametylenotethramin (urothropin, P. P. H. "STANLAB"), xantan (KERRY POLSKA Sp. z o.o.), L-ascorbic acid (POCH S.A.). The butylated hydroxyanisole BHA was obtained from SIGMA-ALDRICH Sp. z o.o. and rosemary extract STABILOTON WS was provided by Biofrost kaltvermahlen RAPS. Major component was carboxyhemoglobin obtained by the addition of carbon monoxide to the hemolysed erythrocytes from collected porcine blood

Xantan (0.1%) was dissolved in hemolysed erythrocytes treated with CO, than potassium sorbate was added in 1% level. IKA RH Basic 2 stirrer was used in dissolving process. Afterwards 9% of rapeseed oil "Kujawski", 1% of dL-α-tocopherol acetale and lysozyme chloride, 0.5% urothropin and 0.1% of L-ascorbic acid was added to emulsion. Lastly synthetic and natural antioxidants were used and samples were homogenized on BüCHI Mixer B-400 (9 000 rotations*min^{-1}) by 5 seconds. Emulsion was storage under refrigeration (4°C) by 0, 5, 10 and 15 days.

Second experiment

Box-Behnken fractional model with three variables was used in this experiment. Addition of antioxidants (Tab. 1), emulsion storage time and meat samples storage time were variables. Experimental meat samples were covered biocomposited stored by 0, 5, 10 and 15 days. Samples were vacuum packaged and stored in 4^{0}C by 0, 5, 10 and 15 days.

Analitical methods

*Instrumental evaluation of colour parameters L*a*b** (also referred to as CIELAB; CIE, 1976) was performed in colourimeterMINOLTA CR-400. In this colour space, L* indicates lightness and a* and b* are the chromaticity coordinates. The a* and b* indicate colour directions: +a* is the red direction, -a* is the green direction, +b* is the yellow direction, and –b* is the blue direction. Colour difference can be expressed as a single numerical value, dE*ab, which indicates the size of the colour difference but not in what way the colours are different.

Colourimeter was calibrated towards white master (Y=93.8, x=0.3158, y=0.3323), before every measurement. For colour indexes calculation the following settings were used: D65 illuminant and 10° observer angle. L*, a*, b * and dE*ab colour indexes were obtained every 5 day of storage, up to the 15 day. First measurement was realized directly after homogenization of emulsion [AMSA 1991].

Table 1

Experimental design

Variants coding	BHA [ppm]	Rosemary extract [ppm]
B0R0	0	0
B100R250	100	250
B100R500	100	500
B100R1000	100	1 000
B150R250	150	250
B150R500	150	500
B150R1000	150	1 000
B200R250	200	250
B200R500	200	500
B200R1000	200	1 000

Haem pigments content byWarris metod in Pikul's modyfication

Experimental meat sample (5 g) was homogenized (BÜCHI Mixer B-400) in 50 cm^3 chilled phosphate buffer (pH 6.8), by 5 seconds. Homogenate was chilled in 4–6°C by 60 minutes and then was centrifuged with 4 000g by 10 minutes (Centrifuge Sigma 3K30). Obtain precipitate was homogenized in 42.5 cm^3 buffer, storage by 60 minutes and cenrifuged. Both supernatants were merged to measuring cylinder and volume was gone down (value V in formula). 60 cm^3 of supernatant were centrifuged with 3000xg by 60 minutes, and then filtrated by Wathman 1 filter paper [Pikul 1993]. The absorption spectra of supernatants were obtained using spectrophotometer with wavelengths: 420 nm, 431 nm, 502 nm, 525 nm, 557 nm and 583 nm.

Total hem pigments content was calculated from the following formula [Pikul 1993]:

$$HPC=A \cdot 17500 \cdot V/7600 \cdot C \quad [mg \cdot g^{-1}]$$

where:
A – absorption value by 525 nm
V – dilution coefficient [cm^3]
C – sample mass [5 grams]
17500 – myoglobins gram-equivalent
7600 – molar coefficient for deo-, oxy- and metmyoglobin by 525 nm wavelength
*Total content of DeoMb, OxyMb, MetMb*were calculated from the following formulas [Krzywicki et al. 1978, Krzywicki et al. 1982, Tang and Faustman 2004]:

$$n[DeoMb]=C_{DeoMb}/C_{Mb}=-0.543R_1+1.594R_2+0.552R_3-1.329$$

$$n[OxyMb]=C_{OxyMb}/C_{Mb}=0.722R_1-1.432R_2-1.659R_3+2.599$$

$$n[MetMb]=C_{MetMb}/C_{Mb}=-0.159R_1-0.085R_2+1.262R_3-0.520$$

where:
n[DeoMb] – deoxymyoglobin content [mg · g^{-1}]
n[OxyMb] – oxymyoglobin content [mg · g^{-1}]
n[MetMb] – metmyoglobin content [mg · g^{-1}]
n[COMb] – carboxymyoglobin content [mg · g^{-1}]
$R_1 = A_{583}/A_{525}$;
$R_2 = A_{557}/A_{525}$;
$R_3 = A_{502}/A_{525}$;
Substituting the measured absorbances of the reference spectra, *the relative amount of CO-Mb* was obtained [Smulevich et al. 1999]:

$$n[COMb]=(A420 \cdot 0.78)-(A431 \cdot 0.67)/(A420 \cdot 0.32)+(A431 \cdot 0.55)\ [mg \cdot g^{-1}]$$

Depth penetration of emulsion in meat

In second experiment depth penetration (DP) of biocomposite in meat was obtained by correlate meat sample gauge and depth emulsion in meat. DP was calculated from the following formula:

$$DP = a \cdot 100/b \quad [\%]$$

where:
DP – Depth penetration of emulsion in meat
a – surface area of emulsion in meat [cm]
b – total gauge meat sample [cm]
The measurement of pH in meat was carried out on 10 g of grounded samples.
Lipid oxidation was evaluated with the determination of *thiobarbituric acid reactive substances* (TBARS) according to the method of Tarladgi et al. [1960] and modified by Novelli et al. [1998], [Ulu 2004].

Statistical analyses

Results obtained were submitted to multi-factor variance analysis ANOVA – Duncan's test and response surface Box-Behnken design in the STATISTICA v.6.1, considering a 5% significance.

Results and discussion

No meaningful significant effect of storage time of meat samples on L* parameter was noted in the present study (Tab. 2). Fernandez-Lopez et al. [2005] reported increasing (5%) of L* value after 12 days of storage. Furthermore, Georgantelis et al. [2007] and Namet et al. [2006] ascertained greatly influence of storage time on lightness of meat colour.

Meat storage by 0 and 5 days had lighter, more intense red colour. Samples covered by biocomposites storage by 15 days, had dark red colour. After covered meat by biocomoposites, a* values decreased from 18.1 (fresh emulsion) to 13.9 for samples with emulsion storage by 5 days. Values of b* parameter increased from -0.56 to 0.88 during storage. Significant

differences in total colour change (ΔE*ab) were observed after 10 days of storage (Tab. 2). Furthermore, colourimeter evaluation of colour indicated an increase in ‘‘red colour’’ score and an absence of "brown colour" development with the use of biocomposites (Tab. 2). Values of a* parameter in meat samples covered by emulsion with antioxidants was higher than in meat with control emulsion (Fig. 2A). Fresh meat samples produced with addition of 150 ppm of BHA and 1 000 ppm of rosemary extract had bright red colour. Samples produced with maximal addition of antioxidants had lower a* values, compare to control sample (Fig. 2A). Liu et al. [2009] reported increased a* value about 54.0% in poultry sausages produced with 500, 1000 and 1500 ppm of rosemary extract. Duong et al. [2008] wrote, that addition of BHA and BHT resulted in increased (32%) a* parameter compare to control samples. Furthemore, Aksu et al. [2005] proved the influence of BHA on red colour of beef products.

Lighter, less intensive red colour was obtained in meat covered by emulsion storage by 15 days [fig. 2B]. No significant differences in a* values were observed in all experimental variants produced with storage emulsion included 1 000 ppm of rosemary extract (Fig. 2B]. Fernandez-Lopez et al. [2005] reported that beef chop produced with 200 ppm rosemary extract had stable red colour. Furthermore, Nam et al. [2006] wrote about increased a* parameter about 9% in meat covered by rosemary extract and tocopherol compare to experimental samples without antioxidants. Balentine et al. [2006] proved profitable activity of rosemary extract on red colour of meat and meat products.

No visual differences in red colour were obtained in 15 days storage meat samples, covered by fresh or storage by 15 days emulsion. Meat produced with antioxidants had stable, bright red colour, compare to samples without antioxidants [Fig. 3A, 3B]. Addition of 200 ppm of BHA decreased values of a* parameter.

Table 2

Colour parameters of experimental meat samples, for difference storage times

Storage time for meat [days]	Storage time for emusion [days]	Colour features			
		L*	a*	b*	ΔE*ab
0	0	42.0^{a}	18.1^{b}	-0.1^{ab}	37.4^{a}
	5	45.0^{b}	13.9^{a}	0.1^{b}	37.9^{a}
	10	44.3^{b}	14.2^{a}	-0.1^{ab}	39.8^{b}
	15	42,0^{a}	14.2^{a}	-0.5^{a}	40.9^{b}
5	0	48.2^{b}	12.3^{b}	-0.5^{a}	34.6^{a}
	5	47.1^{ab}	13.1^{b}	-0.8^{a}	35.8^{a}
	10	47.2^{ab}	12.8^{b}	-0.5^{a}	35.5^{a}
	15	46.2^{a}	11.4^{a}	-0.6^{a}	35.8^{a}
10	0	48.1^{c}	13.6^{b}	-0.6^{a}	15.6^{a}
	5	45.4^{b}	13.8^{b}	-0.6^{a}	18.1^{b}
	10	45.5^{b}	12.4^{a}	-0.1^{b}	17.5^{b}
	15	44.1^{a}	12.3^{a}	0.2^{b}	18.7^{c}
15	0	48.1^{b}	13.5^{b}	1.3^{c}	15.3^{a}
	5	45.7^{a}	13.3^{b}	0.1^{a}	17.4^{b}
	10	46.0^{a}	12.1^{a}	0.4^{a}	17.2^{b}
	15	46.4^{a}	11.6^{a}	0.8^{b}	16.8^{b}

a–b – means followed by the same letter in column do not differ significantly ($p \leq 0.05$)

Samples produced with rosemary extract (1 000 ppm) and BHA (500 ppm) addition had the highest a* values (Fig. 3A, 3B). Analysis of the influence of antioxidants addition has on the variability of dE*ab in fresh meat samples covered by non storage emulsion, showed significant impact addition 500 ppm of rosemary extract (Fig. 2C). Esteves et al. [2006] reported increased dE*ab about 25% in pork pate produced with addition 0.1% of rosemary extract. Furthemore, Sanchez-Escalante et al. [2001] wrote that addition 1 000 ppm of rosemary extract inhibit meat discolouration, after 16 days of storage.

No significant differences in total colour change of meat samples were observed during storage of biocomposite (Fig. 2D).Maximal addition of BHA resulted in increased of total colour changes (Fig. 3C, 3D).

Oxymyoglobin concentration in meat samples covered by emulsion with antioxidants was higher than in meat with control emulsion. Nevertheless, Duong et al. [2008] reported no significant effect on OxyMb concentration in samples produced with BHA. Addition of 500 ppm rosemary extract decreased the metmyoglobin concentration about 8%. Sanchez-Escalante et al. [2001] ascertained decreased MetMb concentration in meats part produced with 1000 ppm rosemary extract.

Metmyoglobin concentration decreased from 0.59 $mg \cdot g^{-1}$ (control samples) to 0.53 $mg \cdot g^{-1}$ in samples produced with 100 ppm of BHA addition (Tab. 3). No significant differences in COMb concentration were observed in all experimental variants.

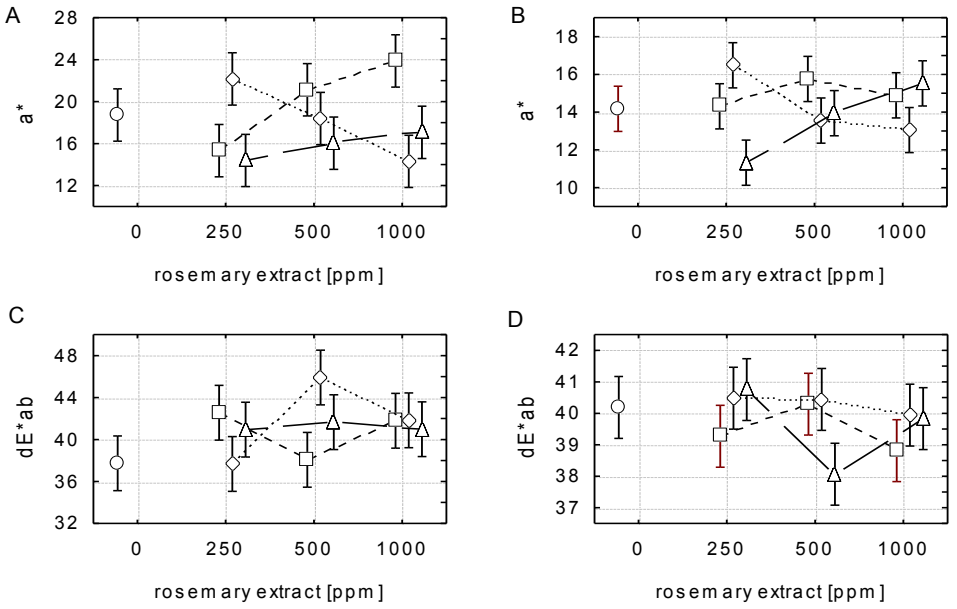


Fig. 2. Effect f rosemary extract and BHA on a* and dE*ab parameters for non storage meat samples; A, C – non storage emulsion, B, D – emulsion storage by 15 days; addition of BHA 0 ppm 100 ppm 150 ppm 200 ppm

Table 3

Myoglobin dyes concentration and total haem pigments content for different levels of BHA and rosemary extract

Factor type	Factor level [ppm]	DeoMb [mg · g^{-1}]	OxyMb [mg · g^{-1}]	MetMb [mg · g^{-1}]	COMb [mg · g^{-1}]	HPC [mg · g^{-1}]
Rosemary extract	0	0.21^{a}	0.19^{a}	0.59^{b}	0.79^{a}	8.67^{a}
	250	0.20^{a}	0.22^{ab}	0.56^{a}	0.77^{a}	8.14^{a}
	500	0.21^{a}	0.25^{b}	0.55^{a}	0.79^{a}	8.43^{a}
	1 000	0.20^{a}	0.22^{ab}	0.57^{ab}	0.76^{a}	8.48^{a}
BHA	0	0.21^{b}	0.19^{a}	0.59^{b}	0.79^{a}	8.67^{b}
	100	0.21^{b}	0.27^{b}	0.53^{a}	0.76^{a}	8.20^{a}
	150	0.20^{ab}	0.22^{a}	0.56^{ab}	0.78^{a}	8.14^{a}
	200	0.18^{a}	0.20^{a}	0.58^{bc}	0.78^{a}	8.71^{b}

a-b – means followed by the same letter in column do not differ significantly ($p \leq 0.05$)

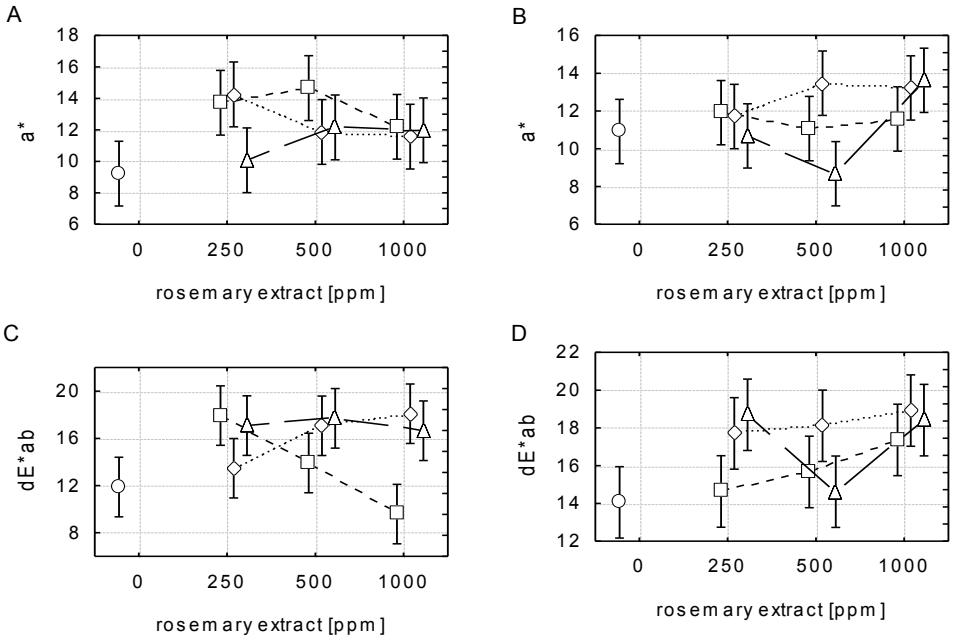


Fig. 3. Effect f rosemary extract and BHA on a* and dE*ab parameters for meat samples storage by 15 days; A, C – non storage emulsion, B, D – emulsion storage by 15 days; addition of BHA 0 ppm 100 ppm 150 ppm 200 ppm

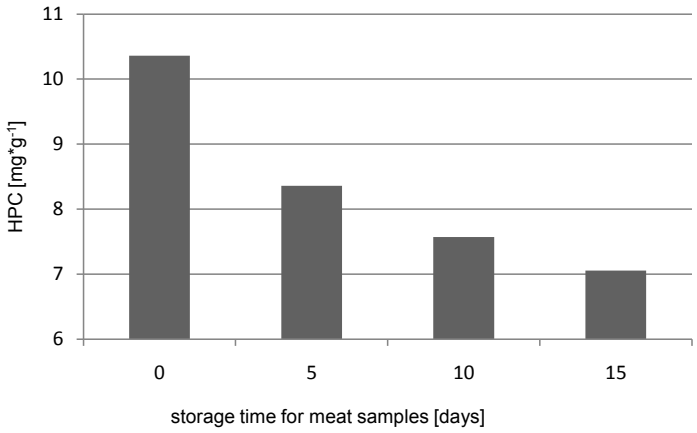


Fig. 4. Effect of storage time on total hem pigments content in meat samples

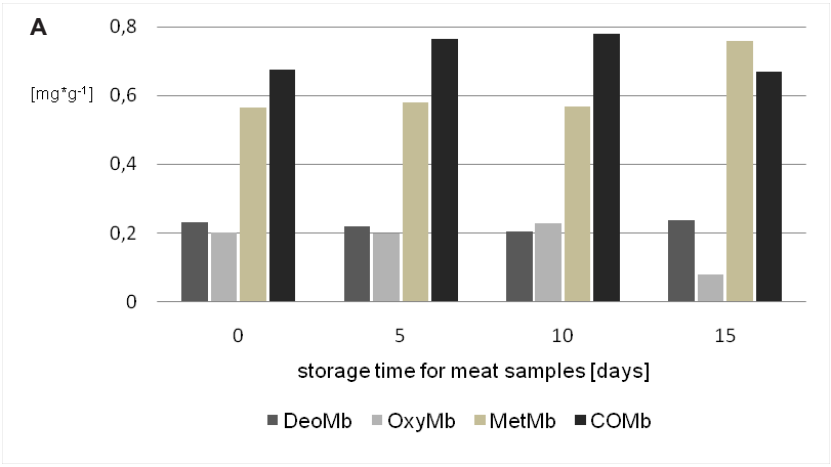
Samples produced with 100 ppm and 150 ppm of BHA addition had the lowest heme pigments content (Tab. 3). In meat samples covered with emulsion immediately after homogenization, oxymyoglobin concentration decreased from 0.20 mg · g^{-1} to 0.08 mg · g^{-1}, during storage (Fig. 5A). Metmyoglobin concentration increased about 34,0% after 15 days of storage. Carboxymyoglobin concentration was 0.76 mg · g^{-1} after 5 days of storage and increased about 13,0% compare to fresh sample (Fig. 5A). Analysis the influence of meat storage time on the variability of carboxymyoglobin in meat samples covered with biocomposytes storage 15 days, showed a increase of COMb concentration about 2,00% after 10 days of storage. Concentrations of all myoglobins dyes were stable during storage (Fig. 5B). Balentine et al. [2006] reported OxyMb concentration decreased during storage.

Analysis of the influence storage time of meat samples has on the variability of total haem pigments content, showed a significant influence of storage time. Values HPC decreased about 42.0% after 15 days of storage (Fig. 4).

Significant differences in depth penetration of emulsion in meat (Fig. 6) were observed immediately after cover meat samples by biocomposites storage in different times. Analyzed parts of fresh meat, the DP parameter was higher in samples covered by emulsion storage by 15 days. After 10 days of storage, depth penetration parameter was higher in meat with fresh biocomposite. After two weeks of storage, equal levels of penetration (approx 25.0%) were obtained in all used variants. Meat samples covered by fresh or 15 days storage emulsion were characterized the same penetration dynamics (Fig. 6).

Analysis influence of rosemary extract and BHA addition has on depth penetration of hydrosols in meat showed no significant effect.

Analysis the influence emulsion storage time has on the variability of pH in meat samples, showed, that the highest leap of pH (approx 9.00%) was obtained in meat covered by fresh emulsion (Fig. 7). After 5 days of storage, for samples with emulsion storage 10 and 15 days, pH values decreased from 5.45 to 5.38. After two weeks of storage, insignificant differences in pH were observed in all variants (Fig. 7).



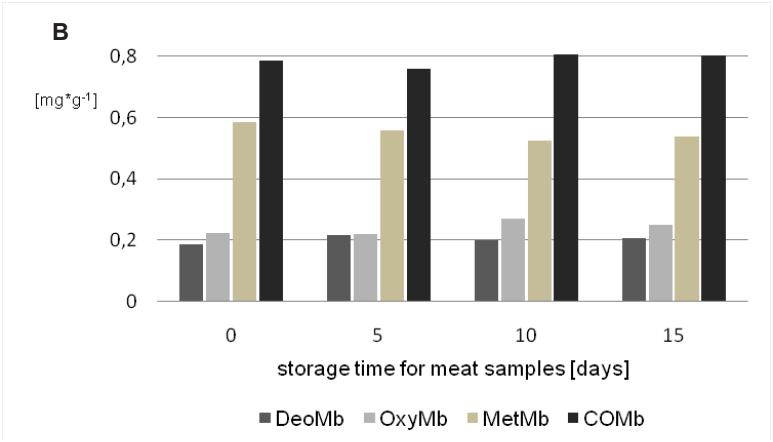


Fig. 5. Effect of storage time of meat samples on concentration of myoglobin dyes;
A. – meat covered emulsion immediately after homogenization,
B. – meat covered emulsion storage by 15 days

Analysis the influence antioxidants addition has on variability of TBARS, showed greatly decreased of parameter in samples produced with antioxidants. Addition of 1 000 ppm of rosemary extract resulted in TBARS decreased about 12.2%, compare to control samples (Fig. 8). Liu et al. [2009] reported increased inhibition lipid oxidation in poultry sausages produced with addition 500, 1 000 or 1 500 ppm of rosemary extract.

TBARS numbers in meat covered by emulsion containing 200 ppm of BHA decreased about 18.9%, compare to hydrosols without antioxidants.

Analysis lipid oxidation in non storage samples, showed that variant B200R500 had the lowest TBARS number and variant B0R0 – the highest (1.52 μgMDA · g^{-1}) (Fig. 8).

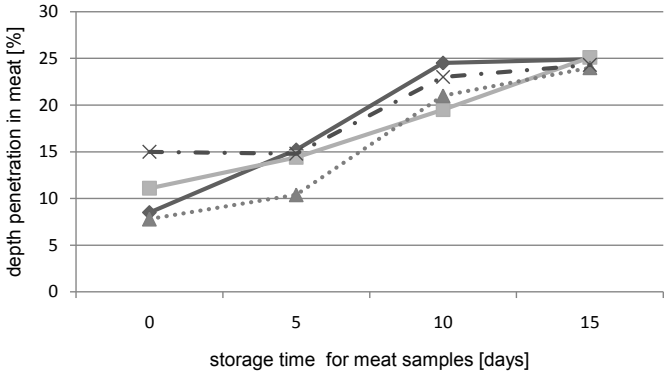


Fig. 6. Influence of storage times of emulsion and meat samples on depth penetration of emulsion in meat; time of storage for biocomposites: 0 days, 5 days, 10 days, 15 days

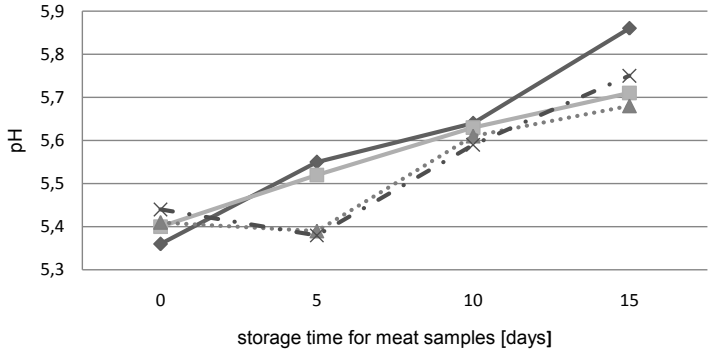


Fig. 7. Influence of storage times of meat samples and emulsion on pH in meat; time of storage for biocomposites: 0 days, 5 days, 10 days, 15 days

Aksu [2005] reported TBARS decreased about 58.0% in samples produced with addition 100 ppm of BHA, compare variants with 50 ppm of BHA.

After 15 days of storage lipid oxidation increased about 48.0% (Fig. 9). After two weeks of storage, the lowest values of TBARS (1.58 μgMDA*g^{-1})were obtained in variants B200R500 and B200R1000 (Fig. 8). Nassu et al. [2003] wrote, that addition of rosemary extract resulted in stabilized lipid oxidation during storage by 90 days. Furthermore, Hernandez-Hernandez et al. [2009] reported decreased TBARS number in meat stuffing produced with rosemary extract. Analysis influence of biocomposites storage time has on TBARS, no significant differences in lipid oxidation were observed. The highest TBARS number (2.03 μgMDA*g^{-1}) were obtained in meat samples covered by emulsion storage by 15 days (Fig. 9). Sebranek et al. [2005] reported increased inhibition of lipid oxidation with increased rosemary extract addition.

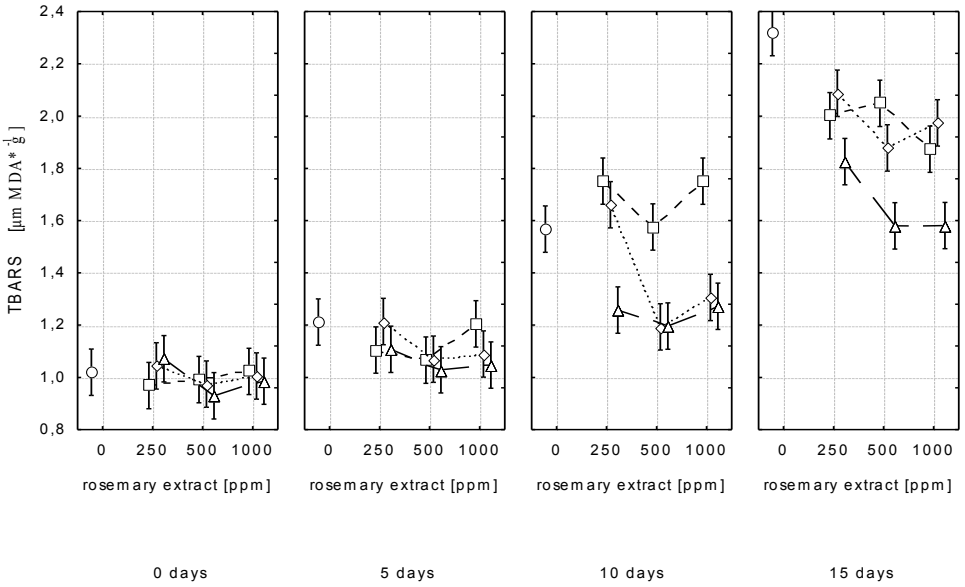


Fig. 8. Effect of rosemary extract and BHA on TBARS during storage of meat samples; addition of BHA 0 ppm 100 ppm 150 ppm 200 ppm

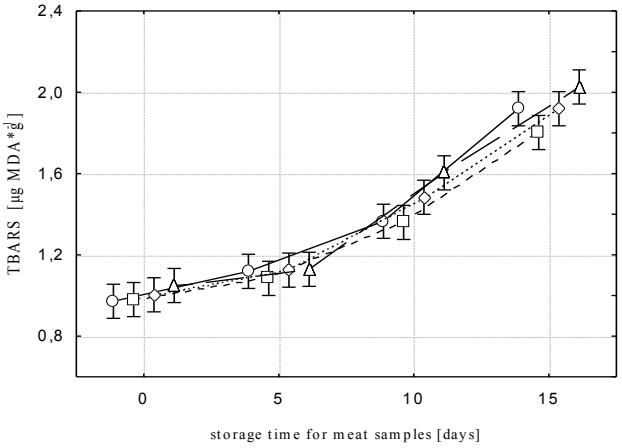


Fig. 9. Influence of storage times of meat samples and emulsion on TBARS; storage time for hydrozols 0 days 5 days 10 days 15 days

Conclusion

Experimental emulsion had greatly cover properties and high coefficientof depth penetration in meat.

The depth penetration of hydrosols in experimental meat reached 25.0% after 10 days of storage.

Meat covered by experimental hydrosols presented a redder colour and lower values of lightness L* during 15 days of storage.

Addition of rosemary extract in hydrosols resulted in dimming colour of meat and increased a* parameter value.

Meat covered by biocomposites produced with 200 ppm of BHA had lower value of b* parameter.

Covering meat by emulsion resulted in double increased a* parameter.

Experimental samples covered by hydrosols produced with addition 200 ppm of BHA and 1000 ppm of rosemary extract had the lowest lipid oxidation degree.

Low, stable metmyoglobin concentration was obtained in meat covered by emulsion with antioxidants addition.

Carboxymyoglobin concentration was stable during storage.

The mean concentration of carboxymyoglobin in sample with 150 ppm BHA and 1000 ppm rosemary extract was 0.81 mg $\cdot$ g^{-1}.

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References

Ahn J., Gruen I.U., Fernando L.N., 2002. Antioxidant properties of natural plant extracts containing polyphenolic compounds in cooked ground beef. Journal of Food Science 67, 1364–1369

Aksu M.I., Kaya M., 2005. The effect of alfa-tocopherol and butylated hydroxyanisole on the colour properties and lipid oxidation of kavurma, a cooked meat product. Meat Science 71, 277–283

AMSA, Mat. 44. Recipr. Meat Conf. "Guidelines for meat color measurement", Chicago, National Live Stock and Meat Board, USA, 9–12 June 1991 r.

Balentine C.W., Crandall P.G., O'Bryan C. A., Duong D. Q., Pohlman F. W., 2006. The pre- and post-grinding application of rosemary and its effects on lipid oxidation and color during storage of ground beef. Meat Science, 73, 413–421.

Commission Internationale de l'eclariage CIE, Paris 1976 r.

Duong D. Q., Crandall P. G., Pohlman F. W., O'Bryan C. A., Balentine C.W., Castillo A., 2008. Improving ground beef safety and stabilizing color during irradiation using antioxidant, reducants or TSP. Meat Science, 78, 359–368.

Estevez M., Ventanas S., Cava R., 2006. Effects of natural and synthetic antioxidants on protein oxidation and colour texture changes in refrigerated stored porcine liver pate. Meat Science, 74, 396–403.
Fernandez-Lopez J., Zhi N., Aleson-Carbonell L., Perez-Alvarez J. A., Kuri V., 2005. Antioxidant and antibacterial activities of natural extracts: application in beef meatballs. Meat Science, 69, 371–380.
Fontes P. R., Gomide L. A. M., Ramos E. M., Stringheta P. C., Parreiras J. F. M., 2004. Color evaluation of carbon monoxide treated porcine blood. Meat Sci., 68, 507–513.
Fontes P.R., Gomide L.A. M., Fontes E.A. F., Ramos E.M., Ramos A. L.S., 2010. Composition and color stability of carbon monoxide treated dried porcine blood. Meat Science, 85, 472–480.
Formanek Z., Lynch A., Galvin K., Farkas J., Kerry J.P., 2003. Combined effects of irradiation and the use of natural antioxidants on the shelf-life stability of overwrapped minced beef. Meat Science, 63, 433–440.
Georgantelis D., Blekas G., Katikou P., Ambrosiadis I., Fletouris D.J., 2007. Effect of rosemary extract, chitosan and alfa-tocopherol on lipid oxidation and colour stability during frozen storage of beef burgers. Meat Science, 75, 256–264.
Grant M.J.C., Clay B., 2002. Accidental carbon monoxide poisoning with severe cardiorespiratory compromise in 2 children. American J. of Crit. Care, no. 11, 128–132.
Hernandez-Hernandez E., Ponce-Alquicira E., Jaramillo-Flores M. E., Guerrero Legarreta I., 2009. Antioxidant effect rosemary (Rosmarinus officinalis L.) and oregano (Origanum vulgare L.) extracts on TBARS and colour of model raw pork batters. Meat Science, 81, 410–417.
Jayathilakan K., Sharma G. K., Radhakrishna K., Bawa A. S., 2007. Antioxidant potential of synthetic and natural antioxidants and its effect on warmed-over-flavour in different species of meat. Food Chemistry, 105, 908–916.
Krzywicki K., 1978. Assessment of relative centent of myoglobin, oxymyoglobin and metmyoglobin of the surface of beef. Meat Science, 3, 2–10.
Krzywicki K., 1982. The determination of heam pigments in meat. Meat Science, 7, 29–36
Lanier T.C., Carpenter J.A., Toledo R.T., Reagan J.O., 1978. Metmyoglobin reduction in beef systems as affected by aerobic, anaerobic and carbon monoxide-containing environments. Journal of Food Science, 43, 1788–1792, 1796.
Liu D., Tsau R., Lin Y., Jan S., Tan F., 2009. Effect of various levels of rosemary or Chinese mahogany on the quality of fresh chicken sausage during refrigerated storage. Food Chemistry, 117, 106–113.
Livingston D.J. i Brown W.D., 1981. The chemistry of myoglobin and its reactions. Food Technology, 35, 244–252.
Luńo M., Beltrán J., Roncalés P., 1998. Shelf-life and colourmstabilization of beef packaged in a low O2 atmosphere containing CO loin steaks and ground meat. Meat Science, 48, 75.
Mancini R.A., Hunt M.C., 2005. Current research in meat color. Meat Sci., 71, 100–121.
Nam K.C., Ko K.Y., Min B.R., Ismail H., Lee E.J., Cordray J., Ahn D.U., 2006. Influence of rosemary-tocopherol packaging combination on meat quality and survival of pathogens in restructured irradiated pork lions. Meat Science, 74, 380–387.
Nassu T.R., Goncalves G.A. L., Pereira da Silva A.A. M., Beserra J.F., 2003. Oxidative stability of fermented goat meat sausage with different levels of natural antioxidant. Meat Science, 63, 43–49.
Novelli E., Zanardi E., Ghiretti G. P., Campanini G., Dazzi G., Madarena G., Chizzolini, R., 1998. Lipid and cholesterol oxidation in frozen stored pork, salame Milano and mortadella. Meat Science, 48, 29–40.
Pikul J., 1993. Ocena technologiczna surowców i produktów przemysłu drobiarskiego, Wyd. ARP, Poznań.

Sanchez- Escalante A., Djenane D., Torrescano G., Beltran J. A., Roncales P., 2001. The effects of ascorbic acid, taurine, carnosine and rosemary powder on colour and lipid stability of beef patties packaged in modified atmosphere. *Meat Science,* 58, 421–429.

Sebranek J.G., Sewalt V.J. H., Robbins K.L., Houser T.A. 2005. Comparison of natural rosemary extract and BHA/BHT for relative antioxidant effectiveness in pork sausage. Meat Science, 69, 289–296.

Smith G.C., Belk K.E., Sofos J.N., Tatum J.D., Williams S.N., 2000. Economic implications of improved color stability in beef. New York: Wiley Intersci.

Smulevich G., Droghetti E., Focardi C., Coletta M., Ciaccio C., Nocentini M., 2007. A rapid spectroscopic method to detect the fraudulent treatment of tuna fish with carbon monoxide. Food Chemistry, 101, 1071–1077.

Sorheim O., Aune T., Nesbakken T., 1997. Technological, hygienic and toxicological aspects of carbon monoxide used in modified-atmosphere packaging meat. Trends in Food Science and Technology, 8, 307–312.

Sorheim O., Nissen H., Nesbakken T., 1999. The storage life of beef and pork packaged in an atmosphere with low carbon monoxide and high carbon dioxide. Meat Science, 52, 152–164.

Sorheim O., Langsrud O., Cornforth D.P., Johannssen T.C., Slide E., Berg P., 2006. Carbon monoxide as a colorant in cooked or fermented sausages. Journal of Food Science, 71, C549-C555.

Stryer L. 2000. Biochemia. Wydawnictwo Naukowe PWN, Warszawa.

Tang J., Faustman C., Hoagland T.A., 2004. Revisited: equations for spectrophotometric determination of Myoglobin redox forms in aqueus meat extracts. Food Chemistry And Toxicology, 69, 717–720.

Tarladgis B.G., Watts B.M., Younatham M.T., 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. Journa of the American Oil Chemist Society, 37, 44–48.

Ulu H., 2004. Evaluation of three 2-thiobarbituric acid methods for the measurement of lipid oxidation in various meats and meat products. Meat Science, 67, 683–687

Wallace W.J., Houtchens R.A., Maxwell J.C., Caughey S., 1982. Mechanism of autoxidation for hemoglobins and myoglobins. J. of Bio. Chem., 257.

Warriss P.D., 1979. The extraction of heam pigments from fresh meat. Journal Food Technology, 14, 75–80.

Wilkinson B., Janz J., Morel P., Purchas R., Hendriks W., 2006. The effect of modified atmosphere packaging with carbon monoxide on the storage quality of master-packaged fresh pork. Meat Science, 73, 605–610.

9

THE EFFECT OF SELECTED PLASTICIZERS ON STRENGTH PROPERTIES OF EDIBLE FILMS

Introduction

The use of edible coatings was found large attention in last few years, mainly because of the possibility for extending the shelf life of foods. An edible coating or film has been defined as a thin, continuous layer of edible material placed on foods or between food components. The aim of this study is to produce the natural biopolymeric coating which may be eaten together with the food and present specific properties,. Their function is to provide a barrier to mass transfer (water, gas and lipids), to serve as a carrier of food ingredients and additives (pigments, flavours, antioxidants and antibiotics), or to provide mechanical protection. Edible coatings for suitably designed mechanical properties can replace synthetic packaging [Krochta et al. 1997, Tendej 2001].

Protective films are manufactured mostly from natural polymers, animal and plant origin, such as proteins, gums, lipids, which are completely biodegradable and safe for the environment [Cao 2007, Debeaufort et al. 1998, Guilbert et al. 1996]. Additive substances, which may present following properties or activity: antimicrobial, antioxidant, plasticizing (glycerol, sorbitol, mannitol, polyethylene glycol), colouring and light-absorbing substances are used in production of edible coatings. Films created solely from polymers are brittle, while the additive of plasticizer increases their flexibility [Fernandez 2007].

A plasticizer is defined as a substance or material incorporated in a material (usually a plastic or an elastomer) to increase its flexibility or workability.

Functionality hydrocolloid coatings depends on their chemical composition, structure and properties of a polysaccharide and a plasticizer used [Yang L. et al. 2000]

Mechanical properties, relevant to the application of edible coatings on the product, determine the sustainability and strength of coatings and stability during the storage time [Fernandez et al. 2207, Jones 2002, Kaya 1997].

The aim of this study was to determine the effect of selected plasticizers (glycerol, polyethylene glycol, sorbitol) on the mechanical properties of protective polysaccharide films.

Materials and methods

In production of protective film were used: hydroxypropylmethylcellulose (HMPC 100 PA 2208 FG) from Wolff Cellulosics and carrageenan (WG 2000) AMCO and following plasticizers, such as: D – sorbitol (POCH. SA), polyethylene glycol PEG 400 (POCH. SA), glycerol (ZCHG "Pollena – Stum").

Experiment was executed according to bifactor model, by assumption: three different concentrations hydroxypropylmethylcellulose 100 (HPMC 100), carrageen (0, 1, 2%) and plasticizer (1, 1,4, 2%).

The first step in obtaining experimental coatings was to obtain an aqueous solution of hydrocolloids, which was placed in a water bath for 20 minutes at 75°C. The cooled sol was stirred using a stirrer speed of R50D CAT 250 r/min, gradually adding the plasticizer (Tab. 1). The resulting mixture was poured to forms coated with Teflon (80 mm x 200 mm) and dried for about 24 hours. at 25°C with a humidity of 60%.

The dried films were used to measure the tensile strength and puncture and elongation at break. Designation of selected mechanical parameters was performed using a Materials Testing Machines Zwick/Roell Z010. Measurement of tensile strength and elongation tensile was made using a test – a simple extension of the appointment F_{maxw} penetration test was performed by using a compression stem F_{maxp} setting. The requirements for this test were as follow: the sample dimensions 15 x 7 x 0.046 mm, drive speed of head for the tensile force was 1 mm/s, for the puncture force was 0.5 mm/s and 6.0 mm shank diameter [ASTM, 1996].

Statistical analysis was performed using the Software STATISTICA (Version 7.0, Statsoft, Inc.). Response surface methodology (RSM) was used to investigate the simultaneous effect of two experimental factors. This test allows for the calculation of the coefficient estimates of quadratic equation. Polynomials were fitted to the experimental data as follows:

$$Y=\beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_{11}X_{11} + \beta_{22}X_{22} + \beta_{12}X_{12}$$

Where Y is the estimated response, β_0, β_1, β_{11}, β_{22}, β_{12} are constant and regression coefficients of the model, and X_1, X_2 are levels of independent variables, i.e., the concentrations of carrageen and plasticizer, respectively. The results of measurements of tensile strength film, puncture and tensile elongation were evaluated by analysis of variance requesting uniform groups based on Duncan's test at $\alpha<0.05$, and response surface method, verifying the importance of factors based on the so-called volatility assess the effects.

Table 1

Experimental design

Code	HPMC 100 [%]	Carrageen [%]	Glicerol [%]	Code	HPMC 100 [%]	Carrageen [%]	Sorbitol [%]	Code	HPMC 100 [%]	Carrageen [%]	PEG 400 [%]
H0G1	0	2	1	H0S1	0	2	1	H0P1	0	2	1
H0G1.4	0	2	1.4	H0S1.4	0	2	1.4	H0P1.4	0	2	1.4
H0G2	0	2	2	H0S2	0	2	2	H0P2	0	2	2
H1G1	1	1	1	H1S1	1	1	1	H1P1	1	1	1
H1G1.4	1	1	1.4	H1S1.4	1	1	1.4	H1P1.4	1	1	1.4
H1G2	1	1	2	H1S2	1	1	2	H1P2	1	1	2
H2G1	2	0	1	H2S1	2	0	1	H2P1	2	0	1
H2G1.4	2	0	1.4	H2S1.4	2	0	1.4	H2P1.4	2	0	1.4
H2G2	2	0	2	H2S2	2	0	2	H2P2	2	0	2

Results and discussion

Puncture strength

Significant effect of HPMC and glycerol on the variability of F_{maxp} obtained from puncture test was found. It was observed that increasing of glycerol content and HPMC content coatings decreases strength to puncture. Similar conclusions are reached by Vanina et al. showing a negative effect of glycerol on the strength of films puncture (F_{maxp}=8.9 N for 0.6% added glycerol, and F_{maxp}=18.28 N at 0.2% added glycerol).

The lowest F_{maxp} value (22.72 N) was obtained for variant H2G2 (Fig. 1). The highest value of (46.74 N) was determined for coatings containing 1.4% glycerol.

Analyzing the puncture strength of experimental coatings with the addition of polyethylene glycol (PEG 400) and sorbitol had a significant effect of plasticizers on the variability of parameter F_{maxp}. It was observed that increasing levels of sorbitol (1–1.4%) caused the increases of F_{maxp} to 9.22%. Further increase of tested plasticizer concentration (1.4–2%) reduces the value of this parameter (Fig. 2).

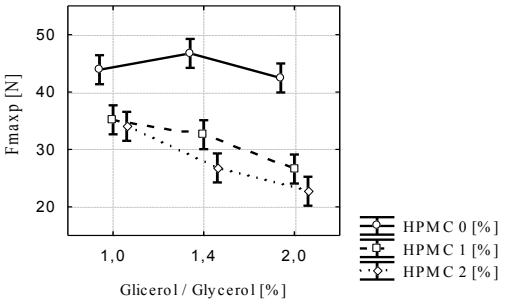

Fig. 1. Influence of HPMC 100 and plastificators on F_{maxp} Glicerol / Glycerol

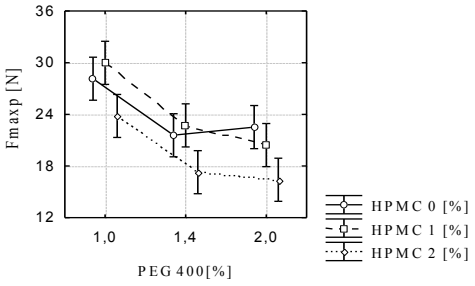

Fig. 2. Influence of HPMC 100 and plastificators on F_{maxp} PEG 400

The maximum of penetration force of coatings with addition PEG 400, showed a linear downward trend (Fig. 3).

The highest F_{maxp} value among all tested coatings was obtained for variant H0S1.4 (51.75 N) while the lowest (16.40 N) for the H2P2.

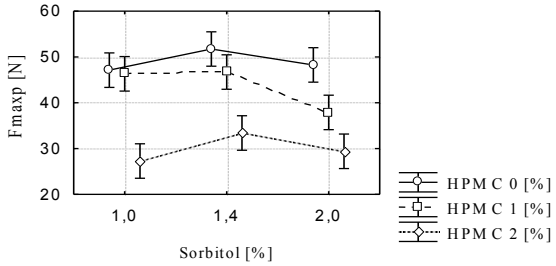

Fig. 3. Influence of HPMC 100 and plastificators on F_{maxp} Sorbitol

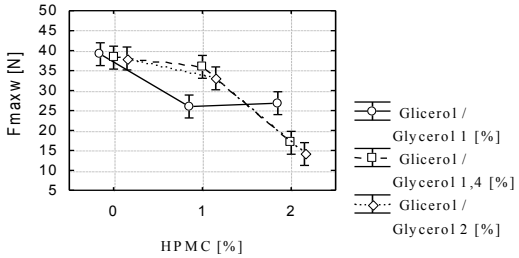

Fig. 4. Influence of HPMC 100 and plastificators on F_{maxw} Glicerol / Glycerol

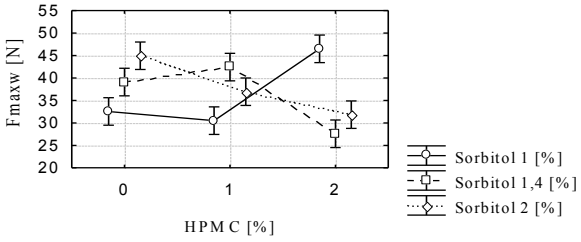

Fig. 5. Influence of HPMC 100 and plastificators on F_{maxw} Sorbitol

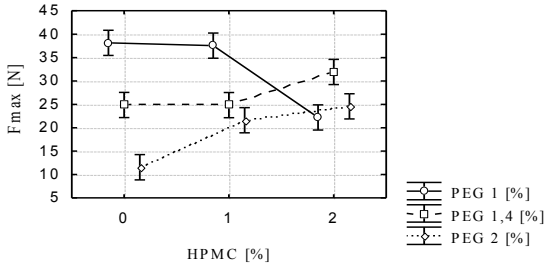

Fig. 6. Influence of HPMC 100 and plastificators on F_{maxw} PEG 400

Tensile strength

The coatings produced with the addition of glycerol at 1.4 and 2% showed no significant differences in the assessment of tensile strength. Increase of HPMC level in the experimental films reduces the value of F_{maxw}. The highest F_{maxw} value in protective films was characterized by a content obtained without hydroxypropylmethylcellulose (Fig. 4–6). In a study conducted by Tang et al. and Cho et al. found a negative effect of the addition of glycerol on the value of the maximum elongation force [Cho, Rhee 2002, Tang et al. 2008].

It was observed that in addition to experimental coatings PEG 400 at 1.4 and 2% and HPMC at 2%, increases F_{maxw}. Comparing hydrocolloid effects on the strength of the experimental coatings was found that regardless of the type of plasticizer, comparable values were obtained for films F_{maxw} protection from participation HPMC at 1%. The results obtained in the tensile test showed that the highest value F_{maxw} (53.03 N) was characterized by a variant of H2S1, and the lowest (11.56 N) for variant H0P2 (Fig. 7). However, in a study conducted by Sothornvit et al. where the base of β-lactoglobulin was found that the highest resistance to elongation were characterized by a the coating with the addition of glycerol, and the lowest of PEG 400 [Sothornvit et al. 2001] comparing the mechanical properties of experimental films made with glycerol or sorbitol, showed that the glycerol-containing the coating have higher coefficient F_{maxw} [Mali et al. 2005].

Elongation at break (εz)

It was noted that value of elongation at break for experimental coatings produced with carrageenan 2%, increased with the increasing concentration of plasticizer. Vavin and Tang were proved that the addition of glycerol increases the flexibility of the protective film [Tang et al. 2008, Vanin et al. 2005]. However Martelli was found that the coatings preparedwith sorbitol were characterized by low values of the coefficient εz [Martelli et al. 2006].

Films obtained with PEG 400 were presented the highest values of elongation – the maximum value of 16.32% for εz H2P1.4. Sothornvita and others were obtained low strength elongation of coatings containing PEG 400, what is in opposite with our results [Sothornvit, Krochta 2001]. Analysing the influence of plasticizer concentration on the variability of the elongation at break, coatings produced with glycerol and sorbitol were characterized by similar values of these parameter (Fig. 8 and Fig. 9).

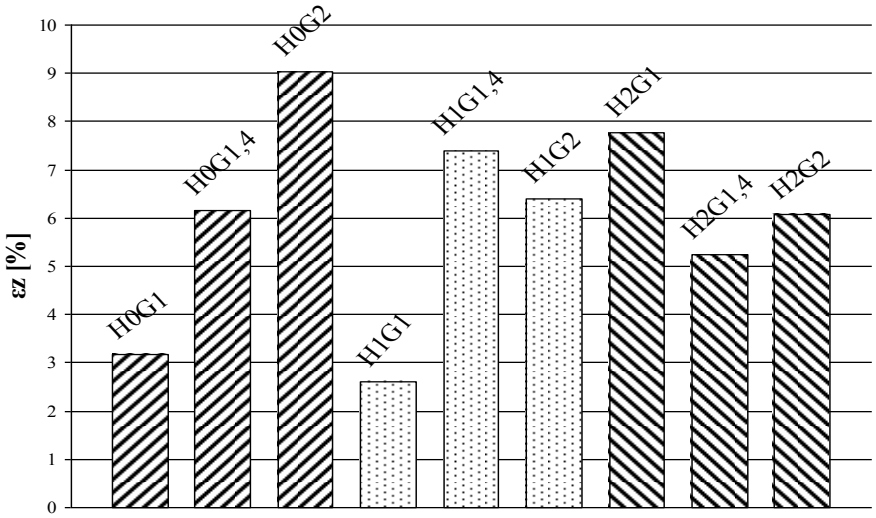

Fig. 7. Influence of HPMC 100 and glycerol on ε_z

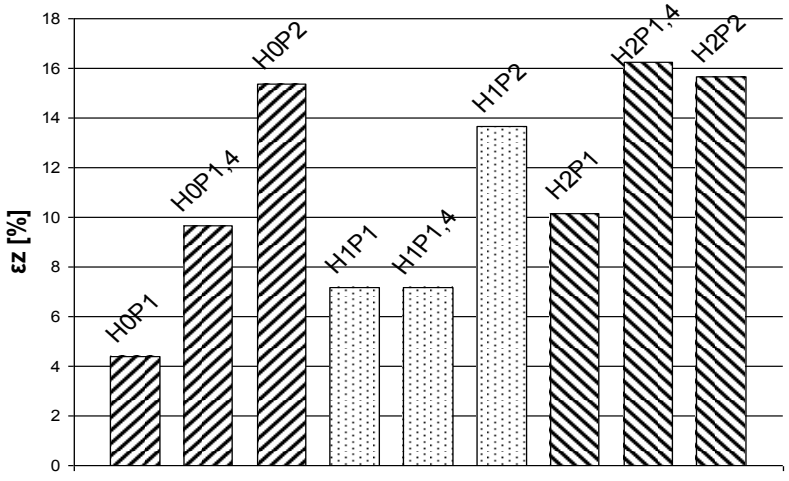

Fig. 8. Influence of HPMC 100 and sorbitol on ε_z

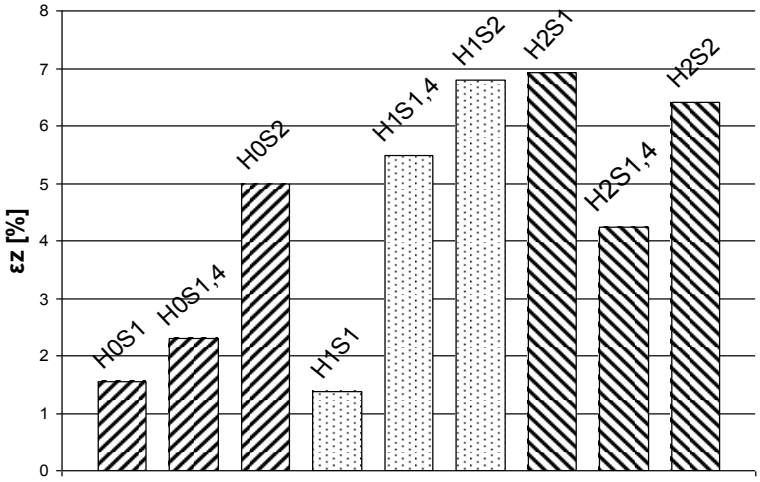

Fig. 9. Influence of HPMC 100 and PEG 400 on ε_z

Conclusions

1. Results of the experiment showed that increasing the concentration of hydroxypropylmethylcellulose in films reduces both the maximum value of puncture force, and the maximum force of elongation.
2. The lowest strength puncture and the highest capacity for elongation at break were observed for coatings containing PEG 400 as plasticizer.
3. Protective films prepared with 1% of glycerol, without addition of HPMC 100 showed the highest elongation and puncture strength.
4. The coatings obtained with the addition of sorbitol characterized the lowest values of strength parameters which were evaluated.

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References

ASTM, 1996. Test methods for tensile properties of thin plastic sheeting, D882–91. Annual book of ASTM. Philadelphia, PA: American Society for Testing and Materials.

Cao N., Fu Y., 2007. Preparation and physical properties of soy protein isolate and gelatin composite films. Food Hydrocolloids, 21, 1153–1162.
Cho S.Y., Rhee Ch., 2002. Sorption characteristics of soy protein films and their relation to mechanical properties. Lebensm.-Wiss. u.-Technol. 35, 151–157.
Debeaufort F., Quezada-Gallo J.A., Voilley A., 1998. Edible films and coatings: Tomorrow`s pacjagings: A review. Critical Reviews in Food Science, 38 (4), 299–313.
Fernandez L., Diaz de Apodace E., Cebrian M., Villaran M.C., Mate J.I., 2007. Effect of the unsaturation degree and concentration of fatty acids on the properties of WPI-based edible films. European Food Reserch Technology, , 224, 415–420.
Guilbert S., Gontard N., Gorris L.G.M., 1996. Prolongation of the shelf-life of perishable food products using biodegradable films and coatings. Lebensm.-Wiss. U.-Technol., 29, 10–12.
Jones D.B., Middelberg A.P.J., 2002. Direct determination of the mechanical properties of an interfacially adsorbet protein film. Chemical Engineering Science, 57, 1711–1722.
Kaya S., Kaya A., 2000. Microwave draying effects on properties of whey protein isolate edible films. Journal of Food Engineering, 43, 91–96.
Krochta J.M., Mulder-Jahnson C., 1997. Edible and biodegradable polymer films: challenges and opportunities. Food Technology, 52 (2), 61–74.
Mali S., Sakanaka M.S. Yamashita F., Grossmann M.V.E., 2005. Water sorption and mechanical properties of cassava starch films and their relation to plasticizing effect. Carbohydrate Polymers, 60, 283–289.
Martelli S.M., Moor G.R.P., Laurindo J.B., 2006. Mechanical properties, water vapor permeability and water affinity of feather keratin films plasticized with sorbitol. Journal Polymer Environ, 14, 215–222.
Sothornvit R., Krochta J.M., 2001. Plasticizer effect on mechanical properties of β-lactoglobulin fims. Journa of Food Engineering, 50, 149–155.
Tang X., Alavi S., Herald T.J., 2008. Effects of plasticizers on the structure and properties of starch–clay nanocomposite films. Carbohydrate Polymers, 74, 552–558.
Tendej, M. Tendej B., 2001. Białka sojowe jako składniki powłok jadalnych. Przemysł Spożywczy, 7, 20–23.
Vanin F.M., Sobral P.J.A. Menegalli F.C., R.A. Carvalho R.A., A.M.Q.B. Habitante A.M.Q.B., 2005, Effects of plasticizers and their concentrations on thermal and functional properties of gelatin-based films. Food Hydrocolloids 19, 899–907.
Yang L., Paulson A.T., 2000. Mechanical and vapour barrier properties of edible gellan films, Food Research International, 33, 563–570.
Yang J., Yu J., Ma X., 2006. Study on the properties of ethylenebisformamide and sorbitol plasticized corn starch (ESPTPS). Carbohydrate Polymers, 66, 110–116.

10

CORRELATIONS BETWEEN QUALITY INDICATORS AND CHEMICAL COMPOSITION FOR CHICKEN BREAST MUSCLE DEPENDING ON SEASON OF THE YEAR AND TRANSPORTATION DISTANCE

Introduction

There is continuous interest of different research laboratories about problem of defective poultry meat like PSE (pal. soft, exudative) and DFD (dark, firm, dry). It looks that in spite that processing of such meat brings economical disadvantages, and in the case of breast muscles on trays its low quality is conveyed on customers the problem of PSE and DFD-like meat is underestimated by poultry companies. There are many factors which can cause the lower quality of poultry meat. Among the most influencing is pre-slaughter stress and struggling; feed withdrawal duration; environmental conditions during transport and holding of livestock: temperature, distance of bird's transportation, seasons; genetic predispositions or long term factors associated with the live bird production [Bianchi et. al. 2006, Bianchi et. al. 2007, Qiao et. al. 2002, Petracci et. al. 2004].

In several papers it was found strong relationship among broiler breast meat lightness (L^*), pH and functional properties [Bianchi et. al. 2005, Bianchi et. al. 2007, Qiao et. al. 2001]. However it was not found more detailed relationships between meat quality parameters and chemical composition in three color groups i.e. PSE, normal (N) and DFD of breast chicken muscles in dependence on season of the year and distance for which birds are transported to processing plant.

Therefore the aim of the present paper was to evaluate the relationship between colour parameters ($L^*a^*b^*$), pH, water holding capacity (WHC) and chemical composition (water, protein and fat composition) for PSE, N and DFD breast chicken muscles after 24 h and 3 h p.m. in relation to seasons of the year and the distance for which birds were transported to poultry company.

Materials and methods

Materials and experimental design

Birds from Ross 508 strain from different farms were slaughtered in industrial conditions during all year. In sixteen separate experiments (4 different suppliers for each of four season) from 50 randomly chosen breast muscles (*pectoralis major*) after 24 h p.m. and in sixteen another experiments measurements after 3 h p.m. were chosen 4 muscles within three groups: lighter than normal (PSE), normal (N), and darker than normal (DFD). The muscles

were chosen on the basis of lightness (L^*), pH and color subjective assessment from each 50 muscles. After measurements of color parameters (lightness L^*, redness a^*, and yellowness b^*) and pH muscles separately for each group were placed in Cryovac bags for subsequent analysis i.e. chemical composition and water holding capacity. Then packed muscles were transported in cooler to university laboratory.

Methods

The pH was determined in duplicate by inserting electrode into each examined muscle using pH-meter Testo 230 (Testo AG, Germany) calibrated at pH 4.0 and 7.0. Color parameters (L^*, a^*, b^*) were measured at three different locations along the longitudinal axis of each muscle by a reflectance colorimeter (Minolta Chroma Meter CR-400, Konica Minolta, Japan) using illuminant source C. The colorimeter was adjusted to white, ceramic tile according to manufactures instructions. WHC (water holding capacity) was measured by method described by Grau and Hamm [1953] with the modification of Szmańko [1986] and was expressed as percentage of water which remained in sample after 5 min. pressure (19.62 N) related to initial water before pressure. The chemical composition (water, protein and lipid content) was carried out on frozen sample obtained from selected breast muscles. The experiment was replicated twice in each seasons of the year. The percentage of moisture was determined in duplicate (drying sample in an oven set at 105˚C for 24 hours) according to PN–ISO 1442:2000. Protein content was determined using a standard Kjeldahl copper catalyst method according to PN-75/A– 04018. Total lipids were measured using Soxhlet method according to PN–ISO 1444:20.

Statistical analysis

The experimental design was: 1x4/1x4 for color group, i.e. separately for PSE, N and DFD muscle, four seasons or separately for spring, summer, autumn and winter, and replications (n=16 or n=4); and 1x8x1 for color group, i.e. separately for PSE, N and DFD muscle, eight transport distances, and short or long distance (n=8). Program "Statistica 9.0" was used to generate correlation coefficients between chicken breast muscle quality indicators and chemical composition. Critical correlation coefficients values were used to find the significance of correlation coefficients (r_k at $P<0.05$) [Zielinski, Zielinski 1990].

Results and discussion

In the first experiment correlations were calculated between the quality indicators (color parameters, pH and WHC) and the values of chemical composition (water, protein and fat content) separately for PSE, N and DFD chicken breast muscles 24 h p.m. and for four seasons (spring, summer, autumn and winter) (n=16).

There were found significant correlations (r_k=0.482 for n-1=15, Tab. 1, Fig. 1) between: lightness (**L***) and **b*** (PSE and at the borderline of significance DFD), **L*** and **pH** (PSE, N and at the borderline of significance DFD), **L*** and **WHC** (DFD), **L*** and **fat** (DFD), **a*** and **b*** (N and DFD), **a*** and **WHC** (N), **a*** and **fat** (N), **WHC** and **fat** (PSE and N), **water** and **protein** (PSE and DFD) and **protein** and **fat** (N).

The tendency of breast meat to show a lower pH when L^* increase is commonly known. It was not found in this study significant relationship between L^* and a^* as well as between WHC and pH or water-moisture. Additionally, WHC had significant reverse correlation with a^* that is not in accordance with results of other authors [Bianchi et. al. 2006, Qiao et. al. 2001, Van Laack et. al. 2000, Zhang, Barbut 2005]. The discrepancy may results from the fact that in present paper correlations were counted not for all muscles but muscles in selected into PSE, N and DFD color groups. Paler breast muscle (L^*) is associated with higher b^* values and this finding is supported by previous research [Boulianne, King 1995, Qiao et. al. 2001] and is inconsistent with other studies [Van Laack et. al. 2000, Qiao et. al. 2002]. Example of matrix figures corresponding with all data in Table 1 was shown in Fig. 1.

Table 1

Correlation matrix for investigated parameters of muscle color (L*a*b*), water holding capacity (WHC), pH and chemical composition (water, protein, fat) calculated separately for PSE, N (normal) and DFD chicken breast muscles 24h p.m., all seasons (spring, summer, autumn, winter) and all distances (short, long) [16 investigated variants separately for PSE, N and DFD]

	PSE chicken breast muscles 24 p.m.							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.124	0.600	-0.111	-0.015	-0.283	-0.385	-0.573
a*	-0.124	1.000	-0.152	-0.324	-0.132	0.356	0.101	0.073
b*	**0.600**	-0.152	1.000	-0.373	0.055	-0.075	-0.135	0.156
WHC	-0.111	-0.324	-0.373	1.000	0.067	-0.376	-0.615	-0.119
water	-0.015	-0.132	0.055	0.067	1.000	-0.697	-0.198	0.000
protein	-0.283	0.356	-0.075	-0.376	**-0.697**	1.000	0.345	0.292
fat	-0.385	0.101	-0.135	**-0.615**	-0.198	0.345	1.000	0.256
pH	**-0.573**	0.073	0.156	-0.119	0.000	0.292	0.256	1.000
	N (normal) chicken breast muscles 24 p.m.							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.083	0.192	-0.193	0.342	-0.386	-0.030	-0.594
a*	0.083	1.000	0.567	-0.595	-0.128	0.155	0.687	0.075
b*	0.192	**0.567**	1.000	-0.189	-0.100	0.192	0.189	0.360
WHC	-0.193	**-0.595**	-0.189	1.000	-0.096	-0.144	-0.489	0.183
water	0.342	-0.128	-0.100	-0.096	1.000	-0.343	-0.196	-0.177
protein	-0.386	0.155	0.192	-0.144	-0.343	1.000	0.553	0.479
fat	-0.030	**0.687**	0.189	**-0.489**	-0.196	**0.553**	1.000	0.188
pH	**-0.594**	0.075	0.360	0.183	-0.177	0.479	0.188	1.000
	DFD chicken breast muscles 24 p.m.							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.068	0.479	-0.509	0.165	-0.352	0.560	-0.467
a*	0.068	1.000	0.610	-0.251	-0.015	0.156	0.185	-0.383
b*	**0.479**	**0.610**	1.000	-0.328	0.276	-0.040	0.210	-0.069
WHC	**-0.509**	-0.251	-0.328	1.000	0.280	0.078	-0.394	0.454
water	0.165	-0.015	0.276	0.280	1.000	-0.498	0.153	0.128
protein	-0.352	0.156	-0.040	0.078	**-0.498**	1.000	-0.421	0.445
fat	**0.560**	0.185	0.210	-0.394	0.153	-0.421	1.000	-0.461
pH	**-0.467**	-0.383	-0.069	0.454	0.128	0.445	-0.461	1.000

Significant correlations are bolded

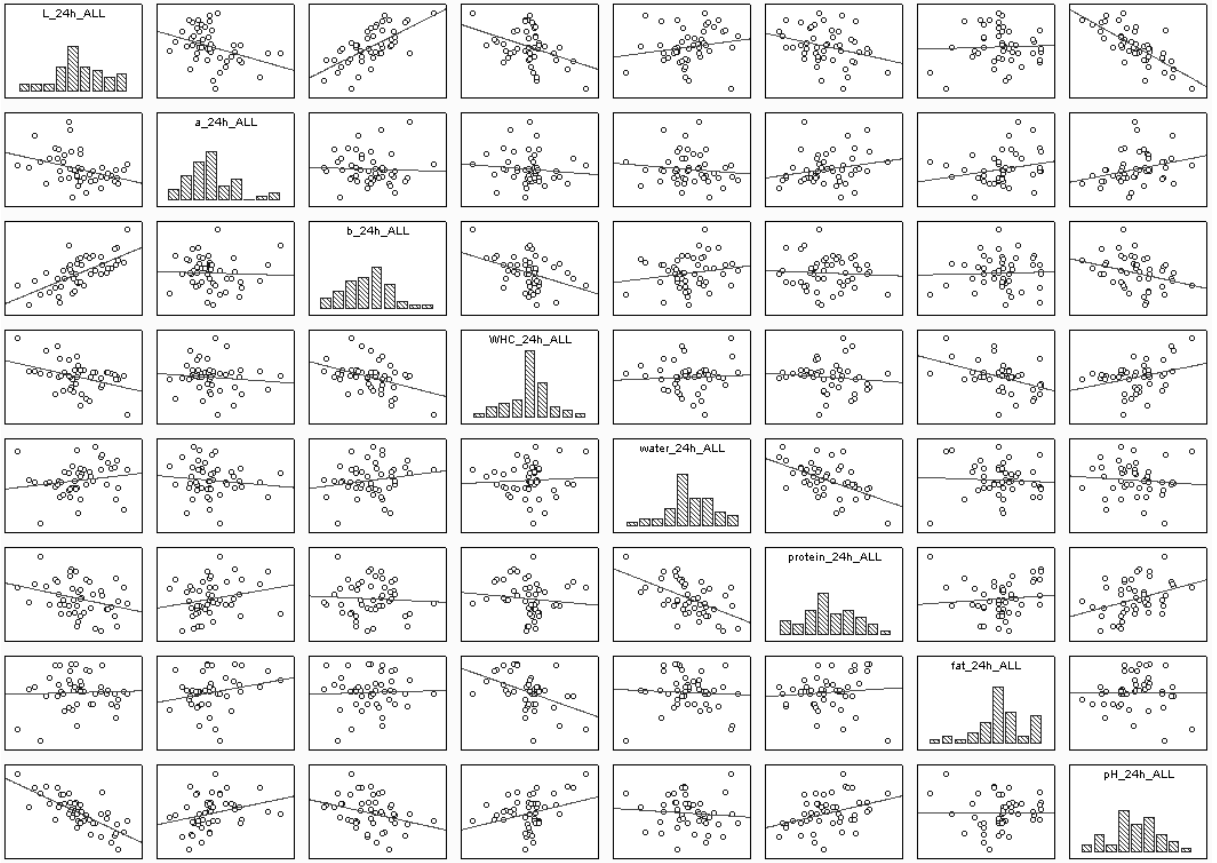

Fig. 1. Example of matrix figures [corresponding with all values in Table 1] for investigated parameters of muscle color (L*a*b*), water holding capacity (WHC), chemical composition (water, protein, fat) and pH calculated for all muscle types (normal, DFD, PSE), all seasons (spring, summer, autumn, winter) and all distances (short, long) for 24h p.m. raw material [48 variants]

In the second experiment the correlations were calculated between the quality indicators (color parameters, pH and WHC) and the values of chemical composition (water, protein and fat) separately for PSE, N and DFD chicken breast muscles 24 h p.m. for individual seasons (n=4).

There were found significant correlations (r_k=0.878 for n-1=3, Tab. 2) between:

- lightness (**L***) and **pH** for PSE muscle (r=-0.914, summer), N muscle (r=-0.886, autumn) and at the borderline of significance for DFD muscle (r=-0.827, autumn) and **WHC** for DFD muscle (r=0.887, summer). Also obtained significant or at the borderline significance correlations between **L*** and **a*** for N muscle (r=0.916, autumn), **b*** for PSE muscle (r=0.980, winter) and N muscle (r=0.953, r=spring, r= 0.865, summer), **water and protein** in PSE muscle (r=-0.917 and r=0.873, summer), N muscle (r=0.813 and r=-0.790, winter) and DFD muscle (r=0.751 and r=-0.846, summer), and **fat** in DFD muscle (r=0.879, autumn and r=0.910, winter).
- **a*** and **pH** for N muscle (r=-0.996, autumn) and DFD muscle (r=-0.908, summer), **WHC** for PSE and DFD muscles (r=0.927 and r=-0.857, spring) and N muscle (r=0.919, spring, r=-0.991, autumn), **protein and fat** in N muscle (r=-0.977 and r=0.988, spring).
- **b*** and **pH** for PSE muscle (r=0.967, spring), **WHC** for N muscle (r=0.893, spring), **water** in the N muscle (r=0.965, winter), **protein** in PSE, N and DFD muscles (r=-0.892, r=-0.987, winter and r=-0.909, autumn) and fat in PSE and DFD muscles (r=0.933, autumn and r=0.943, autumn).
- **WHC** and **pH** for PSE muscle (r=0.935, winter), N muscle (r=0.973, summer and r=0.998, autumn) and at the borderline of significance for DFD muscle (r=-0.778, summer and r=0.847, autumn), **water** in PSE muscle (r=-0.910, spring, r=0.955, summer and r=-0.969, winter) and N muscle (r=-0.941, winter), **protein and fat** in PSE muscle (r=0.935, spring and r=-0.914, autumn) and **fat** in N and DFD muscles (r=0.969, spring and r=-0.900, winter).
- **water** and **protein** content in PSE muscle (r=-0.984, spring and r=-0.964, autumn) and N muscle (r =- 0.965, winter) and **pH** for PSE muscle (r=0.971, summer and r=-0.944, winter) and DFD muscle (r=-0.940, summer and r=0.884 autumn), between **water** and **fat** in DFD muscle (r=-0.967, spring), **protein** and **fat** content in PSE, N and DFD muscles (r=0.943, winter, r=-0.946, spring and r=0.972, summer) and **pH** for PSE muscle (r=-0.994, summer).

Noteworthy is the lack of correlation between L* and pH for all muscle groups in winter; a* and b* for all muscle groups and seasons; opposite tendency of correlations between a* and WHC for N muscles in spring (r=0.919) and autumn (r=-0.991); and significant correlations, not observed in the first experiment (Tab. 1) between color parameters L*, a*, b*, pH, WHC and chemical composition for selected muscles and seasons.

In the third experiment correlations were calculated between the quality indicators (color parameters, pH and WHC) and the values of chemical composition (water, protein and fat) separately for PSE, N and DFD chicken breast muscles 3 h p.m. and for four seasons (spring, summer, autumn and winter) (n=16).

There were found significant correlations (r_k=0.482 for n-1=15, Tab. 3) between: lightness (**L***) and **pH** (PSE and N), **a*** and **b*** (PSE), **a*** and **WHC** (DFD), **b*** and **pH** (DFD), **b*** and **water** (PSE), **b***and **protein** (PSE), **WHC** and **fat** (DFD), **water** and **protein** (PSE and N), and **protein** and **fat** (DFD).

Table 2

Correlation matrix for investigated parameters of muscle color (L*a*b*), water holding capacity (WHC), pH and chemical composition (water, protein, fat) calculated separately for A) PSE, B) N (normal) and C) DFD chicken breast muscles 24h p.m., for spring, summer, autumn, winter, respectively and all distances (short, long) [4 investigated variants separately for 12 combinations of "season x muscle"]

Table 2A (PSE)

	PSE chicken breast muscles 24 p.m. in SPRING season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.769	0.715	0.491	-0.474	0.350	0.124	0.521
a*	0.769	1.000	0.538	0.927	-0.812	0.786	-0.211	0.434
b*	0.715	0.538	1.000	0.235	0.047	-0.094	-0.510	0.967
WHC	0.491	**0.927**	0.235	1.000	-0.910	0.935	-0.227	0.178
water	-0.474	-0.812	0.047	**-0.910**	1.000	-0.984	-0.188	0.172
protein	0.350	0.786	-0.094	**0.935**	**-0.984**	1.000	0.064	-0.177
fat	0.124	-0.211	-0.510	-0.227	-0.188	0.064	1.000	-0.700
pH	0.521	0.434	**0.967**	0.178	0.172	-0.177	-0.700	1.000
	PSE chicken breast muscles 24 p.m. in SUMMER season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.184	0.650	-0.801	-0.917	0.873	-0.464	-0.914
a*	-0.184	1.000	-0.509	0.556	0.311	0.008	-0.555	0.076
b*	0.650	-0.509	1.000	-0.404	-0.412	0.202	0.346	-0.301
WHC	-0.801	0.556	-0.404	1.000	0.955	-0.825	0.360	0.863
water	**-0.917**	0.311	-0.412	**0.955**	1.000	-0.945	0.554	0.971
protein	**0.873**	0.008	0.202	-0.825	-0.945	1.000	-0.791	-0.994
fat	-0.464	-0.555	0.346	0.360	0.554	-0.791	1.000	0.722
pH	**-0.914**	0.076	-0.301	0.863	**0.971**	**-0.994**	0.722	1.000
	PSE chicken breast muscles 24 p.m. in AUTUMN season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.576	-0.177	-0.292	-0.762	0.632	-0.110	-0.802
a*	0.576	1.000	-0.743	0.600	-0.014	-0.228	-0.843	-0.554
b*	-0.177	-0.743	1.000	-0.791	-0.041	0.291	0.933	0.580
WHC	-0.292	0.600	-0.791	1.000	0.641	-0.816	-0.914	0.023
water	-0.762	-0.014	-0.041	0.641	1.000	-0.964	-0.303	0.780
protein	0.632	-0.228	0.291	-0.816	**-0.964**	1.000	0.544	-0.587
fat	-0.110	-0.843	**0.933**	**-0.914**	-0.303	0.544	1.000	0.359
pH	-0.802	-0.554	0.580	0.023	0.780	-0.587	0.359	1.000
	PSE chicken breast muscles 24 p.m. in WINTER season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.226	0.980	-0.600	0.524	-0.858	-0.713	-0.280
a*	-0.226	1.000	-0.400	-0.540	0.459	0.263	0.512	-0.720
b*	**0.980**	-0.400	1.000	-0.432	0.361	-0.892	-0.809	-0.089
WHC	-0.600	-0.540	-0.432	1.000	-0.969	0.263	-0.062	0.935
water	0.524	0.459	0.361	**-0.969**	1.000	-0.097	0.208	-0.944
protein	-0.858	0.263	**-0.892**	0.263	-0.097	1.000	0.943	-0.083
fat	-0.713	0.512	-0.809	-0.062	0.208	**0.943**	1.000	-0.405
pH	-0.280	-0.720	-0.089	**0.935**	**-0.944**	-0.083	-0.405	1.000

Table 2B (N – normal)

	N (normal) chicken breast muscles 24 p.m. in SPRING season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.397	0.953	0.724	-0.238	-0.281	0.537	0.533
a*	0.397	1.000	0.653	0.919	-0.200	-0.977	0.988	-0.210
b*	**0.953**	0.653	1.000	0.893	-0.207	-0.540	0.764	0.410
WHC	0.724	**0.919**	**0.893**	1.000	-0.298	-0.861	0.969	0.035
water	-0.238	-0.200	-0.207	-0.298	1.000	0.347	-0.221	0.610
protein	-0.281	**-0.977**	-0.540	-0.861	0.347	1.000	-0.946	0.411
fat	0.537	**0.988**	0.764	**0.969**	-0.221	**-0.946**	1.000	-0.099
pH	0.533	-0.210	0.410	0.035	0.610	0.411	-0.099	1.000
	N (normal) chicken breast muscles 24 p.m. in SUMMER season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.679	0.865	0.390	0.396	0.559	-0.240	0.513
a*	0.679	1.000	0.816	-0.391	0.448	-0.115	-0.845	-0.218
b*	**0.865**	0.816	1.000	-0.029	0.071	0.465	-0.607	0.056
WHC	0.390	-0.391	-0.029	1.000	0.136	0.710	0.800	0.973
water	0.396	0.448	0.071	0.136	1.000	-0.371	-0.073	0.350
protein	0.559	-0.115	0.465	0.710	-0.371	1.000	0.356	0.623
fat	-0.240	-0.845	-0.607	0.800	-0.073	0.356	1.000	0.699
pH	0.513	-0.218	0.056	**0.973**	0.350	0.623	0.699	1.000
	N (normal) chicken breast muscles 24 p.m. in AUTUMN season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.916	0.241	-0.857	0.279	-0.728	0.411	-0.886
a*	**0.916**	1.000	-0.090	-0.991	0.344	-0.500	0.683	-0.996
b*	0.241	-0.090	1.000	0.160	0.440	-0.181	-0.204	0.108
WHC	-0.857	**-0.991**	0.160	1.000	-0.403	0.381	-0.771	0.998
water	0.279	0.344	0.440	-0.403	1.000	0.398	0.749	-0.405
protein	-0.728	-0.500	-0.181	0.381	0.398	1.000	0.289	0.421
fat	0.411	0.683	-0.204	-0.771	0.749	0.289	1.000	-0.745
pH	**-0.886**	**-0.996**	0.108	**0.998**	-0.405	0.421	-0.745	1.000
	N (normal) chicken breast muscles 24 p.m. in WINTER season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.221	0.699	-0.867	0.813	-0.790	-0.161	0.256
a*	0.221	1.000	0.506	-0.675	0.600	-0.404	0.011	-0.796
b*	0.699	0.506	1.000	-0.820	0.965	-0.987	-0.704	0.118
WHC	-0.867	-0.675	-0.820	1.000	**-0.941**	0.834	0.173	0.188
water	**0.813**	0.600	**0.965**	**-0.941**	1.000	-0.965	-0.496	-0.008
protein	**-0.790**	-0.404	**-0.987**	0.834	**-0.965**	1.000	0.675	-0.230
fat	-0.161	0.011	-0.704	0.173	-0.496	0.675	1.000	-0.490
pH	0.256	-0.796	0.118	0.188	-0.008	-0.230	-0.490	1.000

Table 2C (DFD)

	DFD chicken breast muscles 24 p.m. in SPRING season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.435	0.615	0.085	-0.053	0.034	-0.084	0.557
a*	0.435	1.000	0.589	-0.857	0.673	0.640	-0.592	0.013
b*	0.615	0.589	1.000	-0.366	0.688	-0.236	-0.822	0.808
WHC	0.085	**-0.857**	-0.366	1.000	-0.829	-0.622	0.676	0.228
water	-0.053	0.673	0.688	-0.829	1.000	0.081	-0.967	0.274
protein	0.034	0.640	-0.236	-0.622	0.081	1.000	0.131	-0.726
fat	-0.084	-0.592	-0.822	0.676	**-0.967**	0.131	1.000	-0.509
pH	0.557	0.013	0.808	0.228	0.274	-0.726	-0.509	1.000
	DFD chicken breast muscles 24 p.m. in SUMMER season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.275	0.574	0.887	0.751	-0.846	-0.701	-0.642
a*	0.275	1.000	0.311	0.549	0.742	0.021	0.192	-0.908
b*	0.574	0.311	1.000	0.289	0.805	-0.816	-0.813	-0.567
WHC	**0.887**	0.549	0.289	1.000	0.723	-0.510	-0.296	-0.778
water	**0.751**	0.742	0.805	0.723	1.000	-0.652	-0.513	-0.940
protein	**-0.846**	0.021	-0.816	-0.510	-0.652	1.000	0.972	0.386
fat	-0.701	0.192	-0.813	-0.296	-0.513	**0.972**	1.000	0.202
pH	-0.642	**-0.908**	-0.567	**-0.778**	**-0.940**	0.386	0.202	1.000
	DFD chicken breast muscles 24 p.m. in AUTUMN season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.763	0.649	-0.621	-0.495	-0.284	0.789	-0.827
a*	0.763	1.000	0.281	-0.078	-0.406	0.116	0.580	-0.564
b*	0.649	0.281	1.000	-0.273	0.286	-0.909	0.943	-0.194
WHC	-0.621	-0.078	-0.273	1.000	0.705	0.096	-0.211	0.847
water	-0.495	-0.406	0.286	0.705	1.000	-0.584	0.143	0.884
protein	-0.284	0.116	**-0.909**	0.096	-0.584	1.000	-0.738	-0.159
fat	**0.789**	0.580	**0.943**	-0.211	0.143	-0.738	1.000	-0.317
pH	**-0.827**	-0.564	-0.194	**0.847**	**0.884**	-0.159	-0.317	1.000
	DFD chicken breast muscles 24 p.m. in WINTER season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.00000	-0.63589	0.47750	-0.68808	0.60085	-0.23791	0.90992	-0.14867
a*	-0.63589	1.00000	0.29760	0.29606	-0.70974	-0.06443	-0.63411	-0.66115
b*	0.47750	0.29760	1.00000	-0.18608	0.23138	-0.70932	0.21247	-0.77746
WHC	-0.68808	0.29606	-0.18608	1.00000	0.13992	-0.43815	-0.89972	0.37905
water	0.60085	-0.70974	0.23138	0.13992	1.00000	-0.65430	0.30058	0.42021
protein	-0.23791	-0.06443	-0.70932	-0.43815	-0.65430	1.00000	0.18361	0.18017
fat	**0.90992**	-0.63411	0.21247	**-0.89972**	0.30058	0.18361	1.00000	-0.12145
pH	-0.14867	-0.66115	-0.77746	0.37905	0.42021	0.18017	-0.12145	1.00000

Significant correlations are bolded

The correlations between L^* and pH, a^* and b^*, a^* and WHC, WHC and fat, water and protein and protein and fat were comparable for muscles at 3 and 24 h p.m., however correlations between L^* and pH and a^* and b^* had higher values for muscles 3 than 24 h p.m. Moreover it was found additional correlations between L^* and WHC, L^* and fat, L^* and b^*, and a^* and fat for muscles 24 h p.m. and between b^* and pH, b^* and water, and b^* and protein for muscles 3h p.m. Example of matrix figures corresponding with all data in Table 3 was shown in Figure 2.

Table 3

Correlation matrix for investigated parameters of muscle color (L*a*b*), water holding capacity (WHC), pH and chemical composition (water, protein, fat) calculated separately for PSE, N (normal) and DFD chicken breast muscles 3h p.m., all seasons (spring, summer, autumn, winter) and all distances (short, long) [16 investigated variants separately for PSE, N and DFD]

	PSE chicken breast muscles 3 p.m.							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.272	-0.309	0.208	0.229	-0.412	-0.003	-0.637
a*	-0.272	1.000	0.688	-0.181	-0.366	0.334	-0.371	-0.158
b*	-0.309	**0.688**	1.000	0.015	-0.553	0.667	-0.322	0.037
WHC	0.208	-0.181	0.015	1.000	-0.094	-0.164	-0.210	-0.323
water	0.229	-0.366	**-0.553**	-0.094	1.000	-0.600	0.288	0.048
protein	-0.412	0.334	**0.667**	-0.164	**-0.600**	1.000	-0.325	0.060
fat	-0.003	-0.371	-0.322	-0.210	0.288	-0.325	1.000	0.340
pH	**-0.637**	-0.158	0.037	-0.323	0.048	0.060	0.340	1.000
	N (normal) chicken breast muscles 3 p.m.							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.420	0.022	0.420	-0.049	-0.228	-0.386	-0.796
a*	-0.420	1.000	0.234	-0.181	0.202	-0.121	0.027	0.161
b*	0.022	0.234	1.000	-0.313	-0.024	0.142	0.374	0.079
WHC	0.420	-0.181	-0.313	1.000	-0.221	0.203	-0.246	-0.342
water	-0.049	0.202	-0.024	-0.221	1.000	-0.510	-0.108	0.299
protein	-0.228	-0.121	0.142	0.203	**-0.510**	1.000	0.195	0.062
fat	-0.386	0.027	0.374	-0.246	-0.108	0.195	1.000	0.438
pH	**-0.796**	0.161	0.079	-0.342	0.299	0.062	0.438	1.000
	DFD chicken breast muscles 3 p.m.							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.169	-0.107	0.108	-0.042	0.123	0.078	-0.076
a*	-0.169	1.000	0.392	-0.512	0.039	0.051	0.276	-0.016
b*	-0.107	0.392	1.000	-0.179	0.210	0.226	0.153	0.482
WHC	0.108	**-0.512**	-0.179	1.000	0.194	0.380	-0.599	0.017
water	-0.042	0.039	0.210	0.194	1.000	-0.075	0.316	-0.056
protein	0.123	0.051	0.226	0.380	-0.075	1.000	-0.534	0.323
fat	0.078	0.276	0.153	**-0.599**	0.316	**-0.534**	1.000	-0.225
pH	-0.076	-0.016	**0.482**	0.017	-0.056	0.323	-0.225	1.000

Significant correlations are bolded

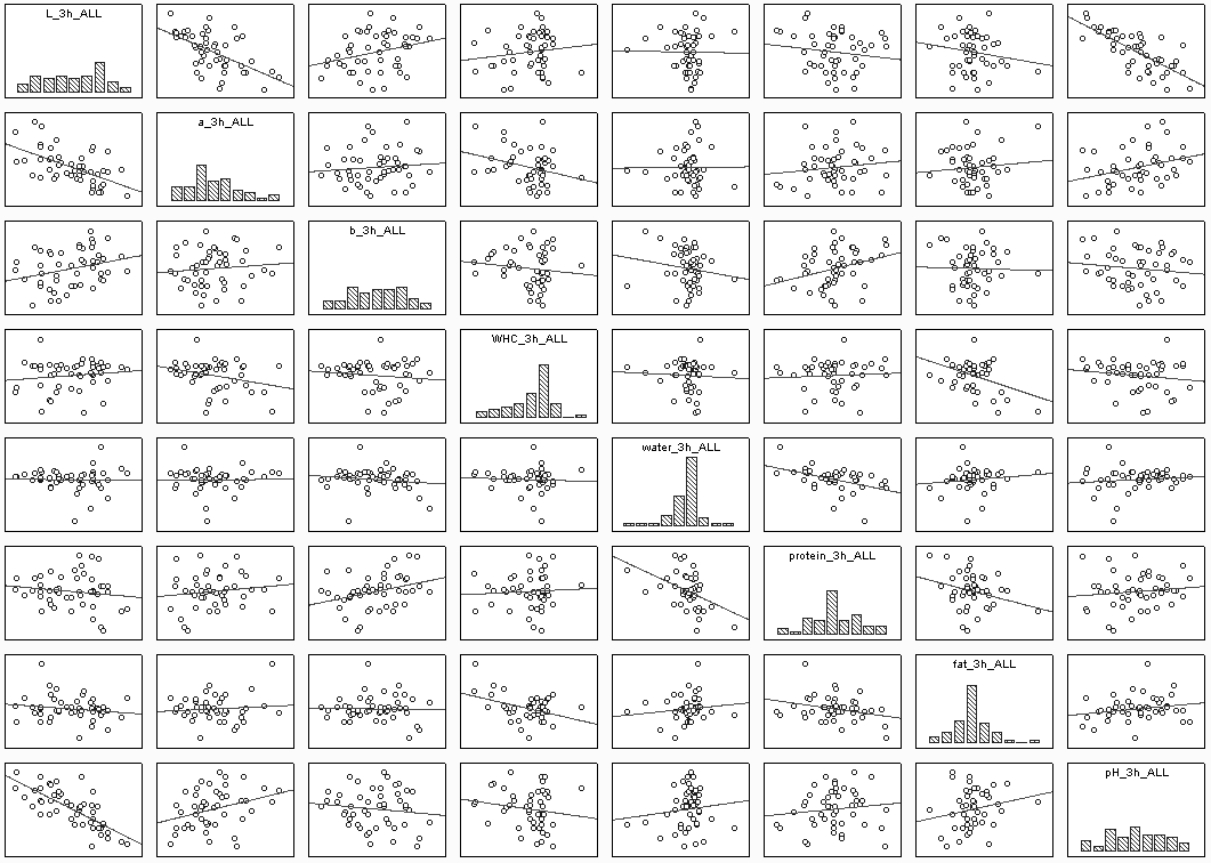

Fig. 2. Example of matrix figures [corresponding with all values in Tab. 3] for investigated parameters of muscle color (L*a*b*), water holding capacity (WHC), chemical composition (water, protein, fat) and pH calculated for all muscle types (normal, DFD, PSE), all seasons (spring, summer, autumn, winter) and all distances (short, long) for 3h p.m. raw material [48 variants]

In the fourth experiment the correlations were calculated between the quality indicators (color parameters, pH and WHC) and the values of chemical composition (water, protein and fat) separately for PSE, N and DFD chicken breast muscles 3 h p.m. for individual seasons (n=4).

There were found significant correlations (r_k=0.878 for n-1=3, Tab. 4, Fig. 2) between: -lightness (**L***) and **pH** for PSE muscle (r=-0.989, summer and r=-0.944, autumn), N muscle (r=-0.895, spring and at borderline of significance r=-0.825, summer and r=-0.823, winter) and DFD muscle (r=0.831, summer) and **WHC** for DFD muscle (r=-0.882, spring). Also obtained significant or at the borderline of significance correlations between **L*** and **a*** for PSE muscle (r=-0.866, spring), **b*** for PSE muscle (r=-0.937, spring and r=0.813, summer) and N muscle (r=0.954, summer and r=-0.897, autumn), **water** in N muscle (r=-0.862, summer), **protein** in N muscle (r=0.985, summer and r=-0.939, autumn) and DFD muscle (r=-0.865, autumn), and **fat** in PSE muscle (r=-0.989, spring) and DFD muscle (r=-0.952, spring).

- **a*** and **b*** for PSE muscle (r=0.929, spring), N muscle (r=-0.996, spring) and DFD muscle (r=-0.890, autumn).
- **a***and **WHC** for N muscle (r=0.909, summer), **water** and **fat** in PSE muscle (r=0.913 and r =- 0.951, summer), and **water, protein** and **fat** in DFD muscle (r=-0.972, r=0.884 and r=-0.848 summer).
- **b***and **water** in PSE, N and DFD muscles (r=-0.961, autumn, r=-0.960, winter, r=-0.924, autumn), **protein** in muscle N (r=0.916, summer), and **fat** in PSE muscle (r=0.965, spring). Noteworthy are also significant or at the borderline of significance correlations between **b*** and **pH** for PSE muscle (r=-0.875, summer) and N muscle (r=-0.915, summer), and **WHC** for PSE muscle (r=0.861, autumn and r=0.856, winter).
- **WHC** and **pH** for DFD muscle (r=0.884, autumn), **water** in PSE muscles (r=-0.874, spring), **protein** in DFD muscle (r=0.952, autumn) and **fat** in PSE muscle (r=-0.938, autumn), N muscle (r=-0.943, autumn) and DFD muscle (r=-0.988, autumn).
- **water** and **protein** in PSE muscle (r=-0.932, spring), N muscle (r=-0.958, spring and r=-0.932, summer) and DFD muscle (r=-0.968, summer), as well as **protein** and **fat** in DFD muscle (r=-0.938, autumn).
- **protein** and **pH** for PSE muscle (r=-0.941, winter) and DFD muscle (r =- 0.900, spring, and at the border of significance r=- 0.860, autumn and r=- 0.868, winter), and **fat** and **pH** for PSE, N and DFD muscles (r=0.900, winter, r=0.915, autumn and r=- 0943, autumn / r=-0.883, winter).

As in muscles 24 h p.m. it is also lack of correlation between L* and pH for all muscle groups in the winter and there are more correlations not observed in the third experiment (Tab. 3) between color parameters L*, a*, b*, pH, WHC and chemical composition for selected muscles and seasons. Moreover in muscles 3 h p.m. correlations between WHC: and pH, water, protein and fat were found only in autumn and between a*: and WHC, water, protein and fat were found only in summer. It was found opposite tendency of correlation between L* and protein in N muscle (r=0.985, summer and r=-0.939, autumn).

It is good agreement between data obtained for muscles after 24 and 3 h p.m. (Tab. 2 and 4). However, only in muscles 3 h p.m. were found significant correlations between a* and b* and lack of correlation between a* and pH.

Table 4

Correlation matrix for investigated parameters of muscle color (L*a*b*), water holding capacity (WHC), pH and chemical composition (water, protein, fat) calculated separately for A) PSE, B) N (normal) and C) DFD chicken breast muscles 3h p.m., for spring, summer, autumn, winter, respectively and all distances (short, long) [4 investigated variants separately for 12 combinations of "season x muscle"]

Table 4A (PSE)

	PSE chicken breast muscles 3 p.m. in SPRING season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.866	-0.937	-0.743	0.382	-0.021	-0.989	-0.133
a*	**-0.866**	1.000	0.929	0.516	-0.289	-0.024	0.859	0.604
b*	**-0.937**	**0.929**	1.000	0.797	-0.577	0.258	0.965	0.398
WHC	-0.743	0.516	0.797	1.000	-0.874	0.653	0.824	-0.047
water	0.382	-0.289	-0.577	**-0.874**	1.000	-0.932	-0.511	-0.123
protein	-0.021	-0.024	0.258	0.653	**-0.932**	1.000	0.165	0.087
fat	**-0.989**	0.859	**0.965**	0.824	-0.511	0.165	1.000	0.160
pH	-0.133	0.604	0.398	-0.047	-0.123	0.087	0.160	1.000
	PSE chicken breast muscles 3 p.m. in SUMMER season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.071	0.813	0.586	0.149	0.712	0.138	-0.989
a*	0.071	1.000	0.636	0.529	0.913	0.038	-0.951	-0.200
b*	**0.813**	0.636	1.000	0.722	0.668	0.612	-0.432	-0.875
WHC	0.586	0.529	0.722	1.000	0.270	-0.043	-0.539	-0.686
water	0.149	**0.913**	0.668	0.270	1.000	0.375	-0.759	-0.238
protein	0.712	0.038	0.612	-0.043	0.375	1.000	0.272	-0.656
fat	0.138	**-0.951**	-0.432	-0.539	-0.759	0.272	1.000	0.003
pH	**-0.989**	-0.200	**-0.875**	-0.686	-0.238	-0.656	0.003	1.000
	PSE chicken breast muscles 3 p.m. in AUTUMN season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.639	-0.029	-0.325	-0.188	-0.427	0.118	-0.944
a*	0.639	1.000	0.587	0.115	-0.623	-0.580	-0.056	-0.789
b*	-0.029	0.587	1.000	0.861	-0.961	0.197	-0.740	-0.302
WHC	-0.325	0.115	**0.861**	1.000	-0.834	0.658	-0.939	0.015
water	-0.188	-0.623	**-0.961**	-0.834	1.000	-0.253	0.806	0.500
protein	-0.427	-0.580	0.197	0.658	-0.253	1.000	-0.776	0.316
fat	0.118	-0.056	-0.740	**-0.939**	0.806	-0.776	1.000	0.151
pH	**-0.944**	-0.789	-0.302	0.015	0.500	0.316	0.151	1.000
	PSE chicken breast muscles 3 p.m. in WINTER season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.483	0.335	0.773	-0.750	0.268	-0.469	-0.312
a*	-0.483	1.000	0.381	0.020	-0.025	0.407	-0.545	-0.569
b*	0.335	0.381	1.000	0.856	-0.175	-0.058	-0.660	-0.277
WHC	0.773	0.020	**0.856**	1.000	-0.556	0.147	-0.730	-0.396
water	-0.750	-0.025	-0.175	-0.556	1.000	-0.838	0.771	0.832
protein	0.268	0.407	-0.058	0.147	-0.838	1.000	-0.711	-0.941
fat	-0.469	-0.545	-0.660	-0.730	0.771	-0.711	1.000	0.900
pH	-0.312	-0.569	-0.277	-0.396	0.832	**-0.941**	**0.900**	1.000

Table 4B (N – normal)

	N (normal) chicken breast muscles 3 p.m. in SPRING season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.634	0.682	-0.825	0.095	-0.037	-0.436	-0.895
a*	-0.634	1.000	-0.996	0.690	-0.764	0.613	0.154	0.250
b*	0.682	**-0.996**	1.000	-0.753	0.753	-0.621	-0.237	-0.300
WHC	-0.825	0.690	-0.753	1.000	-0.485	0.532	0.788	0.559
water	0.095	-0.764	0.753	-0.485	1.000	-0.958	-0.254	0.359
protein	-0.037	0.613	-0.621	0.532	**-0.958**	1.000	0.469	-0.392
fat	-0.436	0.154	-0.237	0.788	-0.254	0.469	1.000	0.300
pH	**-0.895**	0.250	-0.300	0.559	0.359	-0.392	0.300	1.000
	N (normal) chicken breast muscles 3 p.m. in SUMMER season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.338	0.954	0.415	-0.862	0.985	-0.390	-0.825
a*	0.338	1.000	0.278	0.909	-0.016	0.205	0.701	-0.560
b*	**0.954**	0.278	1.000	0.238	-0.715	0.916	-0.339	-0.915
WHC	0.415	**0.909**	0.238	1.000	-0.284	0.339	0.458	-0.394
water	**-0.862**	-0.016	-0.715	-0.284	1.000	-0.932	0.701	0.426
protein	**0.985**	0.205	**0.916**	0.339	-0.932	1.000	-0.531	-0.723
fat	-0.390	0.701	-0.339	0.458	0.701	-0.531	1.000	-0.065
pH	**-0.825**	-0.560	**-0.915**	-0.394	0.426	-0.723	-0.065	1.000
	N (normal) chicken breast muscles 3 p.m. in AUTUMN season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.555	-0.897	0.061	0.168	-0.939	-0.388	-0.412
a*	-0.555	1.000	0.270	0.784	-0.223	0.666	-0.545	-0.491
b*	**-0.897**	0.270	1.000	-0.385	-0.445	0.691	0.640	0.507
WHC	0.061	0.784	-0.385	1.000	0.030	0.167	-0.943	-0.823
water	0.168	-0.223	-0.445	0.030	1.000	0.105	-0.040	0.345
protein	**-0.939**	0.666	0.691	0.167	0.105	1.000	0.168	0.321
fat	-0.388	-0.545	0.640	**-0.943**	-0.040	0.168	1.000	0.915
pH	-0.412	-0.491	0.507	-0.823	0.345	0.321	**0.915**	1.000
	N (normal) chicken breast muscles 3 p.m. in WINTER season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.163	0.191	-0.705	0.023	-0.608	-0.621	-0.823
a*	-0.163	1.000	-0.518	0.789	0.325	-0.682	-0.194	-0.199
b*	0.191	-0.518	1.000	-0.635	-0.960	0.219	0.643	-0.377
WHC	-0.705	0.789	-0.635	1.000	0.392	-0.100	0.095	0.437
water	0.023	0.325	**-0.960**	0.392	1.000	-0.216	-0.796	0.299
protein	-0.608	-0.682	0.219	-0.100	-0.216	1.000	0.567	0.798
fat	-0.621	-0.194	0.643	0.095	-0.796	0.567	1.000	0.282
pH	**-0.823**	-0.199	-0.377	0.437	0.299	0.798	0.282	1.000

Table 4C (DFD)

	DFD chicken breast muscles 3 p.m. in SPRING season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.486	-0.025	-0.882	-0.683	-0.032	-0.952	0.099
a*	0.486	1.000	0.694	-0.068	0.055	-0.856	-0.587	0.700
b*	-0.025	0.694	1.000	0.221	0.717	-0.615	0.069	0.211
WHC	**-0.882**	-0.068	0.221	1.000	0.654	-0.431	0.720	0.370
water	-0.683	0.055	0.717	0.654	1.000	-0.247	0.745	-0.119
protein	-0.032	-0.856	-0.615	-0.431	-0.247	1.000	0.240	-0.900
fat	**-0.952**	-0.587	0.069	0.720	0.745	0.240	1.000	-0.378
pH	0.099	0.700	0.211	0.370	-0.119	**-0.900**	-0.378	1.000
	DFD chicken breast muscles 3 p.m. in SUMMER season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.439	-0.465	-0.038	0.299	-0.177	0.518	0.831
a*	-0.439	1.000	-0.454	0.044	-0.972	0.884	-0.848	-0.402
b*	-0.465	-0.454	1.000	0.493	0.640	-0.776	0.014	-0.632
WHC	-0.038	0.044	0.493	1.000	0.150	-0.371	-0.545	-0.588
water	0.299	**-0.972**	0.640	0.150	1.000	-0.968	0.705	0.182
protein	-0.177	**0.884**	-0.776	-0.371	**-0.968**	1.000	-0.507	0.041
fat	0.518	**-0.848**	0.014	-0.545	0.705	-0.507	1.000	0.739
pH	**0.831**	-0.402	-0.632	-0.588	0.182	0.041	0.739	1.000
	DFD chicken breast muscles 3 p.m. in AUTUMN season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.011	0.344	-0.787	-0.462	-0.865	0.701	-0.493
a*	-0.011	1.000	-0.890	-0.551	0.657	-0.491	0.671	-0.864
b*	0.344	**-0.890**	1.000	0.307	-0.924	0.135	-0.429	0.612
WHC	-0.787	-0.551	0.307	1.000	-0.158	0.952	-0.988	0.884
water	-0.462	0.657	**-0.924**	-0.158	1.000	0.093	0.252	-0.362
protein	**-0.865**	-0.491	0.135	**0.952**	0.093	1.000	-0.938	0.860
fat	0.701	0.671	-0.429	**-0.988**	0.252	**-0.938**	1.000	-0.943
pH	-0.493	-0.864	0.612	**0.884**	-0.362	**0.860**	**-0.943**	1.000
	DFD chicken breast muscles 3 p.m. in WINTER season							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.251	-0.298	-0.284	-0.610	0.611	0.107	0.315
a*	-0.251	1.000	0.427	-0.638	-0.412	-0.058	0.057	-0.376
b*	-0.298	0.427	1.000	0.364	-0.502	0.547	-0.874	0.588
WHC	-0.284	-0.638	0.364	1.000	0.270	0.240	-0.707	0.691
water	-0.610	-0.412	-0.502	0.270	1.000	-0.851	0.414	-0.494
protein	0.611	-0.058	0.547	0.240	-0.851	1.000	-0.704	0.868
fat	0.107	0.057	-0.874	-0.707	0.414	-0.704	1.000	-0.883
pH	0.315	-0.376	0.588	0.691	-0.494	**0.868**	**-0.883**	1.000

Significant correlations are bolded

In the fifth experiment the correlations were calculated between the quality indicators (color parameters, pH and WHC) and the values of chemical composition (water, protein and fat) separately for PSE, N and DFD chicken breast muscles 24 h p.m., depending on the distance of transportation of birds: a short - 100 km and long over 100 km (n=8).
There were significant correlations (r_k=0.6664 for n-1=7, Tab. 5) between:
Short distance

- lightness (**L***) and **a*** for PSE muscle (r=0.913), and **fat** in PSE muscle (r=-0.648, at the border of significance).
- **a*** and **b*** for N muscle (r=0.805) and DFD muscle (r=0.761).
- **a*** and **fat** in PSE muscle (r=-0.652, at the border of significance) and N muscle (r=0.856),
- **b***and **WHC** for PSE muscle (r=-0.789).
- **WHC** and **pH** for PSE muscle (r=-0.637, at the border of significance), **fat** in N muscle (r=-0.673).
- **water** and **protein** in PSE muscle (r=-0.795) and DFD muscle (r=-0.770).
- **Long-distance**
- lightness (**L***) and **a*** and **b*** for PSE muscle (r=-0.710 and r=0.700), **pH** for PSE and N muscle (r=-0.766 and r=-0.843), **WHC** for DFD muscle (r=-0.749), and **fat** in DFD muscle (r=0.745).
- **a*** and **b*** for PSE muscle (r=-0.725).
- **a*** and **WHC** for N muscle (r=-0.739).
- **WHC** and **fat** in PSE and DFD muscles (r=-0.858 and r=-0.962).
- **protein** and **fat** in N muscle (r=0.697) and pH for N and DFD muscle (r=0.630, at the borderline of significance, and r=0.758).

For short distances were found mainly correlations for PSE muscle (L* and a*, L* and fat, a* and fat, b* and WHC, WHC and pH, water and protein) and only a few for N muscle (a* and b*, a* and fat, and WHC and fat) and DFD muscle (a* and b*, and water and protein). For long distances for PSE muscles were found additional correlations for L* and a* (L* and b*, L and pH, a* and b*). In the group of N and DFD muscles correlations were mainly between color parameters and pH and WHC.

Table 5

Correlation matrix for investigated parameters of muscle color (L*a*b*), water holding capacity (WHC), pH and chemical composition (water, protein, fat) calculated separately for PSE, N and DFD chicken breast muscles 24h p.m., all seasons (spring, summer, autumn, winter) and short and long distances [8 investigated variants separately for 6 combinations of "distance x muscle"]

	PSE chicken breast muscles 24 p.m. in SHORT distance							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.913	0.383	0.009	-0.205	-0.137	-0.648	-0.366
a*	**0.913**	1.000	0.442	-0.125	-0.311	0.174	-0.652	-0.183
b*	0.383	0.442	1.000	-0.790	0.158	0.021	0.032	0.600
WHC	0.009	-0.125	**-0.790**	1.000	-0.102	-0.228	-0.429	-0.637
water	-0.205	-0.311	0.158	-0.102	1.000	-0.795	0.058	0.102
protein	-0.137	0.174	0.021	-0.228	**-0.795**	1.000	0.105	0.292
fat	**-0.648**	**-0.652**	0.032	-0.429	0.058	0.105	1.000	0.490
pH	-0.366	-0.183	0.600	**-0.637**	0.102	0.292	0.490	1.000

Table 5 cont.

	PSE chicken breast muscles 24 p.m. in LONG distance							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.710	0.700	0.099	0.160	-0.556	-0.300	-0.766
a*	**-0.710**	1.000	-0.725	-0.529	-0.009	0.556	0.567	0.225
b*	**0.700**	**-0.725**	1.000	0.247	-0.001	-0.241	-0.264	-0.170
WHC	0.099	-0.529	0.247	1.000	0.184	-0.580	-0.858	0.200
water	0.160	-0.009	-0.001	0.184	1.000	-0.611	-0.379	-0.072
protein	-0.556	0.556	-0.241	-0.580	-0.611	1.000	0.587	0.313
fat	-0.300	0.567	-0.264	**-0.858**	-0.379	0.587	1.000	0.125
pH	**-0.766**	0.225	-0.170	0.200	-0.072	0.313	0.125	1.000
	N (normal) chicken breast muscles 24 p.m. in SHORT distance							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.095	0.208	0.177	0.353	-0.557	0.354	-0.481
a*	0.095	1.000	0.805	-0.628	-0.226	-0.191	0.856	0.326
b*	0.208	**0.805**	1.000	-0.316	-0.288	-0.193	0.552	0.585
WHC	0.177	-0.628	-0.316	1.000	-0.041	-0.539	-0.673	0.022
water	0.353	-0.226	-0.288	-0.041	1.000	0.128	0.096	-0.562
protein	-0.557	-0.191	-0.193	-0.539	0.128	1.000	-0.227	0.117
fat	0.354	**0.856**	0.552	**-0.673**	0.096	-0.227	1.000	-0.176
pH	-0.481	0.326	0.585	0.022	-0.562	0.117	-0.176	1.000
	N (normal) chicken breast muscles 24 p.m. in LONG distance							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.233	0.200	-0.548	-0.037	-0.249	-0.119	-0.843
a*	0.233	1.000	0.195	-0.739	0.226	0.273	0.602	-0.122
b*	0.200	0.195	1.000	0.021	0.178	0.446	-0.076	0.201
WHC	-0.548	**-0.739**	0.021	1.000	0.193	-0.198	-0.619	0.390
water	-0.037	0.226	0.178	0.193	1.000	-0.432	-0.229	0.010
protein	-0.249	0.273	0.446	-0.198	-0.432	1.000	0.697	0.630
fat	-0.119	0.602	-0.076	-0.619	-0.229	**0.697**	1.000	0.353
pH	**-0.843**	-0.122	0.201	0.390	0.010	0.630	0.353	1.000
	DFD chicken breast muscles 24 p.m. in SHORT distance							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.318	0.596	-0.169	0.269	-0.271	0.411	-0.172
a*	0.318	1.000	0.761	-0.442	-0.081	0.512	0.134	-0.322
b*	0.596	**0.761**	1.000	-0.462	0.083	0.234	0.068	0.088
WHC	-0.169	-0.442	-0.462	1.000	0.200	-0.091	0.020	0.367
water	0.269	-0.081	0.083	0.200	1.000	-0.770	0.375	-0.284
protein	-0.271	0.512	0.234	-0.091	**-0.770**	1.000	-0.464	0.301
fat	0.411	0.134	0.068	0.020	0.375	-0.464	1.000	-0.570
pH	-0.172	-0.322	0.088	0.367	-0.284	0.301	-0.570	1.000
	DFD chicken breast muscles 24 p.m. in LONG distance							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.047	0.436	-0.749	0.123	-0.512	0.745	-0.550
a*	-0.047	1.000	0.495	-0.136	-0.250	-0.044	0.200	-0.446
b*	0.436	0.495	1.000	-0.234	0.319	-0.265	0.325	-0.167
WHC	**-0.749**	-0.136	-0.234	1.000	0.494	0.384	-0.962	0.531
water	0.123	-0.250	0.319	0.494	1.000	0.254	-0.368	0.380
protein	-0.512	-0.044	-0.265	0.384	0.254	1.000	-0.280	0.758
fat	**0.745**	0.200	0.325	**-0.962**	-0.368	-0.280	1.000	-0.474
pH	-0.550	-0.446	-0.167	0.531	0.380	**0.758**	-0.474	1.000

Significant correlations are bolded

In the sixth experiment the correlations were calculated between the quality indicators (color parameters, pH and WHC) and the values of chemical composition (water, protein and fat) of chicken breast muscles 3 h p.m., depending on the distance of transportation of birds: a short 100 km long and long over 100 km (n=8). There were significant correlations (r_k=0.6664 for n-1=7, Table 6) between:

Short-distance

- **a*** and **b*** for PSE muscle (r=0.714).
- **a*** and **WHC** for DFD muscle (r=-0.843).
- **b*** and **water** in DFD muscle (r=0.769).
- **WHC** and **fat** in DFD muscle (r=-0.775).
- **water** and **protein** in N muscle (r=-0.713), and **protein** and **pH** for PSE muscle (r=-0.661).
- **Long-distance**
- lightness (**L***) and **a*** for muscle N (r=-0.735) and, at borderline of significance with **b***, **pH** and **water** in PSE muscle (r=-0.640, r=-0.644 and r=0.638).
- **b*** and **water** and **protein** in PSE muscle (r=-0.789 and r=-0.753).
- **WHC** and **water** in DFD muscle (r=0.675).
- **water** and **protein** in PSE and DFD muscles (r=-0.714 and r=0.670).
- **protein** and **fat** in the PSE muscle (r=-0.638, at the border of significance).

Table 6

Correlation matrix for investigated parameters of muscle color (L*a*b*), water holding capacity (WHC), pH and chemical composition (water, protein, fat) calculated separately for PSE, N and DFD chicken breast muscles 3h p.m., all seasons (spring, summer, autumn, winter) and short and long distances [8 investigated variants separately for 6 combinations of "distance x muscle"].

	PSE chicken breast muscles 3 p.m. in SHORT distance							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.035	0.176	0.582	0.119	-0.390	-0.288	0.066
a*	-0.035	1.000	0.714	-0.436	-0.344	0.113	-0.536	0.435
b*	0.176	**0.714**	1.000	-0.211	-0.585	0.597	-0.507	-0.146
WHC	0.582	-0.436	-0.211	1.000	-0.045	-0.367	-0.475	-0.042
water	0.119	-0.344	-0.585	-0.045	1.000	-0.552	0.583	0.502
protein	-0.390	0.113	0.597	-0.367	-0.552	1.000	0.063	-0.661
fat	-0.288	-0.536	-0.507	-0.475	0.583	0.063	1.000	-0.218
pH	0.066	0.435	-0.146	-0.042	0.502	**-0.661**	-0.218	1.000
	PSE chicken breast muscles 3 p.m. in LONG distance							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.294	-0.640	-0.157	0.638	-0.379	0.194	-0.644
a*	-0.294	1.000	0.524	0.074	-0.550	0.543	-0.183	0.392
b*	**-0.640**	0.524	1.000	0.236	-0.789	0.753	-0.113	0.212
WHC	-0.157	0.074	0.236	1.000	-0.148	0.018	0.019	0.076
water	**0.638**	-0.550	**-0.789**	-0.148	1.000	-0.714	0.120	-0.429
protein	-0.379	0.543	**0.753**	0.018	**-0.714**	1.000	-0.638	0.304
fat	0.194	-0.183	-0.113	0.019	0.120	**-0.638**	1.000	-0.459
pH	**-0.644**	0.392	0.212	0.076	-0.429	0.304	-0.459	1.000

Significant correlations are bolded

Table 6 cont.

	N (normal) chicken breast muscles 3 p.m. in SHORT distance							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.046	0.567	0.385	0.244	0.143	-0.142	-0.238
a*	0.046	1.000	0.018	0.104	0.184	-0.579	-0.289	0.227
b*	0.567	0.018	1.000	-0.242	0.372	-0.049	-0.066	-0.576
WHC	0.385	0.104	-0.242	1.000	-0.163	0.459	0.323	-0.142
water	0.244	0.184	0.372	-0.163	1.000	-0.713	0.185	0.386
protein	0.143	-0.579	-0.049	0.459	**-0.713**	1.000	0.142	-0.627
fat	-0.142	-0.289	-0.066	0.323	0.185	0.142	1.000	-0.285
pH	-0.238	0.227	-0.576	-0.142	0.386	-0.627	-0.285	1.000
	N (normal) chicken breast muscles 3 p.m. in LONG distance							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.735	0.086	0.342	-0.560	-0.394	-0.318	-0.348
a*	**-0.735**	1.000	0.344	-0.306	0.316	0.515	0.020	0.200
b*	0.086	0.344	1.000	-0.234	-0.495	-0.025	0.390	-0.054
WHC	0.342	-0.306	-0.234	1.000	-0.413	0.310	-0.260	0.341
water	-0.560	0.316	-0.495	-0.413	1.000	0.113	-0.207	-0.280
protein	-0.394	0.515	-0.025	0.310	0.113	1.000	0.081	0.055
fat	-0.318	0.020	0.390	-0.260	-0.207	0.081	1.000	-0.028
pH	-0.348	0.200	-0.054	0.341	-0.280	0.055	-0.028	1.000
	DFD chicken breast muscles 3 p.m. in SHORT distance							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	0.178	-0.097	-0.186	-0.021	-0.008	-0.115	0.520
a*	0.178	1.000	0.288	-0.843	-0.058	-0.113	0.599	0.409
b*	-0.097	0.288	1.000	-0.090	0.769	-0.203	0.530	-0.482
WHC	-0.186	**-0.843**	-0.090	1.000	-0.093	0.454	-0.775	-0.478
water	-0.021	-0.058	**0.769**	-0.093	1.000	-0.600	0.591	-0.540
protein	-0.008	-0.113	-0.203	0.454	-0.600	1.000	-0.565	0.081
fat	-0.115	0.599	0.530	**-0.775**	0.591	-0.565	1.000	0.038
pH	0.520	0.409	-0.482	-0.478	-0.540	0.081	0.038	1.000
	DFD chicken breast muscles 3 p.m. in LONG distance							
	L*	**a***	**b***	**WHC**	**water**	**protein**	**fat**	**pH**
L*	1.000	-0.260	0.216	0.290	-0.174	0.339	0.076	0.020
a*	-0.260	1.000	0.323	0.053	0.327	0.101	-0.117	0.576
b*	0.216	0.323	1.000	-0.319	-0.073	0.415	0.206	0.003
WHC	0.290	0.053	-0.319	1.000	0.675	0.358	-0.313	-0.086
water	-0.174	0.327	-0.073	**0.675**	1.000	0.670	-0.399	-0.112
protein	0.339	0.101	0.415	0.358	**0.670**	1.000	-0.445	-0.235
fat	0.076	-0.117	0.206	-0.313	-0.399	-0.445	1.000	0.155
pH	0.020	0.576	0.003	-0.086	-0.112	-0.235	0.155	1.000

For short distance were found correlations for PSE (a^* and b^*, protein and pH) and DFD muscle (a^* and WHC, b^* and water, WHC and fat) and only one for N muscle (water and protein). For long distances correlations were found mainly for PSE muscles (L^* and b^*, L^* and pH, L^* and water, b^* and water, water and protein, and protein and fat). For long distances,

both for muscles 24 and 3 h p.m. there were more correlations between color parameters: and pH, WHC and chemical composition than at short distances. Moreover there were more found correlations for free color muscle groups after 24 than 3 h p.m. (23 versus 16).

Conclusions

1. For individual seasons in three selected muscle groups there were more significant correlations between quality indicators and chemical composition for particular muscle groups than those observed without isolation the seasons.
2. The found correlations between quality indicators and chemical composition for breast muscles at 24 and 3 h p.m. are generally similar in particular seasons. There were found some more correlations in seasons with muscle groups at 24 h than at 3 h p.m. except of correlation between a^* and b^* and a^* and pH which were found only in muscle 3 h p.m.
3. For short distance more correlations were found for PSE muscles after 24 h and DFD muscles after 3 h p.m. in comparison with remain muscle groups. For short and long distances there were found more correlations for muscles after 24 than 3 p.m. (23 versus 16).

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References

Bianchi M., Fletcher D.L., Smith D.P., 2005. Physical and functional properties of intact and ground pale broiler breast meat. Poultry Science, 84, 803–808.

Bianchi M., Petracci M., Cavani C. 2006. The influence of genotype, market live weight, transportation, and holding conditions prior to slaughter on broiler breast meat color. Poultry Science, 85, 123–128.

Bianchi M., Petracci M., Sirri F., Folegatti E., Franchini A., Meluzzi A., 2007. The influence of the season and market class of broiler chickens on breast meat quality traits. Poultry Science, 86: 959–963,

Boulianne M., King A.J., 1995. Biochemical and color characteristics of skinless pale chicken breast. Poultry Science, 74, 1693–1698.

Lyon B.G, Smith D.P., Lyon C.E., Savage E.M., 2004. Effect of diet and feed withdrawal on the sensory descriptive and instrumental profiles of broiler breast fillets. Poultry Science 83, 275–281.

Oiao M., Fletcher D.L. Smith D.P., Northcutt J.K., 2001. The effect of broiler breast meat colour on pH, moisture, water-holding capacity, and emulsification capacity. Poultry Science 80, 676–680.

Oiao M., Fletcher D.L., Northcutt J.K., Northcutt J.K., 2002. The relationship between raw broiler breast meat color and composition. Poultry Science 81, 422–427.

Petracci M., Bianchi M., Betti M., Cavani C., 2004. Color variation and characterization of broiler breast meat during processing in Italy. Poultry Science 83, 2086–2092.

PN-ISO 1442, 2000 Meat and meat products – Determination of moisture content (Reference method);
PN-75/A-04018 agricultural-food products – Determination of Kjeldahl nitrogen and protein conversion.
PN-ISO 1444, 2000 Meat and meat products - Determination of fat content (Reference method).
Szmanko, T., 1986. The equipment used for measurement of water holding capacity. Poland patent No 40767. Biul. Urz. Pat. RP, 5, 38.
Van Laack, R.L.J.M., Liu, C.-H., Smith, M.O., Loveday, H.D., 2000. Characteristics of pal. soft, exudative broiler breast meat. Poultry Science 79, 1057–1061.
Zhang L., Barbut S., 2005. Rheological characteristics of fresh and frozen PSE, normal and DFD chicken breast meat. British Poultry Science, 46 (60), 687–693.
Zielinski R., Zielinski W., 1990. Statistical tables. PWN, 274.

11

OMELET WITH STEW – NEW PRODUCT FOR GASTRONOMY – CONCEPT AND PROTOTYPE DEVELOPMENT

Introduction

New product development (NPD was introduced in the early 1990s as a market-oriented innovation concept concerning the use of consumers' current and future needs [Costa and Jongena 2006, Earle 1997]. European food industry and gastronomy so far are conservative and invest too little in research and development of the new products. In addition to that only 2.2% of total product launches can be considered as a really new, while over 80% of new food products continue to fail [Steward-Knox, Mitchell 2003, Costa, Jongena 2006].

In such situation the question arises how to better prepare the process of food product development. Traditionally the procedure is described as few step process [Rudder et al. 2001]. The most important parts are idea and concept generation, research and testing of prototype of product as well as marketing [Earle et al. 2010]. Now more flexible methods are accepted [Steward-Knox, Mitchell 2003], but preparation of the prototype of the product is still necessary step in the development process.

Gastronomy plays an important role in the nutrition and tourism, especially serving traditional or regional products [Kivela, Crotts 2006]. There are many kinds of products sold in different parts of the market. The most famous kind of the product distributed by gastromy or food serving chains is fast food. This kind of food of discussed nutritive value due to usage of low quality raw materials and preparation techniques (i.e. frying) increased in volume throughout last 40 years [Handlechner 2007].

The opposite concept, i.e. slow food, is directed to a better quality of food and meals consumed in more comfortable and better designed restaurants [Handlechner 2007].

There are still needs for high nutritive, taste and fast prepared but fresh product. In Polish gastronomy traditional dishes with high nutritional value should be combined with global products prepared anywhere in the world.

Eggs and egg based products for gastronomy are one of the main dishes in almost all national kitchens. As a first generation of the innovative egg products the following can be recognized: egg coated potato [Muller 1994], egg and cheese products [Heick et al. 1997], egg flakes [Lee et al. 1998]. Second generation of the product includes egg and bacon patty, bite-sized egg snacks, frozen egg pizza, eggnog (egg pulp and skim milk, egg fingers (crumb-coated scrambled eggs and bacon bound by white sauce and egg loaf which is kind of a ready-to-eat sandwich [Yashoda et al. 2004].

Although there are many Polish dishes prepared from eggs, only few can be found in gastronomy (scrambled eggs), because many global products i.e. omelets are not very popu-

lar. One of the reason is characteristic taste of eggs which composed to many other food like meat, fish or even sweet fruits (pancakes, crepes, flapjacks) but not with typical Polish traditional meals like stew, fungi, etc.

The aim of the study was to worked out a new innovative product being an alternative to typical lunch dishes including combination of the omelet and traditional Polish meal "bigos" i.e. Hunter's stew prepared from cabbage and various chopped meat. The product would be directed to the young population (students, "yappies") as an alternative to typical lunch meal, which is most often a kind of fast food. Moreover, it should be of high nutritive value but also of middle energy and interesting taste. Such requirements meet the idea to combine component based on eggs product (omelet) and a traditional Polish stew.

Materials and methods

The concept of the product was created during meetings of 12 people being food technologist or students of the Food Technology and Nutrition.

The concept includes requirements for the product to be a combination of omelet and stew with own appearance and sensory profile different from both main components. Preparation of the new product prototypes, which were verified by a laboratory sensory test using modified Quantitative Descriptive Analysis was applied as a methodology. Prototype development is a single step [Rudolph 1995] in the process of the multistage food product development [Earle 1997]. Such procedure is recognized as a modern methodology to prepare new product in fast and logical process.

The quality of each prototype was sensory evaluated and the results were used as a base for the preparation of the next version of the product.

As a quality determinants appearance and color, texture and structure, taste as well as smell were selected by the sensory panel consisted of 12 experts. Sensory panel was trained to include and correctly use the selected terms. In addition to that panelists are asked to judge an overall acceptance of the product. Detailed description of the selected terms are shown in Table 1. An intensity of each sensory parameter with addition of the harmonization of the taste were evaluated using a structural 5-points scale. An overall acceptance was judged with 5-points hedonic scal. where 5 – extremely accepted; 4 – accepted; 3 – like; 2 – not accepted and 1 – extremely not accepted [Baryłko-Pikielna, Matuszewska 2009].

The prototype of the product was developed in four stages:

1. Typical omelet prepared from the whole egg mass with sour cream and stew laid on the top of the typical omelet
2. Typical omelet prepared from the whole egg mass with sour cream and stew mixed together with the omelet dough
3. Sponge cake type omelet prepared from separated egg components (whipped egg white mixed with other ingredients without sour cream) and stew laid on the top of the typical omelet
4. Sponge cake type omelet prepared from separated egg components (whipped egg white mixed with other ingredients including tomato paste but without sour cream) and stew laid on the top of the typical omelet

Table 1

Detailed description of the selected sensory evaluation determinants

Quality highlights	Number of points				
	5	4	3	2	1
Appearance with colour	characteristic of very well-baked and finished product of the combined components, having a uniform color	slightly deviated from the typical very well baked and finished product of the combined components, having a uniform color	deviated from the typical components combined together, unevenly colored	deviated from the typical components not fully combined altogether, flushed unevenly	completely differs from the typical with no combined components, uneven colored
Texture and structure	elastic crumb, the adjusted porosity, good cut, typical for very well aerated and baked omelette	crumb elastic with uneven porosity, and good cut, typical for well aerated dough	crumb low inelastic, slightly moist, defective cut with a tendency to adhere	low non-elastic crumb, moist, flushed unevenly, poor cut	loamy crumb or excessively dry, crumbling, with poor cut
Taste	intensive, harmonized, new type of taste created	medium harmonized, intensive taste of components	slightly harmonized intensive taste	non-harmonized, but taste of eggs less perceptible	perceptible taste eggs and individual taste of stew (seasonings)
Smell	aromatic	medium aromatic	low intense aroma	detectable aroma	burning smell

Components preparation

Materials used in the study consisted of those needed for bigos (stew) preparation i.e. sauerkraut, white cabbage, pork shoulder, bacon, "zwyczajna" sausage, onion, wheat flour, rapeseed oil, plant margarine, tomato paste, salt and paper, as well as for omelets formation i.e. eggs, butter, wheat flour, tomato paste, salt and paper. All the raw materials were purchased on the local market. Bigos was prepared according to the recipe commonly used in gastronomy presented in Table 2.

Following steps of stew (bigos) preparation were carried out:

Dried, spoiled and damaged leaves were removed from white cabbage. The rest of leaves was washed in cold water, cut into small stripes and mixed up with a small amount of table salt. Sauerkraut was boiled with limited amount of water in the second pot. At the same time onion and meat constituents were cut into small pieces and fried with plant margarine. Following, all the constituents were combined together in one big pot, spiced with salt and paper, stirred with tomato paste and simmer for 1.5 hours.

Omelets were prepared according to the commercially recognized recipe presented in Table 3.

Table 2

Hunter's stew recipe

Ingredient	Weight [g]
Sauerkraut	35.0
Cabbage	25.0
Pork shoulder	17.7
Bacon	6.5
"zwyczajna" sausage	10.0
Onion	4.0
Wheat flour	1.5
Rapeseed oil	1.5
Plant margarine	1.5
Tomato paste 30%	0.8
Table salt	Pinch/to obtain a proper taste
Paper	Pinch/to obtain a proper taste

Table 3

Omelets recipe

Ingredient	Amount
Hens eggs	4
Butter	9 g
Wheat flour	14 g
Tomato paste 30%	8 g
Table salt	Pinch/to obtain a proper taste
Paper	Pinch/to obtain a proper taste
Sour cream	optionally

Omelets were formulated from fresh eggs with the addition of wheat flour and spices, with the optional addition of sour cream and tomato paste. Eggs were washed in warm water, dried and separated on yolks and whites. Egg whites were whipped with a pinch of salt for 180 sec using commercial kitchen equipment Hobbart (N50 Quart Mixer, Hobbart, OH, USA). To the stiff egg white foam egg yolks, sal. paper and tomato paste were added sequentially and stirred gently. At last, homogenous dough was formed by mixing egg mass with partially added wheat flour. Obtained dough was then poured on the pan with hot butter and simmer under lid until well done on the induction cooker (Amica, Poland). Following, omelets were turned up side down and previously prepared stew was put on the whole surface of the product. Finally, omelets with stew were baked in the electric oven (Amica, Poland) at 180ºC for 5 min. The product was served to the individual panelists as warm piece of about 50 g. Ready-to-serve product is presented on Figure 1.

Typical structure of the omelets is based on the good quality of used constituents, especially wheat flour. The quality of fresh eggs or egg products such as dried egg powders or frozen egg mass is also required to remain on a high level, especially due to creating a specific functional properties of a final products and providing a strong characteristic smell [Franke, Kiessling 2002, Koc et al. 2011]. Salt enhances physical properties, taste and the overall quality of the omelets. Moreover, final products prepared with salt is characterized by typical elasticity and the given shape is maintained. Tomato paste applied in the omelets production modifies strong egg flavor.

Fig. 1. Omelet with 'bigos' as a prototype of a new product for gastronomy

For statistical analysis of the data software Statistica ver. 10 was used [Stanisz 2007]. The analysis of variance (ANOVA) (Duncan's test at $p<0.05$), regression and Principal Components Analysis (PCA) were applied.

Results and discussion

The results collected in the study showed that first prototype was judged at the level of average score about 4, but the overall acceptability was evaluated at 3.8. The reason for that was non-harmonized taste of the product. Some of the panelists remarked feeling of two separated tastes: typical for omelet and for stew. Appearance was also assessed as low by a few panelists, because in their opinion presented prototype of the product had not fully combined components. It is worth to underline that variation in individual notes was on a very high level. (standard deviation about one third value of the mean for appearance and almost one fourth for taste evaluation) (Tab. 4). Sensory evaluation of food products is directly connected with a decision making analysis and necessary in a new product development. Whilst product and process development in the food industry differs from that of other industries, because the central importance is given to taste in overall consumer preferences,

the decision analysis by the benefit-cost-deficit model can be used additionally as a supportive tool [Sedki et al. 2011].

Table 4

Average data for QDA and acceptance analyses of the omelets

Omelets	Apperance	Texture	Smell	Taste	Overall acceptability
I	4.04±0.75	4.25±0.50	4.42±0.67	4.08±1.16	3.83^{a}±1.27
II	4.08±0.70	4.04±0.96	3.92±1.00	3.96±1.10	3.96^{a}±0.72
III	3.92±0.87	4.42±1.00	4.29±0.86	4.00±1.09	4.08^{ab}±0.63
IV	4.46±0.45	4.67±0.44	4.46±0.66	4.79±0.40	4.71^{b} ±0.40

a,b – represents a significance at $p<0.05$

Mixing together two of the product components (prototype 2) i.e. omelet dough with stew followed by a thermal treatment did not improve quality of the product. However, variation in scores was lower in comparison to prototype 1, especially for the overall acceptability (Tab. 4). Higher variation was observed between notes for smell and texture. Tendency of lowering the scores for texture was also noted, which was probably affected by mixing components together, while appearance (no stew on the top of the omelet) was judged as good.

Changing the kind of omelet to sponge cake type did not affect appearance, taste and smell in relation to the prototype 1 (but also to prototype 2), but insignificant statistically tendency to increase the score for texture was noticed.

The change of the recipe for prototype 4 involving an incorporation of tomato paste on had the highest effect on the quality of the omelet with stew. This increased an overall acceptability to the score level more than 4.7 (Tab. 4), which is significantly ($p<0.05$) higher than the assessment of the prototype 1 and 2. The highest increase was observed for taste parameter, the average was 4.8. As the sensory evaluation is one of the most important factors in creating a new product like egg chips [Yashoda et al. 2008], egg loaf [Yashoda et al. 2004] or formulated fried egg [Merkele et al. 2007], it can be stated that a good quality new egg product prototype was developed. Moreover, an omelet with "bigos" as a the newly achieved product can perfectly meet the requirements for small and medium gastronomy, as well as it fulfills the concept of culinology® [Cheng et al. 2011] as the blending of culinary arts and food science.

Principal component analysis (PCA) is the most widely used multivariate statistical tool in sensory analysis, which the main objective is to explain of as much of the variability of the original data as possible with as few of these principal components as possible [Borgognone et al. 2001, Czernyszewicz 2008, Gajewski 2004, Gramacki, Gramacki 2008]. Data collected in the study subjected to PCA revealed that the variable in 2D graph, what can be helpful for finding the groups of variable, having some kind of "similarity". For omelet I as a new product prototype (Fig. 2) it can be seen that one cluster could be created with two variables: appearance and texture, second with taste and overall acceptance. However, the fifth variable smell seemed not to have "similarity" to the rest of four variable, what can be seen also in the circle plot of factor coordinates of variables. The factor values of variables shown on the graphs (Fig. 2) are also given in the table 5. Thus, smell might not be used in further evaluation of the product. In case of the prototype II two clusters were formed

(Fig. 2); one consisted of smell, texture and taste, whilst other with appearance and overall acceptability. So, all of the quality highlights should be applied in further evaluation during a new product development process. Changing the preparation method and modification of the traditional omelet recipe in order to prepare prototype III resulted in different arrangement of the selected sensory traits on the PCA graph (Fig. 2). One main cluster containing taste, texture, appearance and overall acceptance was formed indicating a significant importance of those sensory traits in the quality evaluation of this type of the products. Smell had no similarity to the main cluster when evaluated the sensory quality of the prototype III, likewise the prototype I. PCA carried out for the prototype IV of the product revealed that appearance was the only one sensory trait which had no similarity to the rest of the selected quality highlights evaluated in the study (Fig. 2). What can be explained by achieving a high level of appearance acceptance for newly formulated products. Amongst others some of the application of PCA methodology in the process of new product development was reported by Singh Chauhan and Sharma [2003] for new products from fresh eggs and egg powder, by Ghosh and Chattopadhyay [2011] for fermented products created with lactic acid bacteria and Ueda et. al. [2008] for ready-to eat cup soup. Zalewski [1993] showed that objective characteristics together with consumers preferences analyses can be useful tools in optimalization of the new products, what was confirmed in presented study.

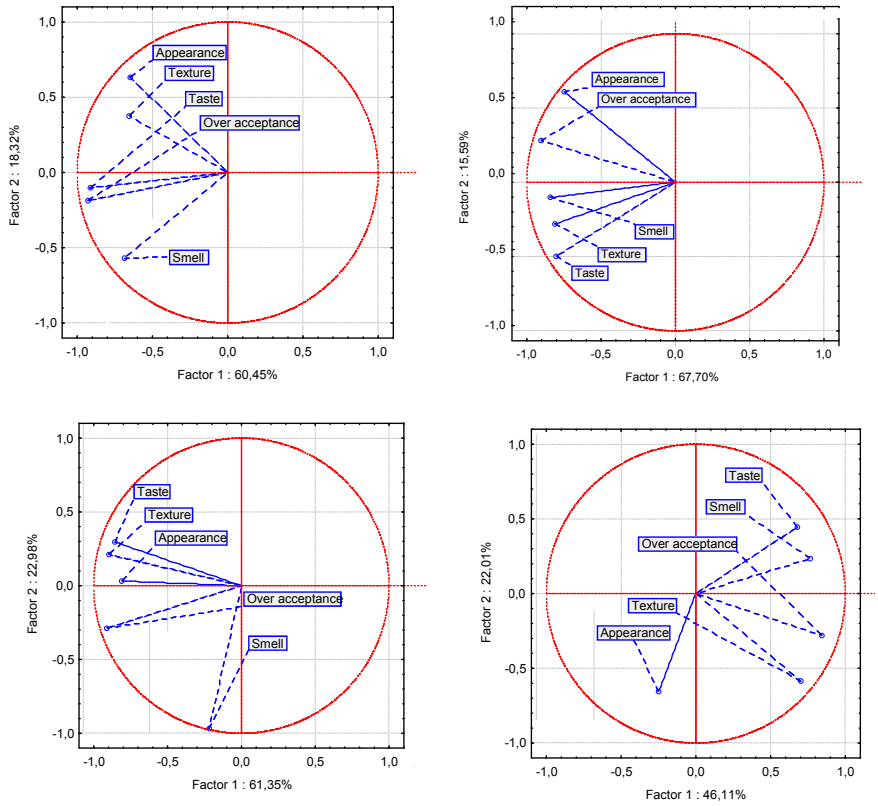

Fig. 2. PCA analysis of the prototype's omelets I (top-left), II (top-right), III (bottom-left) and IV (bottom-right)

Table 5

The values of factors 1 and 2 of selected sensory evaluation variables in PCA analysis

	Prototype I		Prototype II		Prototype III		Prototype IV	
	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2
Appearance	-0.650	0.633	-0.747	0.606	-0.808	0.0339	-0.252	-0.653
Texture	-0.653	0.379	-0.812	-0.277	-0.897	0.214	0.701	-0.588
Smell	-0.686	-0.572	-0.843	-0.100	-0.219	-0.967	0.761	0.238
Taste	-0.915	-0.103	-0.802	-0.496	-0.855	0.294	0.680	0.441
Overall acceptability	-0.930	-0.186	-0.902	0.282	-0.911	-0.285	0.842	-0.278

The highest correlation coefficient between an overall acceptability and individual parameters of the product quality was the highest in case of relation between taste and overall acceptability (R=0.75) (Tab. 6). Although, the other correlation coefficients were also statistically significant (R=0.5–0.6).

Table 6

Correlation coefficients R for the main effects

Overall acceptability	Appearance	Texture	Smell	Taste
prototype I	0.49	0.43	0.63*	0.93*
Prototype II	0.77*	0.69*	0.69*	0.54
Prototype III	0.63*	0.73*	0.45	0.73*
Prototype IV	0.20	0.69*	0.47	0.30
Population correlation	0.54*	0.56*	0.51*	0.75*

*represents a significance at $p<0.05$; n=12, n=48 for the whole population

Conclusions

It can be concluded that as the effect of the prototype testing procedure the product, which can be easily implemented to gastronomy practices was developed. The product i.e. omelet with stew was characterized by the combination of the components with own highly accepted taste and appearance, and as well it can be proposed to be introduces as lunch meal in small (bistros, bars) and middle size gastronomy (restaurants).

References

Baryłko-Pikielna N., Matuszewska I., 2009. Sensoryczne badania żywności. Wydawnictwo Naukowe PTTŻ, Kraków.

Borgognone M.G., Bussi J., Hough G., 2001. Principle Component Analysis in sensory analysis: covariane or correlation matrix. Food Quality and Preference, 12, 323–326.

Cheng M., Ogbeide G.C.A., Hamouz F.L., 2011. The development of culinary arts and food science into a new academic discipline-culinology. Journal of Culinary Science and Technology, 9, 17–26.

Costa A.I.A., Jongena W.M.F., 2006. New insights into consumer-led food product development. Trends in Food Science and Technology, 17, 457–465.

Czernyszewicz E., 2008. Zastosowanie analizy składowych do opisu konsumenckiej struktury jakości jabłek. Żywność, Nauka. Technologia. Jakość, 2 (57), 119–127.
Earle M., Earle R., Anderson A., 2007. Opracowanie produktów spożywczych. Podejście marketingowe. Wydawnictwa Naukowo-Techniczne. Warszawa.
Earle M.D., 1997. Changes in the food product development process. Trends in Food Science and Technology, 8, 19–24.
Franke K., Kiessling M., 2002. Influence of spray drying conditions on functionality of dried whole egg. J. Sci. Food Agric., 82, 1837–1841.
Gajewski M., 2004. Wykorzystanie ilościowej analizy opisowej (QDA) do modelowania jakości sensorycznej brokułu. Folia Univ. Agric. Stetin Agricultura.239 (95), 91–96.
Ghosh D., Chattopadhyay P., 2011. Application of principal component analysis (PCA) as a sensory assessment tool for fermented food products. J. Food Sci. Technol., Pub. Online on 18 February 2011.
Gramacki J., Gramacki A., 2008. Statystyczne odkrywanie zależności w danych. Przegląd Telekomunikacyjny, LXXXI, 6, 711–713.
Heick J.T., Case P.E., Chawan D.B., 1997. Egg and cheese product and method of making same. US Patent US 5614244, Borden, Columbus, OH, USA.
Kivela J., Crotts J.C., 2006. Tourism and gastronomy: gastronomy's influence on how tourists experience a destination. Journal of Hospitality and Tourism Research, 30, 354–377.
Koç M., Koç B., Susyal G., Yilmazer M. S., Ertekin F. K., Bağdatlıoğlu N., 2011. Functional and physicochemical properties of whole egg powder: effect of spray drying conditions. Journal of Food Science and Technology, 48, 141–149.
Lee C.H., Yang S.H., Chi S.P., 1998. The development and quality evaluation of two-stages drum-hot air dried egg flakes. [in:] Effect of various egg yolk and egg white ratio and drying conditions. Journal of the Chinese Society of Animal Science, 27 (4), 579–587.
Muller C.L., 1994. Method of preparing egg coated potato slices. US Patent US 5372830, Mission Hills, KS 66208, USA.
Rudder A., Ainsworth P., Holgate D., 2001. New food product development: strategies for success?, British Food Journal, 103, 9, 657–670.
Rudolph M.J., 1995. The food product development process. Br. Food J., 97, 3–11.
Sedki K., Polet P., Vanderhaegen F., 2011. Decision Analysis Using the Benefit-Cost Deficit model. Aix-Les-Bains, France. The 7th conference of the European Society for Fuzzy Logic and Technology.
Singh Chauhan V., Sharma A., 2003. Studies on organoleptic properties of food products from fresh egg and egg powder through principal component analysis. Nahrung/Food, 47, 102–105.
Stanisz A., 2007. Przystępny kurs statystyki z zastosowaniem *Statistica PL* na przykładach z medycyny. Tom 3. Analizy wielowymiarowe. Wydawnictwo StatSoft Polska.
Statistica 10.0 manual book (electronic version), StatSoft, 2011.
Stewart-Knox B. Mitchell P., 2003. What separates the winners from the losers in new food product development? Trends in Food Science and Technology, 14, 58–64.
Ueda R., Araki T., Sagara Y., Ikeda G., Sano C., 2008. Industrial sensory evaluation for developing ready-to-eat cup-soup product based on food *Kansei* model. Food Sci. Technol. Res., 14 (3), 293–300.
Yashoda K.P., Jagannatha Rao R., Mahendrakar N.S., Narasimha Rao D., 2004. Egg loaf and changes in its quality during storage. Food Control, 15, 523–526.
Yashoda K.P., Modi V.K., Jagannatha Rao R., Mahendrakar N.S., 2008. Eggs chips prepared by using different millet flours as binders and changes in product quality during storage. Food Control, 19, 170–177.
Zalewski R., 1993. Optymalizacja produktów przez badania preferencji konsumentów, profili sensorycznych i charakterystyk obiektywnych. Przemysł Spożywczy. 5, 122–126.

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