Summary of professional accomplishment
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*Appendix no 2 – pp. 2*
1.1. PERSONAL DATA

Dominika Elżbieta Guzek

1.2. EDUCATION AND SCIENTIFIC DEGREES

- **Doctor of Philosophy degree in agricultural sciences**, discipline: food technology and nutrition; Faculty of Human Nutrition and Consumer Sciences, Warsaw University of Life Sciences WULS-SGGW, 2010, thesis entitled: *Analysis of the effects of various process parameters on quality of vegetables*

- **Master of Science degree in agricultural sciences**, specialization: food technology and human nutrition, field: human nutrition and consumer sciences; Faculty of Human Nutrition and Consumer Sciences, Warsaw University of Life Sciences WULS-SGGW, 2005, thesis entitled: *Influence of various aspects of the technological process on quality of filled meat products*

1.3. INFORMATION ON PREVIOUS EMPLOYMENT

- **Adjunct**, Laboratory of Food Chemistry (Head of Laboratory of Food Chemistry), Faculty of Human Nutrition and Consumer Sciences, Warsaw University of Life Sciences WULS-SGGW, since 1 March 2015

- **Adjunct**, Division of Engineering in Nutrition, Faculty of Human Nutrition and Consumer Sciences, Warsaw University of Life Sciences WULS-SGGW, 2010-2015 (at the begin in Department of Functional Food and Commodities, after reorganization in 2013 in Division of Engineering in Nutrition)

- **Assistant**, Division of Engineering in Nutrition, Faculty of Human Nutrition and Consumer Sciences, Warsaw University of Life Sciences WULS-SGGW, 2009-2010 (at the begin in Department of the Technique and Technology in Gastronomy, after reorganization in Department of Functional Food and Commodities)
1.4. SCIENTIFIC ACHIEVEMENT BEING THE BASIS OF THE HABILITATION PROCEDURE

A. Title of the scientific achievement

The scientific achievement, in accordance with Article 16, Paragraph 2 of the Act of 14 March 2003 concerning the scientific degrees and titles (Journal of Laws No. 65, item 595, as amended), is the series of 7 publications entitled: “Analysis of the factors influencing meat texture and their interdependencies”

B. The list of publications constituting the scientific achievement¹

(numbering according to appendix no 3, I.B.):


¹Publications realized as a part of the “Optimization of beef production in Poland, according to the strategy from fork to farm” Project (POIG.01.03.01-00-204/09-00) and “BIOFOOD – innovative, functional products of animal origin” Project (POIG.01.02-014-090/09)


Accomplishment in total amounts: 160 MSaHE points, IF=4.234

In all publications, I am the first and the corresponding author. My contribution to the mentioned works is presented in Appendix no 3 and the statements of co-authors are presented are Appendix 4, while the full texts are presented in Appendix no 5.

C. Presentation of the scientific aim of studies and their results accompanied by the possibilities of application of results of achievement

1. Introduction

The quality is defined as the extent to which the collection of inherent features meet the requirements (ISO 9001:2005 norm). For meat, quality includes nutritional value, safety and consumer acceptance (Kołczak, 2008). However, while defining the meat quality, the researchers are not consensual and they indicate various ways of its assessment and of the measurement of included features (Acebrón and Dopico, 2000). In spite of mentioned inconsistence, researchers are trying to indicate features influencing the quality of red meat and to specify what methods of assessment may be chosen to verify and predict quality (Hocquette et al., 2010; Legrand et al., 2013).
From among the features of meat quality, indicated by Kołczak (2008), special role is attributed to consumer acceptance. It is associated with the fact, that according to the current requirements of food law, the agri-food products available on the market must guarantee safety on each stage of production and distribution (Regulation no 178/2002), however their eating quality may be different. The consumer acceptance is associated not only with sensory features, but also features associated with convenience, with influence on health, with ethical considerations and with animals well-being (Bernués et al., 2003).

Consumer acceptance is directly associated with sensory quality, that may be defined as combined perception of such features as texture\(^2\) and flavour\(^3\), as mentioned features to the greatest extent influence the final quality assessed by consumers (Grunert et al., 2004).

The texture of meat is the complex physical phenomenon, that may be described by such features, as hardness, elasticity, chewiness, cohesiveness and juiciness (Solomon et al., 2008). The term of hardness\(^4\) is for meat commonly used instead of the term of texture of meat (Solomon et al., 2008). Moreover, according to the classical work of Bourne (1982, 2002), hardness (that is according to its definition measured using instrumental methods), is the best feature to predict tenderness\(^5\) of meat (that is according to the definition assessed using sensory methods), so many authors simplify it and use both terms interchangeably. In the presented accomplishment mentioned terms would also be used interchangeably.

The tenderness of meat depends on the type of the muscle fibers, the quantity and type of the connective tissue (Kirchofer et al., 2002) as well as sarcomere\(^6\) length (Wheeler

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2 Texture – group of physical features (mechanical and rheological), being influenced by the structure* of food products. It is a multiparameter feature, that is perceived with somatic senses (Bourne, 2002). Surmacka-Szcześniak (2002) indicates, that texture may be also perceived with senses other than somatic. In the original definition of Bourne, the senses of sight and hearing were not included, but they also may participate in perceiving actuations associated with quality (Marzec et al., 2005). Definition of Bourne (2002) indicates also, that the texture of food products may be measured in objective way, as the function of mass, time and distance.

* Structure – built on the molecular, microscopic and macroscopic level.

3 Flavour – the impression perceived by combined chemical senses (senses of taste and smell).

4 Hardness (meat hardness) – is assessed using instrumental methods, e.g. using the universal testing machines (values expressed as the SI units). For the instrumental measurement, most often Warner-Bratzler shear force is measured, while less often texture profile analysis is applied or slice shear force is measured. In the case of all the mentioned methods, the determined parameter is the maximum force* of shearing/compressing.

* Maximum force is interpreted as the highest value of force observed for the graph of the test of shearing or compressing.

5 Tenderness (meat tenderness) – sensory feature, that is perceived to be the most prominent single component influencing meat quality perceived by consumer.

6 Sarcomere – is the basic unit of striated muscle tissue.
et al., 2000). For the beef meat, the various tenderness of beef meat is one of the most important problems for production (Delgado et al., 2006). Except from the problems associated with providing for the market beef meat of the acceptable and repeatable quality, the second major problem is associated with deteriorating meat quality by inappropriate preparing it at home by consumers (improperly chosen method of thermal treatment or improperly chosen temperature and/or time of treatment) (Behrends et al., 2005).

The tenderness of meat may be assessed both using sensory methods (untrained consumers, qualified expert panel) and instrumental methods (Hildrum et al., 2009). Various values of tenderness assessed using instrumental methods of assessment may be associated mainly with the breed (Rhee et al., 2004). Various tenderness notes obtained in the sensory methods of analysis may be also associated with the individual influence of assessing person, as well as the influence of environment (Van Wezemael et al., 2014). Moreover, it is hard to predict, even while objective data obtained using mentioned methods are used, how do consumers perceive tenderness of meat at home (Lorenzen et al., 2003). It is associated with the fact, that consumers in various countries may perceive tenderness in different way (Van Wezemael et al., 2014), as well as they may prefer various methods of preparing meat.

The presented achievement, comprising collection of publications, entitled “Analysis of the factors influencing meat texture and their interdependencies”, brings a lot of new analytical and scientific elements associated with dependencies between pre-slaughter, as well as post-slaughter features (fat class, conformation class) and general quality of meat assessed using instrumental and consumer methods.

2. Scientific objective and hypotheses

The main aim of the presented accomplishment was to analyze the features of texture of beef and pork meat, in the instrumental and consumer assessment, as well as to analyze their interdependencies.

Detailed objectives:

- assessment of the influence of the structure of meat, type of muscle and its pre-slaughter function on the quality features of meat,
- assessment of the influence of the pre-slaughter features and post-slaughter classification on the structure and texture of meat,
- assessment of the interdependencies between quality features of meat,
- assessment of the possibilities of applying proper method of thermal treatment for meat cuts to obtain consumer satisfaction.

On the basis of the above-mentioned objectives, the following hypotheses were specified:
- the length of the sarcomeres depends from the type of muscle and the chosen individual features of animal,
- the inherent structure of muscle influences texture of meat in the instrumental assessment and its tenderness, assessed by consumers, after thermal treatment,
- the conformation class and fat class of beef carcasses does not influence the quality of meat perceived by consumers, including its texture,
- type of muscle and applied thermal treatment influence the general final quality of meat in the consumer assessment.

3. Discussion of publications

3.1. The influence of pre- and post-slaughter factors on the sarcomeres length


Sarcomeres length, being associated with inherent structure of meat, according to the literature may be created by various factors, including pre-slaughter, as well as post-slaughter features (Rhee et al., 2004). In the studies that I have conducted, I have...
analyzed the influence of the features creating the sarcomeres length, while from among post-slaughter features (features of meat), I have analyzed pH of meat (publication no I.B.1.) and marbling (publication no I.B.2.), while from among pre-slaughter features (features of animal), I have analyzed applied crossbreeding (publication no I.B.3.) and age of animal (publication no I.B.2.). I have conducted studies for various muscles, that allowed also to indicate the influence of muscle on the observed associations.

For the analyzed samples of beef meat, I have stated a statistically significant influence of pH values on the sarcomeres length (publication no I.B.1.). It may result from the fact, that some relations exist between the structure of muscle and transformations of glycogen (anaerobic glycolysis, while the final product is the lactic acid, that causes the decline of muscle tissues pH). Nonetheless, the observed correlation between pH values and sarcomeres length was moderate (R=0.5354; p=0.039). Taking into account the fact that for the analyzed beef meat, no meat defect due to the improper pH values was stated, it may be concluded, that pH is an important factor influencing sarcomeres length, but not the only one.

For the samples of beef meat, that I have analyzed, the higher the marbling level was, higher was also sarcomeres length (publication no I.B.2.). I have stated the positive correlation between sarcomeres length and marbling level, that was stronger, than previously indicated correlation observed for pH, even in the analysis conducted for the all the muscles combined (p=0.011; R=0.6353). The important achievement of the presented studies was deepening the knowledge associated with the influence of type of muscle on the strength of observed correlation. I have proven, that the strength of correlation between sarcomeres length and marbling level depends on the type of muscle (it was very strong for the *longissimus dorsi lumborum* p=0.006; R=0.9692). Moreover, observations of some authors let to attribute mentioned association to simultaneously higher tenderness of meat in the consumer assessment (Ngapo et al., 2012). It indicates, that there exists the complex mechanism of meat tenderness modeling, as it is dependent not only from marbling and factors creating marbling, but also from sarcomeres length and factors creating sarcomeres length.

The influence of genetics of animals on the sarcomeres length is widely analyzed, but the results obtained by various authors are not consistent. In the results, that I have
conducted, I have compared meat of the purebred animals and meat of animals obtained from the crossbreeding of Polish Landrace and Duroc animals. In the case of *longissimus dorsi* muscle, no statistically significant influence of applied crossbreeding on the sarcomere length and Warner-Bratzler shear force was stated (publication no I.B.3.). The obtained results may be compared with the results of the study of Wood et al. (1996), who did not observe the difference of sarcomere length between meat of Duroc and Large White animals. However, the opposite results were observed in the studies of Jeleníkova et al. (2008) and Sorapukdee et al. (2013). In the mentioned studies, the differences of tenderness were stated between the samples of meat from the White Czech Landrace and Duroc animals, both in the sensory assessment and instrumental measurement (Jeleníkova et al., 2008) and the differences of sarcomeres length were stated between the samples of meat from the Landrace, Duroc and Large White animals (Sorapukdee et al., 2013).

The fact, that available literature data are inconsistent, may result from not only various breeds analyzed in various studies, but also from individual genetics not included in the analysis. It may be concluded from the results of the study of Monin et al. (1999), who assessed the influence of halothane genotype on the sarcomere length observed for Pietrain and Large White animals and concluded, that sarcomere length may depend on the halothane genotype. Taking it into account, it should be emphasized, that own studies (publication no I.B.3.) were conducted for the meat of the HAL-gene free animals. It may indicate, that in the case of elimination of the HAL gene from the population of animals, for the assessed breeds and applied crossbreeding, no difference of sarcomeres length may be stated.

In the area analyzed in the presented studies (publication no I.B.1.), no effect of age on the length of the sarcomeres, or the tenderness measured instrumentally was stated. I had the similar conclusions in the case of the assessment of the influence of conformation class and fat class, also being post-slaughter factors, but assessed not for single muscles, but for whole carcass. In the studies, that I have conducted, for analyzed area, I did not observe the influence of mentioned factors on the sarcomeres length in beef meat (publication no I.B.1.).

Simultaneously, the analysis that I have conducted let to conclude, that there is both an influence of type of the muscle and of animal on the sarcomeres length, as well as combined influence of mentioned factors on the sarcomeres length (publication no I.B.2.).
It was observed in the analysis, that the shortest sarcomeres were stated in the case of *longissimus dorsi thoracis* muscle and the longest – in the case of *infraspinatus* muscle. I found also, that the location of samples in *longissimus dorsi* muscle (thoracis or lumbar part – *thoracis* or *lumborum*) has influenced the sarcomere length (publication no I.B.2.). As a result of mentioned observation, I have formulated an important assumption, that in the case of large muscles or cuts (including more than one muscle), the sampling procedure must be planned to guarantee representativeness and repeatability of results of the sarcomeres length. It means, that methodological assumptions of the sarcomeres length measurement must provide for dividing elements into single muscles and dividing large muscles additionally into anatomical parts. It may also explain the reason of some inconsistencies of the published results of sarcomeres length, that are often presented for *longissimus dorsi* muscle, being the longest muscle in carcass, without specifying the anatomical part of the muscle.

The new original analytical value of the study that I have conducted was associated with indicating the important role of the meat features (pH, marbling) in creating the sarcomere length, as well as with indicating the influence of muscle on the strength of association. In the conditions of studies that I have conducted, for samples of beef and pork meat obtained from Polish animals, minor role of individual features may be indicated, while major role of the post-slaughter features of meat in creating sarcomeres length must be emphasized. Especially for, proven by me, influence on the sarcomeres length of not only muscle, but also of the sample location in muscle, the observations have a practical aspect and may motivate to presented methodological assumptions.

### 3.2. The influence of the type of muscle fibers on the quality features of meat

**Publications no I.B.1., I.B.2., I.B.3.**


The inherent structure of meat is associated *inter alia* with the type of striated muscle fibers. There are two main types of muscle fibers: I type (slow-twitch oxidative fibers – ST) and II type (fast-twitch glycolytic fibers – FT) (Shi et al., 2008). In the studies, that I have conducted, I have analyzed the influence of the type of muscle fibers on the chosen quality features, including mainly basic composition. While planning the studies, I have assumed, according to the classification of Kirchofer et al. (2002), that among the muscles with dominant I type muscle fibers, there are infraspinatus and supraspinatus muscles, while among muscles with dominant II type muscle fibers, there are longissimus dorsi, as well as triceps brachii caput longum and caput laterale muscles.

I have conducted the analysis for muscles consisting of I and II type muscle fibers including the influence of age (publication no I.B.1.) and of sarcomeres length (publication no I.B.2.) on the basic composition. Moreover, I have assessed muscles consisting of the II type muscle fibers, obtained from the animals of various breeds (publication no I.B.3.).

The results of the published studies of the dependencies between type of muscle fibers and quality features are not consistent. Chang et al. (2003) stated the positive correlation between the share of the I type fibers in muscles and the Warner-Bratzler shear force (tenderness), while Ryu and Kim (2005) for the same muscle observed the opposite association.

The analysis, that I have conducted let to conclude, that for the analyzed samples (publication no I.B.1.), some differences of basic composition of infraspinatus and longissimus dorsi muscles exist and are dependent from the age of animal. However, for the fat and connective tissue content, I have concluded, that depending from the type of muscle fibers, the nature of differences between animals may be not invariable.

I have deepen the conducted analysis in the later study analyzing the same muscles (publication no I.B.2.) as previous in the study, but assessing the basic composition as dependent from the type of muscle. The previously indicated differences of the fat and connective tissue contents were confirmed also in the presented study. Moreover, I have observed the differences of the intramuscular fat and protein contents between analyzed
muscles, assigned to the various types of muscle fibers. While analyzing the protein content, I have concluded, that it may differ from 19.8%, for infraspinatus muscle, to 22.8%, for longissimus dorsi lumbrorum muscle. In the conducted study I have also stated statistically significant correlation between sarcomeres length and protein content (p=0.039; R=-0.5365), as well as intramuscular fat content (p=0.011; R=0.6353). Hence, it may be concluded, that protein and intramuscular fat content are simultaneously associated with type of fibers and sarcomeres length.

In general, it may be stated, that depending on the breed and crossbreeding procedure, some differences in the basic composition of meat may exist (Kim et al., 2008). Hence, the next analysis, that I have conducted was associated with influence of applied crossbreeding of the Polish Landrace and Duroc breeds on the chosen quality features of meat, including basic composition (publication no I.B.3.). It let to relate the previous observations to dependencies stated for pork meat. In the study conducted for animals of various breeds, but the same cut, while no sarcomeres length differences were stated, also no difference of protein content was observed.

The presented observations, linking the protein content in muscle with sarcomeres length and muscle fibers type, may be important, taking into account the fact, that in some tenderness prediction models, as an additional factor, is taken into account the protein content (Pospiech et al., 2007), or even the free amino acids content (Mullen et al., 2000). However, in the case of free amino acids, correlation with tenderness is stated to be moderate. As the models of beef meat tenderness prediction, elaborated so far, are not characterized by the sufficient level of precision and/ or utility, deepening the knowledge about interdependences of mentioned factors may be crucial.

### 3.3. The influence of the conformation and fat class of beef carcasses on the quality features of meat


The quality of beef, that is influenced by a number of factors, both pre-slaughter (race, genetics, age, gender, nutrition, pre-slaughter handling) and post-slaughter ones (slaughtering procedure, chilling of carcass, aging), is the complex notion. In order to paid producers accurately to the quality of raw material they offer, the European system of carcases classification (S)EUROP\(^7\) was effectuated.

The results of the studies indicate, that improvement of the fat class in the (S)EUROP system of carcases classification and assessment, associated with increasing meatiness of pigs, may be associated with decreased meat quality. It was proven, that for such features, as tenderness and juiciness, lower sensory ratings were obtained for the pork meat assessed as the “E” conformation class, than for ones assessed as the “O” conformation class (Wajda et al., 2004). It may result from the fact, that while pig meatiness is increased, simultaneously fat content is decreasing, including intramuscular fat content (Orzechowska et al., 2012).

The small number of studies analyzed the influence of the (S)EUROP beef carcases classification for the beef cattle or dual purpose (beef and dairy) cattle on the general quality, including tenderness measured using instrumental or sensory methods. I have analyzed it in my studies, as they were associated with the influence of the conformation class and fat class of the: beef cattle on the quality features measured using instrumental methods (publication no I.B.1.), dual purpose cattle on the intramuscular fat content (publication no I.B.4.), as well as beef and dual purpose cattle on the quality features assessed by consumers (publication no I.B.5.).

\(^7\) (S)EUROP is the system of the classification and assessment of beef and pork carcases, conducted by experts. The (S)EUROP system of pork carcases classification is based on the criteria of lean meat share in carcase. The 6 classes are distinguished, taking into account lean meat share: S – 60% or more, E – 55% or more, but less than 60%, U – 50% or more, but less than 55%, R – 45% or more, but less than 50%, O – 40% or more, but less than 45%, P – less than 40%. In the case of beef carcases, conformation class and fat class are as following: conformation classes: S – superior conformation (used for double-muscled carcass type), E – excellent conformation, U – very good conformation, R – good conformation, O – fair conformation, P – poor conformation; fat classes: 1 – low fat class, 2 – slight fat class, 3 – average fat class, 4 – high fat class, 5 – very high fat class.
Analysis of the relationship between the quality assessment, conducted in the (S)EUROP system, and physical attributes of blade muscles (*infraspinatus, supraspinatus, triceps brachii caput laterale, triceps brachii caput longum* and *triceps brachii caput mediale*) from 33 animals (publication no I.B.4.) revealed, that there exist a combined influence of type of muscle and conformation class (p=0.0330), as well as combined influence of type of muscle and fat class (p=0.0424) on the share of the intramuscular fat for muscles from blade. Moreover, I have stated no combined influence of the conformation class and fat class on the intramuscular fat content. At the same time, for the connective tissue content, I have observed no combined influence of the type of muscle and conformation class, as well as no combined influence of the type of muscle and fat class.

It may let to conclude, that there is a stronger correlation of the type of muscle, than of the (S)EUROP carcass classification (conformation class and fat class) with the content of intramuscular fat. It was confirmed by the additional post-hoc analysis, that revealed significantly higher content of intramuscular fat observed for *triceps brachii caput mediale*, than for *supraspinatus* (“O” conformation class – fair conformation). The presented observation may be associated with the fact of various pre-slaughter functions of analyzed muscles, in spite of the fact, that both are from the same cut. Totland and Kryvi (1991) in their study concluded, that taking into account the types of fibers, the muscles from the blade may differ significantly. According to the classification of Kirchofer et al. (2002), the fibers of the *supraspinatus* are classified as I type (“red muscles”), while the fibers of the *triceps brachii caput longum* and *caput laterale* are classified as II type (“white muscles”). Moreover, in the conducted own study, I have stated, that muscles obtained from the carcasses of the lowest fat class of the analysed ones, were characterized by lowest intramuscular fat content, only in the case of *supraspinatus* muscle. Hence, it may be concluded, that (S)EUROP classification is not enough related to the quality of meat.

The other study, that I have conducted (publication no I.B.1.), that was associated with analysis of the influence of the conformation class and fat class on the tenderness, sarcomeres length, basic composition and components of color of meat, was deepening the previous analysis. In the conducted study, I have concluded, that in the analyzed area, there is no influence of both conformation class and fat class, assessed in the (S)EUROP system, on the tenderness, sarcomeres length and color of beef meat. The only observed associations
were stated for fat class and elements of basic composition (fat, water and connective tissue contents). The presented results of the studies of the beef quality deepen the previous studies of French et al. (2001), who concluded, that there is no relation between post-slaughter assessment of carcasses fat class, according to the (S)EUROP system, and beef meat tenderness measured in the instrumental assessment.

However, not always the differences of the beef meat tenderness, that are stated in the instrumental measurement, are the same as differences observed by consumers (Destefanis et al., 2008). Hence, there was a need to conduct also the analysis including associations between post-slaughter assessment of carcasses according to the (S)EUROP classification and consumer perception. The analogous study was conducted by McKenna et al. (2004), for the post-slaughter assessment of the beef carcasses according to the USDA (ang. United States Department of Agriculture) standard. They concluded, that there is no relation between beef meat quality assessed by consumers and post-slaughter assessment of carcasses according to the USDA standard. The conducted own study (publication no I.B.5.) included assessment of tenderness, juiciness, aroma and general acceptability, conducted by consumers of 8 cuts obtained from 30 animals of various characteristics. In the conducted study, it was concluded, that conformation class, fat class and ossification score did not influence mentioned features assessed by consumers.

The original value of the conducted studies was associated with indicating, that lack of association between (S)EUROP classification and quality features of beef meat is stated both for tenderness assessed in instrumental measurement and assessed by consumers, as well as for other features of meat.

3.4. **The influence of the type of muscle and applied thermal treatment on meat texture features assessed by consumers**


Beef palatability in consumer perception is generally determined by tenderness (Destefanis et al., 2008) and juiciness (Robbins et al., 2003). However, lack of palpable fibers (low level of fibrousness) is also quite often indicated as feature contributing to obtaining high ratings of beef meat tenderness in consumer assessment (Otremba et al., 2000).

Taking into account the role of indicated features in creating palatability of beef meat assessed by consumers, in the studies that I have conducted, I have analyzed co-dependencies between indicated features (publication no I.B.6.), influence of the type of muscle (cut) (publication no I.B.5., I.B.7.) and influence of applied thermal treatment on the tenderness and juiciness, as well as on other features assessed by consumers (publication no I.B.7.).

The study, that I have conducted, associated with analysis of co-dependencies between tenderness, juiciness and fibrousness assessed by beef meat consumers (publication no I.B.6.), indicated strong correlation between analyzed features. The presented study was carried out on samples of beef meat (total number of 860 samples was assessed) from 24 various batches characterized by various level of general quality. The quality of meat depended on the country of origin (meat from Poland, Argentina, Brazil and USA) and the type of production (production based on the extensive and intensive farming). The choice of samples characterized by various quality enabled obtaining a wide range of results for modeling. Also the consumers participating in the assessment were characterized by various age, educational background and monthly income – being representative for two voivodeship capital cities (Warsaw and Olsztyn). The samples of beef meat before the consumer assessment were subjected to standardized grilling process conducted until the moment of obtaining the temperature of 71±1°C at the geometric center of a steak (medium done treatment). The consumer assessment was conducted in the 23-point intensity scale, according to the method elaborated at the Texas A&M University. In the study, *inter alia* a strong negative correlation between tenderness and fibrousness of beef meat (R=-0.9246; p=0.0000) was defined, that is associated with the fact, that the more muscle fibers were palpable in consumer assessment, the tenderness level was perceived to be lower.
conducted studies indicated the significant role of the inherent structure of meat, perceived by consumers as a fibrousness (the presence or lack of palpable fibers), in the general perception of the textural features of product.

Taking into account the indicated role of the structure of muscle in creating the tenderness of meat assessed by consumers, in order to analyze the influence of type of muscle and applied thermal treatment on the general quality of beef meat, two experiments were designed. It was planned to assess 8 cuts (publication no I.B.5.) and 13 cuts (publication no I.B.7.) from 30 carcasses characterized by various fat class and conformation class, that were subjected to roasting (publication no I.B.5., I.B.7.), grilling and slow cooking (publication no I.B.7.).

In the study that was associated with influence of cut of meat subjected to roasting, on the consumer perception of the quality of beef meat (publication no I.B.5.), it was concluded, that depending on the applied cut (obtained from the same carcasses), various level of tenderness, juiciness, aroma and overall acceptability may be obtained in the consumer assessment. For all analyzed factors, the highest values of all consumer attributes were observed for *psoas major* muscle, but in the case of tenderness, aroma and overall acceptability (but not juiciness), the muscle was comparable in the consumer assessment with *gluteus medius* muscle.

Conducting thermal treatment in the stable and controlled conditions, that was applied in the conducted consumer study, is important to obtain repeatable and comparable results in the case of consumer analysis (Wheeler et al., 1994). However, improperly chosen thermal treatment may contribute to deteriorating tenderness and, as a result to deteriorating quality of meat even characterized by very good initial parameters. Moreover, consumers at home often don’t have possibility to control temperature and degree of doneness and they are preparing meat based on their culinary knowledge and preferences, that not always guarantee obtaining high quality and satisfaction (Wheeler et al., 2004).

The consecutive study, that I have conducted was associated with combined influence of cut and thermal treatment on the consumer perception of beef quality (publication no I.B.7.). In the conducted study, I have confirmed statistically significant influence of cut on tenderness (p=0.0000), juiciness (p=0.0052), aroma (p=0.0011) and overall acceptability (p=0.0001). Moreover, I have observed the influence of thermal
treatment on tenderness (p=0.0102), juiciness (p=0.0000) and aroma of beef meat (p=0.0057). In the conducted research, I have also confirmed the combined influence of cut and thermal treatment on juiciness of beef meat (p=0.0002). I have concluded, that general quality of various cuts, independently from the type of animal, may be enhanced, while appropriate thermal treatment method is applied. The presented study let to indicate, that not only the cut, but also applied thermal treatment may exert a decisive influence, not only on the general quality, but also on the share of specific features in the general assessment.

Detailed analysis indicated, that the tenderness of grilled meat samples is characterized by higher ratings than tenderness of roasted meat samples. Simultaneously, the highest ratings of general acceptability was obtained by roasted meat samples. It may indicate, that meat tenderness does not directly influence the general consumer acceptability. The analogous studies were conducted in Japan, for traditional methods of thermal treatment, such as yakiniku, or shabu shabu (Polkinghorne et al., 2011). In the mentioned study it was stated, that for applied methods, flavor was determinative for the general quality, while for grilling beef, rather tenderness was decisive for general quality (Polkinghorne et al., 2011). Hence, it may be stated, that for Polish consumers, the tenderness of beef meat is not the most important feature in the general assessment. In the majority of the European countries, in which beef meat is consumed more frequently, than in Poland, the tenderness of beef is indicated to be the determinative factor, notably influencing quality of meat, assessed by consumers (Verbeke et al., 2010). However, some studies indicate, that the flavor may be an equally important factor, as tenderness (Neely et al., 1998; Behrends et al., 2005).

The original value of the conducted studies was associated with demonstrating the determinative influence of applied cut and destined method of thermal treatment on the quality of beef meat assessed by consumers. On the basis of the results of conducted studies, it may be concluded that the method of thermal treatment, being properly chosen for single cuts, characterized by specified chemical composition and structure, may contribute to obtaining higher consumer meat acceptability.
4. Summary

The obtained results let to verify positively the research hypotheses. With reference to hypotheses associated with features of meat structure, it was stated, that there exist both an influence of type of muscle and an individual influence of animal on the sarcomere length, as well as combined influence of type of animal and muscle on the sarcomere length. Simultaneously, the combined effect of muscle and conformation class on the intramuscular fat tissue was stated and intramuscular fat tissue content was observed to be correlated with sarcomere length. Moreover, in the consumer assessment, it was stated, that the fibrousness, resulting from the inherent structure of muscle, may influence its tenderness. With reference to hypotheses associated with features of meat texture, it was stated, that the conformation class and fat class of beef carcasses do not influence meat tenderness, both analyzed in instrumental measurement and assessed by consumers. Moreover, the hypothesis associated with the influence of muscle and thermal treatment on the general quality of meat assessed by consumers was also positively verified.

Taking into account the results of the conducted research, it should be indicated, that the studies of the various aspects of meat quality should be complex and should include variety of features, that may determine quality, in order to assess the influence of single variables. While instrumental measurement and assessment conducted by consumers are combined, transferring the results obtained using instrumental methods on the consumer perception of eaten meat, is becoming possible.

Summing up the obtained results, it must be emphasized, that the studies of meat quality determinants should be complex and should include variety of features, in order to assess the influence of single variables. It must be stated, that in relation to meat quality, combining instrumental assessment and consumer assessment enables obtaining results, that may be helpful in the advertising message placed on the packaging of product, indicating inter alia proper thermal treatment for detailed cuts.

5. Conclusions

- The assessment of the quality of beef carcasses, conducted in the (S)EUROP system, is not sufficient to specify the general quality of meat, including its texture. It seems,
that other methods of assessment of quality of beef meat are essential, in order to
assure specified and predictable general quality.

- Stronger influence of type of muscle, than influence of animal, from which muscle
was obtained, on the texture features, indicates the necessity of seeking other
possibilities of meat analysis, than assessment of whole carcasses.

- Applying proper method of thermal treatment and conditions of thermal treatment
for meat cuts may lead to obtaining appropriate level of meat quality, as well as
consumer satisfaction.

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1.5. DISCUSSION OF OTHER SCIENTIFIC – RESEARCH ACHIEVEMENTS

I graduated from Warsaw University of Life Sciences in Warsaw, Faculty of Human Nutrition and Consumer Sciences with a master engineer degree in 2005 year. My thesis entitled: Influence of various aspects of the technological process on quality of filled meat products was very well graded (5.0), as well as my master degree exam (5.0), so my final grade was also very good (5.0). The same year, I started my Ph.D. studies in Faculty of Human Nutrition and Consumer Sciences of Warsaw University of Life Sciences in Warsaw. In 2010 year, I presented my Ph.D. thesis entitled: Analysis of the effects of various process parameters on quality of vegetables to the Faculty Board of the Faculty of Human Nutrition and Consumer Sciences. My Ph.D. thesis was associated with the influence of the preliminary low-temperature blanching processing of vegetables on the physical and sensory features and was very well graded (5.0), so after passing all the exams and public dissertation defense, I obtained Ph.D. degree in agricultural sciences in the discipline of food technology and nutrition. I started my professional work in December 2009, as assistant in the Division of Engineering in Nutrition of the Department of the Technique and Technology in Gastronomy. My research work is associated with analysis of the physical features of the plant and animal raw materials and products, including application of modern methods of assessment and analysis of mentioned features.

Among my research interests, I may indicate following subject groups (numbering according to appendix no 3, II.A. II.D.):

1. **Subject group A.1.**: Nondestructive analytical methods in the assessment of the physical features of food products (publications no II.D.23., II.D.25., II.D.26., II.D.28., II.D.31.)
2. **Subject group A.2.:** Pork and beef meat sector and perspectives of their development (publications no II.A.2., II.D.2., II.D.3., II.D.35., II.D.34., II.D.36., II.D.37.)

3. **Subject group A.3.:** Trends of changes in red meat and meat products processing (publications no II.A.3., II.A.4., II.A.5., II.D.22., II.D.24., II.D.25., II.D.27., II.D.29., II.D.30.)

4. **Subject group A.4.:** Analysis of the possibilities of application of the computer image analysis method in the assessment of the meat quality (publications no II.D.4., II.D.5., II.D.6., II.D.8., II.D.18.)

5. **Subject group A.5.:** Analysis of the possibilities of assessment and creating color of meat and meat products (publications no II.A.9., II.D.7., II.D.9., II.D.11., II.D.12., II.D.13., II.D.14., II.D.16., II.D.17., II.D.32.)

6. **Subject group A.6.:** Possibilities of modification of the recipe composition of bakery products (publications no II.D.1., II.D.21.)

7. **Subject group A.7.:** The quality of meat obtained from the niche production (publications no II.A.7., II.A.8., II.D.10.)

8. **Subject group A.8.:** Creating and assessment of the quality of plant products (publications no II.A.1., II.A.6., II.A.10., II.D.15., II.D.19., II.D.20 II.D.33.)

A. Discussion of publications in the cycles of subjects

1. **Nondestructive analytical methods in the assessment of the physical features of food products**
   (numbering according to appendix no 3, II.D.)

   Analysis of the food quality is the source of number of information associated with physical, chemical and biological features of food products. Among the most important elements of food quality analysis, qualitative and quantitative analysis may be indicated. Majority of the research of quality of food products are the destructive methods (when preparing sample includes its fragmentation, mineralization, etc.), but currently, nondestructive methods are becoming more frequently applied, as they allow not only to conduct analysis without limitations associated with costs of raw material, but also to conduct more analysis in the unit of time. Observations indicated previously induced me to
analyze the possibilities of using nondestructive analytical methods in the assessment of the quality of food products (publications no II.D.23., II.D.25., II.D.26., II.D.28., II.D.31.).

Consumers expect to receive beef meat characterized by high tenderness, juiciness and discriminant of flavor (Grunert et al., 2004), while they are able to pay for such meat the price proportional to the quality (Lyford et al., 2010). As a consequence, producers are interested by offering beef meat characterized by high, expected by consumers, quality. In Europe, the system of beef carcasses classification and post-slaughter assessment – S(EUROP)\(^8\) is applied, whereas whole carcasses, not cuts are assessed. As a consequence, the situation, associated with various quality of cuts obtained from the same carcass of defined (S)EUROP note, is observed. Such assessment of meat quality in the (S)EUROP system do not provide sufficient meat quality information for consumers. The reflection specified above motivated me for analysis of the possibilities of application of nondestructive methods of physical features of quality assessment, including visual features, in the general assessment of quality. Such methods could also be used in the prediction of the consumer acceptance of beef meat.

At the beginning, I have analyzed European and applied internationally systems of assessment of the beef meat quality (publication no II.D.28.). In Europe, carcasses are assessed post-slaughter using the (S)EUROP system and the price of carcasses depends on the mass of carcass, conformation class and fat class. As it was previously mentioned, it is not a system directly oriented on the assessment of quality perceived by consumers. In some countries, inter alia in the United States of America, Japan, or Australia, in the assessment of beef quality, except mentioned above features, are taken into account also other features, e.g. marbling\(^9\), color of meat and color of fat (Tatum, 2004). Mentioned features, are better notes, than (S)EUROP system, in the explaining the total quality of beef meat. Grading of the additional features may be conducted by the qualified experts or using the specialist devices using the image analysis.

Possibilities of mentioned measuring instruments induced me to analyze the potentials and possibilities of using the computer image analysis (CIA) in the agri-food industry (publication no II.D.31.). Using such techniques allows to assess the chosen

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\(^8\) see footnote no 5
\(^9\) see footnote no 6
parameters of the raw material, as color, shape, size and to determine dependencies between parameters (Sánchez et al., 2008). The research indicate also, that mentioned methods are currently more frequently applied in the agri-food industry in order to predict other features, such as texture, basic composition (including the quantity of intramuscular fat) or production efficiency, on the basis of parameters directly assessed using computer image analysis. It is possible, due to the fact, that CIA is the nondestructive method, that allows quick, reproducible and objective assessment of quality and sometimes also, allowing to overcome the limitations of traditional methods, associated with their time- and cost-consuming character (Du and Sun, 2005).

Researchers are trying to elaborate the tools and methods being adequate to the perceiving and assessment of the food products by consumer. In order to define the possibilities of using mentioned nondestructive methods, I have analyzed the literature and on the basis of the current publications I have elaborated an article associated with assessment of the quality of food products using the computer image analysis (publication no II.D.26.). Except for possibilities of using computer image analysis, indicated previously in the publication no II.D.31., the deepened analysis was conducted, while the practical application of the computer image analysis was proven. It is used as the tool to assess such features, as color of pork meat, water-holding capacity of meat, thickness of fat cover in carcass, drip loss and pH of meat, sensory features of food products, salt content in meat products, quality of bakery products, cheddar-type cheeses, tomatoes, as well as for sorting and classification of fresh fruits (related literature is presented in the publication no II.D.26.). Analysis of the mentioned possibilities was for me also the occasion for the original studies associated with possibilities of using computer image analysis in the assessment of the beef and pork meat quality (cycles of subjects A.4. and A.5.).

The summarizing of the described part of my research interests were two publications (publication no II.D.23., II.D.25.) indicating possibilities and recommendations for application of methods, including nondestructive methods, for the assessment of physical features of the agri-food products. Both publications concentrated on the modern methods of the measurement of physical features of agri-food products, indicating their strengths and weaknesses. Modern, nondestructive methods of the assessment of quality, in spite of the fact, that they may be objective, reproducible, quick and accurate, will not be a
substitute for classical reference methods. However, due to the ease and quickness of conducting measurement, they are and will be applied in the agri-food industry. Applying the new, nondestructive analytical methods imposes the laboratory assessment of their validity and possibilities of application. Moreover, in the publication no II.D.25., the assumptions for application of the instrumental on line measurements of meat quality were formulated, while in the publication no II.D.23. – also the assumptions for application of the instrumental measurements of meat quality in the laboratory were defined.

2. **Pork and beef meat sector and perspectives of their development**

(numbering according to appendix no 3, II.A., II.D.)

The publications incorporated into cycle of subjects A.2. are associated with the changing situation on the world beef and pork meat market, including especially factors influencing their consumption. It is the complement of knowledge from the area of factors influencing the red meat demand, as well as changes of the world meat market and their influence on the Polish meat market.

In the publication no II.D.36., the possibilities of production of beef meat in the quality-assurance systems, being the tool to obtain high and reproducible quality of the culinary meat, were presented. Taking into account the fact, that in Poland decrease of beef meat consumption to the very low level, not observed so far, was recently observed, systemic solutions are needed, to obtain the improvement of the quality of meat and its reproducibility. Polish consumer is not interested in purchasing beef meat, due to the fact, that its quality is not repeatable and due to negative price-quality relation.

The described situation does not mean, that on the Polish market is only available beef meat of a low quality. The quality of beef is very diverse while meat is purchased, but it may be also deteriorated by improper preparation methods applied by consumers before consumption (publication no II.D.35.).

The factors being determinants of consumption and changes of consumption of beef meat all over the world and in Poland were characterized in the publication no II.D.2. It let to specify changes of beef consumption and to define both local and global consequences of mentioned changes. In general, it may be stated, that the current situation observed on the Polish beef meat market is determined by expectations of consumers associated with high
and reproducible quality beef meat, while market is not able to realize mentioned expectations. The reason of low interest in purchasing beef meat on the Polish market, on the one hand, are quality of the available beef meat being hard to predict, accompanied by high prices in the single-line shops, but, on the other hand, are lack of traditional beef meat consumption and of ability to prepare it (Gutkowska, 2012).

The different situation is observed in the case of pork meat, being traditionally most frequently consumed in Poland. Mentioned situation was presented in the publication no II.D.3. The pork meat market is characterized by the lack of balance between supply and demand. In the pork meat production, the cyclical changes are observed (so called cycle of pork production), being a consequence of forage and livestock prices instability. In spite of this, pork meat is dominant in the general meat consumption, both in Poland and in the world.

In Poland, the increase of general meat consumption is observed, but the share of pork meat in total meat consumption is all the time decreasing, in spite of the stable pork meat consumption. The changes of proportion may result from the recommendations of dietitians, physicians and nutritionists, to consume rather lean meat (e.g. poultry meat), but also from relatively lower prices of poultry meat. However, the producers successfully apply crossbreeding, to improve the productivity of pork carcasses, with accompanying decreasing fat content, that may improve the general quality of meat. Other solutions aimed at improving the quality were described in the publications no II.D.34., II.D.37.

The changing structure of consumption of beef and pork meat may be associated with their quality and needs of consumers. The needs of Polish consumers associated with meat functional and convenient products were an object of my analysis in the publication no II.A.2. In the mentioned study, it was observed, that the highest share of “innovators” or “early adopters” (individuals who purchase product very early or quite early) in case of meat and sausages consumers, were stated for clients of natural food shops (75%, 83%), supermarkets (59%, 58%) and specialist meat stores (50% for sausages), whereas the lowest interest in novelty was expressed by the respondents purchasing meat and sausages in the local grocery shops (35%, 26%) and discount stores (29%, 36%). In the case of cold cuts deluxe the highest interest in novelty was observed among respondents purchasing in discount stores (71%), while the lowest – among respondents purchasing in supermarkets.
(27%) and natural food shops (17%). The identified trend suggesting that customers are willing to buy various novel meat and meat products in the different places may be a contribution to the formulation of the modern marketing strategies. As a consequence, analysis of factors determining choice of meat products as well as meat quality and possibilities of improvement, must be analyzed, that was the consecutive area of my research interests.

3. Trends of changes in red meat and meat products processing
   (numbering according to appendix no 3, II.A., II.D.)

The situation, described in publications of cycle of subject A.2., observed on the beef and pork meat market, imposes the need for consistent research of the process of production and modification of food products, to not only ensure satisfaction of consumers, but also to meet needs for consuming products characterized by functional and health-promoting features.

The publication no II.D.30. indicates the most important aspects of creating new attitudes and expectations of consumers associated with red meat and red meat products. Taking into account the red meat products, among the most important needs of consumers may be indicated reduction of sodium content, that may be obtained e.g. by replacement of the part of sodium chloride by potassium chloride, magnesium chloride or calcium chloride, as well as by application of herbs and spices mixes, that are improving the saltiness of product without including sodium. The last of mentioned solutions was elaborated and implemented on an industrial scale, by the group with me as a member and co-author of the patent (appendix no 3, II.B.1.).

Taking into account the unified purpose of pork production, the producers concentrate mainly on the improvement of the efficiency of the production. However, enhancing the quantity of meat in the carcass is not always accompanied by improving its quality, but quite the opposite – it may contribute to its deterioration. Simultaneously, with efficiency improvement applied for gilts and boars, the RYR1 (ryanodine receptor-1) gene of stress susceptibility is becoming more important issue, because it contributes to the higher risk of deteriorating quality of meat due to higher frequency of PSE (pale, soft, exudative) meat. Mentioned observation imposed me to analyze the presented above issue in the
Animals characterized by the presence of mutated RYR1 gene, except from the especially high quantity of muscle tissue in carcasses, are characterized by lower efficiency in reproduction, higher hyperthermia susceptibility and higher frequency of falling. Mutation of the RYR1 gene leads to disturbance of the action of the calcium channels in the endoplasmic reticulum of skeletal muscles, resulting in higher amount of liberated calcium ions in response to the factor of stress (Werner et al., 2010). As a consequence, it leads to higher peace of metabolic transformations of carbohydrates (glycogen), causing, as a result, higher share of PSE meat (Van den Maagdenberg et al., 2008). The elimination of animals being carriers of mutated RYR1 gene from the animals for culinary pork meat production seems to be correct option to obtain improvement of the quality of meat. The results of mentioned analysis were used during elaborating patent associated with culinary pork meat (appendix no 3, II.B.2.).

Further changes of the red meat market are associated with meat products characterized not only by designed sensory features, but also by designed health-promoting features. At the beginning, I have interested in possibilities of modifying meat products to adjust them to needs of chosen groups of consumers. I have concentrated on the needs of patients with inflammatory bowel diseases (publication no II.D.29.). During relapses, individuals with inflammatory bowel diseases, due to lower appetite, absorption disturbances, nausea, vomiting, diarrheas, loss of protein to the lumen of intestine and gastrointestinal pain, appearing especially after meal, are frequently malnourished and deficits of numerous nutrients are stated (Schölmerich et al., 2003). As a consequence, group of dedicated food products, for inflammatory bowel disease patients should be characterized by high nutrient density.

Simultaneously, it is observed, that diet being rich in meat and meat products may be one of the reasons of inflammatory bowel diseases (Asakura et al., 2008), but in spite of this fact, demonstrable preference of meat is stated in this group (Sood et al., 2003). Taking into account previously mentioned, it seems, that in this group of patients, meat and meat products enriched with biologically-active compounds may be a good alternative for typical meat products. Such products may let to fill the needs in the case of nutrients for which deficits are common, while simultaneously components, that may have negative impact on the symptoms of disease may be removed.
The red meat (if is consumed in the quantity typical for Polish population), may be also a good source of iron and vitamin D (as except from the skin vitamin D biosynthesis, induced by UV light, and intake of vitamin D from fish, not being frequently consumed in Poland, meat products may be a reasonable source of vitamin D), both being characterized by an inadequate intake by a part of Polish individuals. Taking it into account, I participated in two analysis aiming at designing and validation of food frequency questionnaires for iron (publication under review) and vitamin D (publication no II.A.4.), that would be a quick tool to assess intake in dietary screening. On the basis of the conducted study, it was stated, that among young Polish women, 85% is characterized by intake of vitamin D lower than 5.0 μg a day (AI – Adequate Intake level – Jarosz M. 2012. Human Nutrition Recommendations for Polish Population; Warsaw: National Food and Nutrition Institute). Hence, the vitamin D fortification may be expedient and may contribute to improvement of the public health.

Reflections presented above induced me to analyze possibilities of meat and meat products supplementation with biologically-active compounds, that may have a positive influence on health of whole population (publication no II.D.24.). An example of such trace element may be a selenium, as the nutrient, that may be added to the forage of pigs and as a result successfully change the composition of meat.

Selenium is such a nutrient, that may help to prevent negative consequences of diabetes, that is stated both for cardiological, and nephrological complications, as well as may limit the risk of prostate cancer, by suppressing the increase of cancer cells due to reduction of the regulation of expression of androgen receptor. Insufficient intake of selenium in diet is a factor that promote generation of rheumatoid arthritis, circulatory disorders, congestive called Keshan disease and nephropathy (related literature is presented in the publication no II.D.24.).

The study of Kim and Mahan (2001) indicates, that a dose of selenium of 5 mg per kg of forage does not have the negative impact on daily weight gain or amount of forage consumed by animals, while an effective dose (that may limit the natural drip loss) is observed to be from 0.1 mg of organic selenium and from 0.3 mg of inorganic selenium per kg of forage, being much lower than the value of 5 mg. Meat products obtained from the meat of animals fed with forage with addition of selenium may be a good source to introduce mentioned nutrient to diet of consumers. However, it must be indicated, that an
excessive intake of trace elements may be associated with adverse effect for health of consumers. As a consequence, moderate enrichment of forage in this nutrient should be recommended, taking into account, that only a small share of selenium added may be incorporated into animal muscle tissue.

Selenium incorporating into the forage of the farm animals, in order to increase its quantity in meat, except from the effect of product enrichment with biologically active compound, may result in limitation of meat unsaturated fatty acids oxidation, as a consequence of antioxidative properties of selenium. However, the mentioned dependency is not observed during the prolonged (9 months) storage (publication no II.A.3.). Moreover, the addition of selenium and/or vitamin E to the forage of animals do not contribute to the changes of the share of saturated, monounsaturated and polyunsaturated fatty acids, but may contribute to the changes of the share of palmitic acid (publication no II.A.5.). Independently from the stated lack of the influence of selenium and/or vitamin E supplementation on the total antioxidant status of pork meat and the share of saturated, monounsaturated and polyunsaturated fatty acids, the differences of volatile profile are stated in the case of meat from animals on the supplemented and not supplemented diet (publication no II.A.3., II.A.5.).

All mentioned above modifications lead to obtaining a new product – meat or meat product, that is characterized by new functional and/or health-promoting features, that must be suitably protected by application of dedicated packaging technologies. To fulfill the growing needs of consumers, it is becoming necessary to apply modern packaging methods. Chosen aspects of this issue were presented in the publication no II.D.22.

The basic criterion of choice of meat and meat products are visual features, especially color, being an indicator of freshness and expiry date (Mancini et al., 2009). In the meat industry, the most often is applied modified atmosphere packing, including vacuum packing and modified atmosphere packaging (Ripoll et al., 2013). Suitable choice of the mixture of gases in packaging may contribute to keeping freshness and quality of meat and meat products.

Currently, more often are used new technologies of vacuum packing, such as Pi-Vac (packing meat immediately after slaughter into foil, that eliminate of limit the contraction of
muscle), or vacuum packing with an effect of “skin” (the applied foil has the function of independent steam removing, allowing to prepare meat without removing foil).

The other group of methods of packing, that may contribute to ensuring quality of the product is interactive packing, being able to control changes inside the packaging or deliver an information about changes of the quality of the product. All the above mentioned packaging are applied not only to protect product from losing quality, but also to deliver an information for the consumer.

4. Analysis of the possibilities of application of the computer image analysis method in the assessment of the meat quality

(numbering according to appendix no 3, II.D.)

My interests associated with nondestructive analysis of the physical features of red meat and possibilities of application of such methods of analysis, described in the cycle of subjects A.1, were reflected in a lot of studies, conducted using computer image analysis to assess the visual features of beef and pork meat. Among the most important quality features of meat, that are subjected to visual assessment, conducted using computer image analysis, intramuscular fat content and color analysis may be indicated (color, due to its role, was extracted as a separate cycle of subjects A.5.).

The intramuscular fat content to a large extent influences creating of taste, aroma and tenderness of beef meat (Yang et al., 2006), so the assessment of the quantity of intramuscular fat, as well as dependencies between pre-slaughter and post-slaughter factors, may be a contribution to definition of the final quality of meat.

Two publications, analyzing dependencies between intramuscular fat content and connective tissue content in the beef meat observed for cross section of beef striploin (publication no II.D.5.), as well as of beef topside and striploin (publication no II.D.4.), were elaborated on the basis of the results obtained for 15 animals (20 animals in the case of topside). In the publication no II.D.5. the analyzed factors were the inter-individual variation and thermal treatment (roasting, “delta T” roasting, grilling, pan-frying), while the

\[10 \text{ see footnote no 6} \]

\[11 \text{ “delta T” roasting method – the method of roasting in the steam-convection oven, while the constant difference of temperatures between the temperature inside sample and the temperature of heating medium is maintained} \]
influence on the marbling (intramuscular fat content), as well as connective tissue content were assessed. Simultaneously, in the publication no II.D.4., the analyzed factors were conformation class and fat class, while the influence on the intramuscular fat content, as well as connective tissue content were assessed.

The values obtained for fat tissue were characterized by the parametric distribution, contrary to the values obtained for connect tissue. In the case of fat tissue, that during thermal treatment is being fluidized, for the majority of samples, after thermal treatment very low quantity of tissue was stated. For the single samples, the higher share of visible connective tissue was observed, as also for raw meat this share was higher.

The two-factor analysis of variance conducted to assess the combined influence of cut and thermal treatment on the share of visible fat tissue and connective tissue in the surface of the cut, being subjected to thermal treatment, revealed lack of statistically significant influence. The conventional methods of thermal treatment applied in the comparable conditions do not cause significant differences of the physicochemical properties of the meat, that was stated in the research (Nikmaram et al., 2011).

In the studies presented in the publication no II.D.4., no combined effect of the fat class and conformation class assessed in the (S)EUROP system on the share of fat tissue and connective tissue, was stated. However, it was observed, that in the case of lower fat classes, higher marbling level (share of intramuscular fat) is stated for the sample, if carcass is characterized by higher conformation class, that may be indicated as a fact of an important practical meaning for creating the final quality of beef meat. In the study of Śmiecińska and Wajda (2008), it was also indicated, that the higher conformation class is associated with higher marbling, that was concluded for the carcasses of the “R” conformation class in comparison with the carcasses of the “O” and “P” conformation classes.

The analogical study, as previously mentioned, was analyzing the marbling level and the share of connective tissue in the cube roll, as associated with conformation class and fat class of carcasses (publication no I.D.6.). In the presented study, the objects were meat samples from 20 crossbreeds of Limousine sires and Holstein-Friesian dams. Similarly, as in the studies presented in the publications no I.D.4. and I.D.5., no significant combined influence of fat class and conformation class on the share of intramuscular fat tissue, was
It may be concluded, that the assessment of the conformation class, even if is combined with the assessment of the fat class, may not be the source of information about the share of intramuscular fat tissue in the beef cube roll. The share of intramuscular fat tissue (so called marbling) influences the beef steak consumer acceptability. Hence, additional assessment of the marbling, conducted on the slaughter line, may allow to obtain more information about characteristics of the meat in cuts.

Moreover, computer image analysis method could be used to assess the meat quality thought sarcomere length variability within muscles. In the publications II.D.18., I have analyzed the possibilities of applying the microscopic technique to assess the structure of beef meat. The assessment of the variation of length of sarcomeres for the Infraspinatus muscles obtained from the animals of the Limousin breed was conducted. The isolated myofibrils were observed using the Carl Zeiss Axio Imager.M2 microscope with the EC Plan-Neofluar 100x/1.30 Oil Ph 3 M27 lens and AxioCamMR5 camera. The observations were conducted using the differentia interference contrast.

The obtained results corresponded with the previous observations of other researchers, associated with the (Joumaa and Herzog, 2010). It may be stated, that in the single myofibrils, the length of the adjoining sarcomeres may differ significantly. As a consequence, it was stated, that it is necessary to conduct a series of measurements, to obtain the trustworthy results. Especially, in the case of a large groups of muscles, the choice of representative sample is important.

The statistical analysis revealed, that the distribution of the results of measurement of the sarcomere length was normal (the assessment of the normality of the distribution was conducted using the Shapiro-Wilk test, while significance level α=0.05 was assumed), that may indicate, that observed differences were typical for natural variability in the biological material. The conducted research let to conclude, that in the case of observations of the single isolated myofibrils and measurement of the length conducted in the repeatable conditions, it is possible to specify the mean sarcomere length for the sample.

As a part of the “BIOFOOD – innovative, functional products of animal origin” Project (POIG.01.01.02-014-090/09), the analogical, as presented previously, pilot assessment of the intramuscular fat and connective tissue share for loin before and after thermal treatment.
was conducted (publication no II.D.8.). The object of the study was meat from the standard and designed fattening system.

For the loins from carcasses of animals obtained in the pork quality system (designed fattening system), no statistically significant individual influence of animal on the share of intramuscular fat, was stated. While comparing the intramuscular fat content in the samples of loins from animals not obtained in the pork quality system and obtained in the pork quality system, no statistically significant differences were stated, both for Polish Landrace breed and Polish Landrace x Duroc crossbreed. Due to the lack of promising results associated with variability of intramuscular fat content for pork studies, comparing standard and designed fattening system, no further analysis were conducted.

5. Analysis of the possibilities of assessment and creating color of meat and meat products

(numbering according to appendix no 3, II.A., II.D.)

The method of computer image analysis to assess the color of food products in the RGB color space model is applied by many authors in various applications (Brosnan and Sun, 2004; Du and Sun, 2004; Tan, 2004). It lets to assess the components of color and to predict other visual features of agri-food products (Zheng et al., 2006). Among the quality features of meat, the color is this attribute, that has the highest possible influence of the consumer purchase decision in the moment of purchase (Mancini and Hunt, 2005; Gutkowska, 2012), so this issue was assigned as a separate cycle of subjects.

My research interests in the case of possibilities of applying computer image analysis were associated with predicting color of beef meat after thermal treatment (publications no II.D.7., II.D.9., II.D.13., II.D.14., II.D.16., II.D.17.) and of pork meat (publication no II.D.32.). Moreover, I have analyzed changes of the components of color of pork meat products obtained from animals being fed with forage characterized by modified composition (publications no II.A.9., II.D.11., II.D.12.).

On the basis of conducted research and analysis, some the most important observations may be indicated. To obtain the reproducible final quality of beef meat, applied thermal processes and their conditions are essential. In the conducted studies, no influence
of applied thermal treatment (“delta T”\textsuperscript{12} roasting, frying, grilling) on the meat color components was stated for the cross section (publication no II.D.7.). Such dependency was observed in the publication no II.D.9. Hence, for thermal treatment, essential is to conduct process to the required temperature. It was confirmed in the publication no II.D.16., as in the case of treatment conducted to the well done degree of doneness, no possibilities of prediction of color of meat after grilling and “delta T” roasting thermal treatment on the basis of the color of raw meat was stated.

The construction of the model of prediction of color of beef meat after thermal treatment requires the measurement and analysis of the components of color of various cuts before and after thermal treatment, so a number of analysis was conducted and it was concluded, that color of raw meat measured in the RGB color system is significantly correlated with color of browned surface of sample after thermal treatment of loin (publication no II.D.13.), topside (publication no II.D.14.) and blade (publication no II.D.17.). In the case of pork meat similar situation was stated for the R component of color (publication no II.D.32.).

Analysis of the influence of applied packaging (2 types of modified atmosphere packaging, vacuum packaging, control packaging) on the components of color of smoked pork ham obtained from the meat of animals fed with the forage with addition of rapeseed oil or typical forage was the aim of the publication no II.D.11. It was stated, that both applied packaging and forage influence the components of color of muscle tissue of pork ham, but the lack of interaction and of combined influence of factors was observed. However, while other forages were applied (forage with addition of antioxidative compounds, e.g. selenium), the combined effect of applied forage and packaging on the components of color of pork loin was stated (publication no II.D.12.). Moreover, the final color of pork product may be influenced by breed of animals (publication no II.A.9.). Hence, it is necessary, to apply dedicated systems of packaging, to reduce unfavorable changes of the quality of product, that may take place during storage.

6. **Possibilities of modification of the recipe composition of bakery products**

(numbering according to appendix no 3, II.D.)

\textsuperscript{12} see footnote no 11
Simultaneously with previously mentioned cycles of subjects, I have started to deal with new issue associated with possibilities of modification of bakery products recipe composition in order to obtain the product characterized by health-promoting properties. I have presented the characteristics of chosen possibilities of modification of recipe in the publication no II.D.21. Mentioned analysis mentioned me to establish cooperation with bakery industry, producing inter alia bread characterized by modified recipe composition, designed for consumers following low glycemic index diet\textsuperscript{13} (GI). The effect of mentioned cooperation was conducting study of the physical features of brown bread characterized by reduced amount of carbohydrates and low glycemic index (publication no II.D.1.).

The benefits associated with consumption of products characterized by low glycemic index were presented in numerous studies of various researchers. Diet characterized by low glycemic index may contribute to reduction of type 2 diabetes and ischaemic heart disease risk, so increasingly often on the market appear food products characterized by low glycemic index (related literature is presented in the publication no II.D.1.).

The analyzed material was the brown bread with sunflower seed characterized by reduced amount of carbohydrates and glycemic index lower than stated for typical product, while the control sample was typical brown bread produced by the same producer. The brown bread with sunflower seed, characterized by reduced amount of carbohydrates, was characterized by low glycemic index IG=33.5\%, while for the typical brown bread IG=50-55\% and for white bread IG=65-75\%.

Applied modification of the recipe of bread contributed to significant differences stated for majority of features. In the case of the components of color, analyzed in the CIE L* a* b* color system, both for crumb and crust, differences between analyzed samples and control samples were stated (only for crust in the case of a* component of color difference was not significant p =0.3043). Moreover, modified bread in comparison with typical bread was significantly harder (p=0.0000), in spite of comparable flexibility (p=0.0880). The obtained results are confirmed by the results of Mohamed et al. (2006), as in their study of bread characterized by reduced amount of carbohydrates, in the sensory assessment, also

\textsuperscript{13} Glycemic index (GI) – defined as an area under the curve presenting blood glucose level after consumption of analyzed product containing 50 grams of carbohydrates, divided by an area under the curve presenting blood glucose level after consumption of 50 grams of carbohydrates from control food product – pure glucose or white bread (Wolever et al., 1991)
higher hardness was stated in comparison with control sample. It results from the fact of lower share of carbohydrates in the recipe of bread characterized by low glycemic index, as mentioned nutrient has inter alia the role in creating texture.

The studies of the possibilities of changing the recipe of bread in order to obtain the product characterized by health-promoting properties seem to be promising. However, the further studies, including consumer preference and acceptance of such products, are needed.

7. **The quality of meat obtained from the niche production**

(numbering according to appendix no 3, II.A., II.D.)

My research interests associated with beef and pork meat texture and structure were broaden, as I also get interested in the properties of meat obtained from the animals of other species, such as wild boar, or ostrich.

In the publication no II.D.10., I compared the length of sarcomeres from the loin of domestic swine (*Sus scrofa domestica*) and wild boars (*Sus scrofa scrofa*). It was stated, that the length of the sarcomere in the samples of meat obtained from domestic swine was significantly higher (3.28 ± 0.23 μm) in comparison with sarcomere length in the samples of meat from wild boars (2.51 ± 0.14 μm). Moreover, it was stated, that the length in the case of pork meat depends from the myofibril from which the material was obtained. The lower level of differentiation was stated in the case of wild boar meat. The lower and less diverse length of the sarcomeres in the case of the wild boar meat, in comparison with pork meat, resulted in generally harder texture.

The mentioned observations induced me to conduct deepened analysis of the quality features, including the texture, of the wild boar meat (publication no II.A.8.). The 40 samples of the wild boar meat (loin) were chosen and the analysis of the basic composition, components of color (in the L*a*b* color system), texture (using the INSTRON 5965 universal testing system) and sensory features was conducted.

Tenderness, juiciness, color, taste and aroma analyzed during the sensory assessment were significantly correlated with the general quality of the wild boar meat, but their share in creating the general quality was different than indicated in literature for other types of red meat. The tenderness in the case of the wild boar meat is not so important in creating
general quality of meat as in the case of beef meat. The taste and aroma were in the conducted own study the major components of quality, that to a large extent influenced the quality perceived by consumers. The mentioned observations are parallel to results of the studies presented by Żochowska-Kujawska et al. (2012), who analyzed possibilities of improving the texture of wild boar meat by applying the marinades. In the mentioned study it was observed, that in spite of the fact, that the addition of the pineapple juice was the major factor contributing to the reduction of toughness of meat, the samples after such marinating obtained low rates of their juiciness and, as a consequence, of general quality. The mentioned results confirm, that texture in the case of the wild boar meat plays the minor role, being less important, than other quality features, in creating general quality of meat in the consumer assessment.

As a part of the “BIOFOOD – innovative, functional products of animal origin” Project (POIG.01.01.02-014-090/09), the quality of the ostrich meat and products with addition of the ostrich meat were analyzed and I did participate in the analysis. The result of the mentioned studies was a publication associated with the oxidative stability of the ostrich meat, while the forage was supplemented with linseed and alfalfa (publication no II.A.7.). In the mentioned study it was proven, that applied supplementation influences the oxidative stability of meat, but the obtained oxidative stability is not high enough and further studies of oxidative stability of the ostrich meat, enriched with n-3 fatty acids and chosen antioxidative compounds, are needed.

Moreover, as a part of the mentioned Project, elaborated technologies were proposed for patenting as the patent claims (appendix no 3; II.C.4. – Innovative method of producing high-quality, controlled allergenicity products from pork and ostrich meat and II.C.7. – Production of culinary ostrich meat).

8. Creating and assessment of the quality of plant products

(numbering according to appendix no 3, II.A., II.D.)

The other area of my research interests is the analysis of the influence of the thermal processing on the creating texture features of plant unprocessed material. At the beginning, I got interested in the influence of the vacuum thermal treatment (thermal treatment applied in the pressure steam oven) on the texture of potatoes characterized by various
share of starch (Satina cultivar – 13%; Asterix cultivar – 15%, Saturna cultivar – 17% of starch). The results of the mentioned study are presented in the publication no II.D.20., that was published before achieving my Ph.D. degree. The differences of starch share stated for the analyzed potato cultivars contributed to differences of the hardness of the analyzed material after thermal treatment. The applied time of thermal treatment also contributed to the statistically significant differences of the texture of potatoes. However, the results were not explicit enough to enable formulating recommendations for optimizing thermal treatment application in the process of preparing potatoes to the frozen vegetable mixes or salads.

The analysis, that I conducted, as a part of my Ph.D. research, associated with possibilities of applying low-temperature blanching (LTB)\textsuperscript{14}, before the exact blanching\textsuperscript{15} in the process of vegetables processing, induced me to deepen the previous analysis and to conduct the LTB process studies for the potatoes.

The LTB method allows to obtain the promising results for the plant products, as after thermal treatment, including LTB, they are characterized by the texture desired by consumers, being is stable during further processing (Abu-Ghannam and Crowley, 2006). The analogous results, that I obtained for the potatoes of the Satina cultivar were presented in the publication no II.D.15.

The influence of the low-temperature blanching on the obtaining desired by consumers texture of plant products is attributed to the action of the pectin methyl esterase (PME), as the optimum temperature for its activity is the temperature of the LTB process. As a result of the action of the mentioned enzyme, the free carboxylic groups may create cross link between polymers of pectin and divalent cations (especially calcium ions) due to the formation of saltbridges (Lin et al., 2005).

In the publication no II.D.15., the statistically significant influence of the preliminary soaking of potatoes in the 1% solution of the calcium chloride on the hardness of analyzed samples in comparison with samples not subjected to such treatment was stated. The

\textsuperscript{14} LTB process (low temperature blanching) – the preliminary processing of plant unprocessed material, being conducted in water or saturated steam in the temperature of 50-80°C, for the time of 5-60 min (Abu-Ghannam and Crowley, 2006)

\textsuperscript{15} Blanching – the preliminary processing of plant unprocessed material (being conducted in water or saturated steam, predominantly in the temperature of 97°C, for the time of 3 min), while the main purpose is deactivation of enzymes (inter alia polyphenol oxidase, ascorbate oxidase, peroxidase, chlorophyllase, lipoxygenase), that may contribute to the material quality deterioration
addition of calcium salts enables creating bridges between galacturonic acid residues belonging to adjoining pectin chains. The mentioned complexes, created by divalent calcium ions and pectin, comprising intracellular binders, that improve the texture of tissues (Degraeve et al., 2003). The mentioned bondings are a factor stabilizing the texture of potatoes in such way, that the texture does not undergo unfavorable changes during thermal treatment.

The optimum temperature of the LTB process, that is aimed at preserving appropriate texture parameters during further processing is, for Satina cultivar potatoes, the temperature of 50°C applied for the time of 10 minutes. The mentioned conditions contribute to obtaining higher values of hardness and, as a consequence contribute to obtaining the product being more resistant to hardness loss during the storage in the elevated temperature conditions before serving (e.g. in the bain-maries).

The analysis, that I conducted, as a part of my Ph.D. research, associated with possibilities of applying the LTB process during the vegetables processing (broccoli, carrot, cauliflower and green beans) were predated by the pilot study. The results of mentioned pilot study were published in the publication no II.D.19. The material for the study was Perfekcja cultivar carrot, that before the LTB process conducted in the temperature of 50°C, 60°C, 70°C and 80°C, for the time of 5, 10 and 15 minutes, was subjected to soaking in the 1% solution of calcium chloride.

The samples, that before the LTB process were subjected to soaking in the 1% solution of calcium chloride were characterized by significantly higher values of hardness, in comparison with the control samples. The higher hardness of carrot subjected to the LTB process with addition of calcium ions was confirmed by the results of the study of Smout et al. (2005).

The analysis of the influence of the LTB process on the color and consumer acceptance of broccoli, that was in detail presented in my Ph.D. thesis, was also presented afterwards in the publication no II.A.10. The thermal treatment of the green vegetables may play the decisive role in creating the level of consumer acceptability of such products. Taking into account the fact, that the LTB thermal treatment may contribute to the texture improvement, the analysis of its influence on the color and its consumer acceptance seems also to be expedient.
In the conducted analysis, it was concluded, that the proposed LTB process applied with addition of the calcium ions contributed to the improvement of the color in the consumer assessment, that was observed independently from the applied temperature conditions (50-80°C), while for the temperature of 50°C and 60°C applied for 10 minutes, the highest rates of consumer color acceptance were obtained. It may have resulted from the lightening of the green color (L* component of color) and increasing greenness (a* component of color). The analogous improvement of quality (higher values of L* component of color) was obtained by Martin-Diana et al. (2008) in their study of the LTB process applied in the processing of the lettuce. Simultaneously, Nisha et al. (2004) observed the influence of applying the 2% solution of calcium chloride on the stabilization of the color of spinach, but in their study no mechanism of such influence was defined.

Analysis of the possibilities of maintaining color and texture of white mushrooms (Agaricus bisporus L.) was analyzed during 14 days of storage. It was the object of my studies published in the publication no. II.A.1. The conducted analysis indicates, that using in the packaging with film characterized by thickness of the 39 μm (quite high permeability) initial oxygen content of 50%, allows to obtain optimum conditions for satisfactory quality of white mushrooms. The higher levels of oxygen (higher than 50%) in the modified atmosphere packaging are not associated with color and texture improvement.

The consumer acceptance of plant products, with regard to soya bean, was also the object of my study in the publication no II.D.33. The soy products are the specific type of merchandise, as consumers may have the dichotomous attitude to them. On the one hand, soya bean and the soy products may limit the risk of the specific diseases (inter alia circulatory system diseases, osteoporosis, hypertension, diabetes, as well as colon, breast, liver, lungs and kidneys cancers) and induce the improvement of the hormonal regulation, relieving the symptoms of menopause (related literature is presented in the publication no II.D.33.). However, on the other hand, consumer are afraid of consuming products being genetically modified, while soya bean is one of such products.

In the conducted study, it was stated, that the reasons of not consuming soy products by the analysed group were the other factors, than the information, that the product was obtained from the genetically modified soya bean. The respondents indicated, that the factors, that would induce them to purchase such products would be broaden
access to the information, *inter alia* associated with health-promoting values of such products. The results of conducted studies were confirmed by the studies of Wansink et al. (2001, 2005), who observed, that the consumer awareness associated with the health-promoting attributes of soya beans, influences the increase of their consumption.

The studies on the texture of vegetables resulted in my cooperation with the Department of Forest Botany of the Faculty of Forestry of the Warsaw University of Life Sciences, associated with the mechanical strength of the plant unprocessed material. The material in the conducted experiment was the Bambino cultivar pumpkin (*Cucurbita Maxima*). The results of the study were presented in the publication no II.A.6. In the published analysis, the role of trichomes in the biomechanics of the plant movements was proven. In the study, it was confirmed, that trichomes are an additional reservoirs of the hydrostatic pressure, that are necessary for maintaining petioles in the proper state.

**References**


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16 Trichomes, “hairs” (łac. *pilus*) – unicellular or multicellular, living or dead structures of plant epidermis (external tissue)

B. Summary of the overview of the scientific-research work

My scientific achievements are 101 papers, including 17 publications in the journals being indexed in the Journal Citation Report (JCR) list, 21 popular scientific publications and 26 publications in national and international conference proceedings.

Table 1. Total number of published scientific papers accompanied by the number of the MSaHE – Ministry of Science and Higher Education points and the Impact Factor points

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A. Scientific papers published in journals indexed in Journal Citation Reports (JCR) with Impact Factor
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Appendix no 2 – pp. 48
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### Appendix no 2 – pp. 50

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**C. The chapters in scientific monographs in Polish**

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**D. Publications in conference proceedings do not included in the Web of Science**

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**E. Popular science publications**

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**Summary**

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* The number of MSaHE – Ministry of Science and Higher Education points, attributed to the publication, according to the to the relevant list of journals:

1. The unified list from the website of the Ministry of Science and Higher Education (2007-2010),
2. The Communication of the Minister of Science and Higher Education regarding the list of scientific journals from 20 December 2012
3. The Communication of the Minister of Science and Higher Education regarding the list of scientific journals from 17 December 2013
4. The Communication of the Minister of Science and Higher Education regarding the list of scientific journals from 31 December 2014 (with amended from 25 March 2015)
5. The Communication of the Minister of Science and Higher Education regarding the list of scientific journals from 23 December 2015

** The number of MSaHE – Ministry of Science and Higher Education points multiplied by number of attributed publications

I am the author of 17 scientific papers published in the journal indexed in the JCR list, while all the mentioned works were published in the period of 2012-2016. The number of citations of my publications, according to the Web of Science database is equal to 9, while according to the Google Scholar it is 44. H-index (Hirsch Index), according to the Web of Science database is equal to 2, while according to Google Scholar it is 3.
Total Impact Factor of my publications (according to the JRC list, appropriate for the year of publication) is 19.801, while the 5-year Impact Factor for them is 21.41.

Total number of points of my scientific papers is 615 points (according to the MSaHE – Ministry of Science and Higher Education list, appropriate for the year of publication). The number of points of my scientific papers published after achieving my Ph.D. degree is 600 points (according to the MSaHE list, appropriate for the year of publication).