Appendix 2

Self – presentation

(in English)

PhD Katarzyna Antosik

Siedlce 2014

1. **Name and surname** Katarzyna Antosik

2. Diplomas and research degrees:

25.06.1999 master of science (Msc)
Warsaw University of Life Sciences (SGGW)
Faculty of Food Technology, Field of Food Technology and Human Nutrition in Food Technology range, major Meat Technology
Title of the MSc Thesis: "*Effect of genetic line on selected traits of carcasses and meat quality of chickens*"
supervision: PhD Mirosław Słowiński

04.10.2006 PhD of agricultural sciences in the field of zootechnology
University of Podlasie in Siedlce, Faculty of Agricultural
title of the PhD Thesis: "*Usefulness of electrical conductivity in the diagnosis of pork meat quality*" – work awarded
supervision: Prof. PhD DSc Maria Koćwin – Podsiadła

06.03.2012 postgraduate diploma
Warsaw University of Life Sciences (SGGW)
Faculty of Human Nutrition and Consumer Sciences
1,5 – year post-graduate studies Nutritional Counseling
title of the thesis: " *Dietotherapy of obesity*"

3. Information about employment in scientific units:

01.03.2000 – 31.01.2001 **technical employee**
Department of Pig Breeding
University of Podlasie, Siedlce
(actually: Siedlce University of Natural Sciences and Humanities)

01.02.2001 – 16.01.2007 **assistant scientist**
Department of Pig Breeding and Meat Science
University of Podlasie, Siedlce
(actually: Siedlce University of Natural Sciences and Humanities

17.01.2007 – 28.02.2011 **postdoctoral scientist**
Department of Pig Breeding and Meat Science
Siedlce University of Natural Sciences and Humanities

01.03.2011 – 30.09.2013	**postdoctoral scientist** Interdisciplinary Study of Dietetics – teaching and organizational activities Department of Pig Breeding and Meat Science – scientific activities Siedlce University of Natural Sciences and Humanities
of the 01.10.2013	**postdoctoral scientist** Institute of Health Sciences, Faculty of Natural Science Siedlce University of Natural Sciences and Humanities

4. Indication of the achievements under from Art. 16 Par. 2 of the Act of 14 March 2003 on Academic Degrees and Title and Degrees and Title in Art (Journal of Laws No. 65, item 595, as amended.)

The scientific achievement, referred to in Art. 16 paragraph 2 of the Act of March 14, 2003, about scientific degrees and scientific titles as well as degrees and titles in the field of art (Journal of Laws no. 65, point 595 with later modifications) and constituting the basis for aspiring to the scientific degree of habilitated doctor is a monograph entitled***: „Genetic determinants of intramuscular fat content and its usefulness in diagnosing pork quality".***

a) Author, Title, Year of publication, Name of publisher

Katarzyna Antosik, Genetic determinants of intramuscular fat content and its usefulness in diagnosing pork quality, 2014, Publishing House UPH w Siedlcach.

4.1 This is a research-based discussion of the scientific objective of the aforementioned studies and the results achieved with the discussion of their possible use

4.1.1. Introduction

Over the last years one may observe on the market an increased share of fresh culinary meat. For this reason, those meat properties which the consumer takes into consideration when deciding about buying are becoming of special value for the meat industry [Barbut *et.al* 2008]. It is the consumer demands that are the principal criterion deciding about the product quality. The understanding of the consumers' requirements, preferences and opinions about the properties of meat and meat products is extremely important and products not accepted by the consumer will simply be rejected by the market [Babicz – Zielińska and Zabrocki 2007]. The consumer preferences as regards the choice of meat or meat products are undoubtedly

decided by the level of intramuscular fat, as it has a pronounced effect on the colour, taste, tenderness and juiciness of meat. A considerable majority of consumers, when buying fresh meat, prefers its red-pink colour, without a visible marbling and without drip loss [Połom and Baryłko – Pikielna 2005, Fortomaris *et.al* 2006]. However, culinary meat, to meet the expectations of buyers as regards the sensory attractiveness of the product, should contain a required amount of intramuscular fat, because lean meat, preferred by consumers, during heat processing is characterised as a rule by a lower sensory value than meat with a higher marbling [Resureccion 2004, Jaworska *et. al* 2007].

However, the higher awareness of the public as regards nutritional and health issues has forced the meat industry to introduce new methods of its production and processing. The intensive selection for high meat content in the pig carcass resulted in a lower carcass adiposity, what in turn lead to qualitative and quantitative changes in subcutaneous, intra- and inter-muscular fat [Różycki 2005, Lisiak *et. al* 2011]. However, one should remember that fat is the meat component which cannot be completely eliminated through breeding selection or technological processes. In fatty meat fat is clearly visible, but even the leanest meat contains fat in cells and cell membranes, in the connective tissue and inter-cellular spaces. Intramuscular fat, in international nomenclature known as IMF, is located within muscle fibres and in the connective tissue in-between muscle fibre bundles [Blicharski *et. al* 2006].

Taking into consideration the requirements of both consumers and the meat processing industry, it is important to aim at ensuring such a level if intramuscular fat in pork which retains a high level of sensory meat properties, in particular tenderness and palatability [Wood *et. al* 2004]. Institutions responsible for pig breeding concentrate at present on the possibilities of controlling the meat properties by using the achievements of molecular genetics, as well as by modifying environmental factors [Rosenvold and Andersen 2003, Koćwin-Podsiadła and Krzęcio 2004]. Studies conducted on the molecular mechanism of fat tissue storage in pigs may, on one hand, enhance the efficiency of animal production and improve the dietetic value of meat and, on the other, constitute a basis for research on predispositions to obesity in human beings [Spalding et. al 2008; Świtoński et. al 2010, Cieślak et. al 2011]. The results and inconsistencies reported by a number of research centres, both in Poland and throughout the world, indicate that the problem of genetic conditioning of the level of intramuscular fat in pigs is not yet univocally explained.

Differences, observed in many countries, in determining an optimum IMF level in meat, as satisfactory for its sensory properties, arise from different consumer preferences in relations to pork quality [Wood et. al 2004, Molenda et. al 2005, Ellis 2006]. As a rule, in European countries it is accepted that the minimum content of fat it meat should amount to

2.0%. Currently, a majority of authors considers that in good quality meat the content of fat should range from 2 to 3% [Wood et al. 1994, Koćwin – Podsiadła et al. 2004, Przybylski et al. 2007]. In turn, an IMF level below 1% is considered unacceptable, as it may result in a poorer taste, juiciness and tenderness of meat, which after thermal processing becomes dry and tough [Schwörer et al. 2000].

The quality of raw material is an important factor affecting the processing value and properties of the ready product of the meat industry, as well as its acceptance by the consumer, for which reason it is important to detect its defects at an early post slaughter stage [Słowiński and Chmiel 2013]. Most often in the meat industry a quick evaluation of the raw meat is performed by measuring pH, colour lightness, electrical conductivity and the R_1 indicator of energy metabolism. The content if intramuscular fat may also be one of the useful indicator of meat quality, what is confirmed by the significant correlations between IMF and the technological and sensory meat properties. In times of a widespread interest of consumers in the problems of obesity, diabetes and diseases of the heart, the content of fat and fatty acids in meat is gaining in importance.

The carcass composition, the content of intra- and inter-muscular fat, depends principally on the breed, sex, age, nutrition level and diet composition as well as the genetic potential, which is, to a considerable degree, related to the animal's type and carcass meatiness [Migdał et al. 2007]. Undoubtedly, the most important genetic factor affecting the nutritional and technological value of pork, including the content on intramuscular fat, is the breed or the cross-breeding schema from which the porker originated [Grześkowiak *et al*. 2010].

According to Blicharski and Hammermeister [2006], the IMF content in a majority of contemporary pig breeds, both in Poland and in many European countries, is considerably below 3% and thus there is no need to worry that this level may be exceeded in porkers from mass production. Różycki [2005] reports, that in the paternal breeds maintained in Poland Pietrain pigs are characterised by the lowest adiposity, while the highest amount of fat is obtained from Duroc animals. The USA reports [Wood *et al*. 1994] indicate that the content of intramuscular fat in the *Longissimus dorsi* muscle of Duroc pigs ranges from 5 – 8 %. In turn, the Duroc breed, maintained in Denmark, is characterised by a decidedly lower, but still optimum IMF level in the *LD* muscle – 2,5 – 3 %. Beside the required content of IMF, animals of the Duroc breed are characterised by a small thickness of subcutaneous fat, for which reason, as stated by Stachowiak and Świtoński [2009], this breed is of special interest for the determination of the gene expression profile, typical for pigs producing meat of the desired culinary value.

Currently in Poland, for the improvement of pork quality are used animals imported from Denmark (landrace, yorkshire, duroc) and France (naima, P76), which represent a high breeding value both as regards quantitative indicators and the quality of the pork obtained [Koćwin – Podsiadła *et al.* 2003, Przybylski *et al.* 2010]. Both in Europe and throughout the world, for the production of pork are preferred porkers obtained from crossing (landrace x yorkshire) and duroc breeds [Candek – Potokar *et al.* 1998, Krzęcio *et al*. 2004]. Due to the fact that in such crossbreeds the stress susceptibility gene $RYR1^{T}$ or acid meat gene RN^{-} do not appear, this type of crossbreeding renders it possible to produce porkers characterised by a high meat quality.

The level of intramuscular fat affects significantly several meat quality traits what induced numerous scientists to seeks for its genetic determinants. Due to the dynamic development of molecular genetics in animal breeding it became possible to determine the location, structure and functioning of genes responsible for traits important from an economic point of view [Kmieć *et al.* 2010]. Special attention is given to genes described as QTL (*quantitative trait loci*), which have a significant effect on the variability of quantitative (polygenic) traits [Świtoński 2008, Ernst and Steibel 2013].

As stated by Urbański [2003], as well as Stachowiak and Świtoński [2009], the following genes are mentioned as candidates to a significant role in forming the variability of adiposity traits:

- Adipocytokin genes, which code proteins produced and secreted by the fat tissue (*LEP,LEPR, ADIPOQ*),
- Genes controlling feed intake and the energy homeostasis of the organism (*MC3R, MC4R, CART, TG, GHRL*),
- Genes coding proteins engaged in lipid metabolism and transport (*FABP, HFABP, DGAT1, SCD1*),
- Genes coding functional proteins connected with the cell growth and differentiation processes, as well as the development of skeletal muscles (*GH, GHR, GHRH, IGFI* and *II, PIT1, MYOG, MYF5, MYF6*).

Zhao *et al*. [2009] report that the mechanism leading to an increased IMF content in pigs characterised by outstanding adiposity, may arise from a higher expression level of genes related to lipogenesis, or the transport of fatty acids, together with a lower expression of genes participating in lipid catabolism. In turn, Cánovas *et al*. [2010] suggest that selection for increased IMF content in pigs leads to a shift, but not disturbances, in the metabolic homeostasis in muscle cells. For this reason, more research work should be conducted in order to explain the effect of storing lipids in the muscle metabolism in pigs. Thus genes

related to lipogenesis, cell growth and differentiation may be analysed also as regards their effect on the content of intramuscular fat.

The content of intramuscular fat may be affected also by genes coding proteins participating in the transport and metabolism of fatty acids within cells. The transport of fatty acids through cell membranes and within the cytoplasm takes place, among much else, with the participation of fatty acid-binding protein (FABP) [Chmurzyńska and Świtoński 2004]. A majority of works on the genetic determination of the intramuscular fat level indicates that responsible for this trait is gene *HFABP*, which is expressed in cells of the heart muscle and in skeletal muscles [Gerbens *et al.* 1999, Koćwin – Podsiadła *et al.* 2004]. The relation between the polymorphism of this gene and IMF was shown by Gerbens *et al*. [1999], Ovilo *et al*. [2000] as well as Sieczkowska *et al*. [2006 a] in pigs of the duroc breed and crosses with Duroc. Similarly, Schwab *et al*. [2009] reported a significant differentiation in the intramuscular fat content in duroc porkers, related to the genotypes of genes *FABP3* and *MC4R* (melanocortin receptor gene). In turn, Urban *et al*. [2002] did not confirm such relations in large white and landrace porkers, while Sieczkowska *et al*. [2006 b] in a population of landrace and landrace x yorkshire pigs.

As has been reported by Ruść *et al*. [2011], the intramuscular fat may also be determined by other polymorphic genes participating in the synthesis of lipids and degradation of fatty acids. The synthetize gene for long-chain acylo-CoA (*ACSL*), subject to expression in various tissues, such as liver, heart, lung, stomach, spleen, brain, skeletal muscles, lard, uterus, ovaries and testicles, may be a candidate gene for this role [Mercade et al. 2006]. In turn, gene *DECR1* codes the mitochondrial enzyme participating in the beta-oxidation of fatty acids and is engaged in the control of tat and protein storage [Kamiński *et al.* 2009].

Lin [2009] reports, that both the ability to store fat and the fatty acid composition are extremely complex traits, which may be controlled by many genes. For this reason it is necessary to evaluate other genes, coding enzymes participating in processes of glycolysis and proteolysis, candidates for those traits (among others *GLUT4*, *PKM*2, *PRKAG*3, *CAST*). Some genes coding enzymes from proteolytic routs demonstrate a significant relation with meat tenderness and may be good indicators of meat quality, including for instance the content of intramuscular fat. For example, the capain/calpastatine and cystatin B/cathepsin B proteolytic systems play an important role in the growth and development of muscles, processes of muscle protein degradation and the post slaughter maturation of meat [Urbański *et al.* 2010].

Studies on the co-operation between genes as regards effect on porkers' meatiness and meat quality indicate that a mutation at the *locus* of one gene may increase or alleviate the

effect of mutation at the *locus* of another gene [Koćwin-Podsiadła *et al.* 2009]. One should emphasise that as till now not many research papers have been published on the determination of meat quality, including the content of intramuscular fat, which would describe associations between genes, principally genes *RYR1*, *RN*¯, *HFABP*, *CAST*, *MYOG*, *PKM2* and *GLUT4*.

As stated by Morrow [2012], in a live cell epigenetic mechanisms are responsible for the regulation of the expression of genes. Under the influence of various external factors the genetic information may be subject to modifications of a chemical character, such as DNA methylation, modifications of histones or of *micro*RNA. The changes that arise decide about the activity of regulatory genes, what results in a precise control of the expression of structural genes. This is the method of, among much else, regulating the differentiation and development in a given direction of individual cells in the organism [Morrow 2012].

In turn, McCarthy [2010] in his studies demonstrated how small is the relations between obesity or diabetes and genes. The author observed a lack of stronger relations between the genotype and the greatest epidemic of our times (obesity and diabetes) – he used expressions such as "small effect", "comparatively few positive results", "remains unclear" or "poorly explained by contemporary biological sciences".

In turn, other authors [Grayson 2010, Hyman 2011] state that the quality and combinations of the nutrient macro-components (proteins, fats, carbohydrates), micro-components (vitamins and minerals), plant components and cellulose present in food, affect human DNA – turning on or off, strengthening or weakening signals send by genes. Thus one may assume that examining the genome – nutrition interaction would create a possibility to elaborate nutrition recommendations for animals in such a way, as to prevent the appearance of numerous disturbances or meet the requirements of specific consumers.

Taking into consideration the above the determination of correlations between the intramuscular fat and individual polymorphic forms of chosen genes and their interactions would be very useful for conducting selection aimed at obtaining breeding progress and thus improving the level of intramuscular fat in animals from mass production and in consequence for the improvement of the sensory properties of pork.

4.1.2. Aim of the research

The basic objectives of the research were: analysis of the sources of variability including genetic determinations – also at the molecular level – of the content of intramuscular fat in pork and analysis of consumer nutritional behaviour and attitudes in

relation to the consumption of raw and processed meat, taking into consideration the importance of visible fat as a criterion of the choice of meat products.

The study covered two main research.

Within the I research, which was treated as leading, and comprised an analysis of the variability, including genetic determination, of the content of intramuscular fat in pork as well as its diagnostic value for meat quality traits, the following detailed objectives were specified:

1) determining the variability of the intramuscular fat content in the *Longissimus lumborum* (*LL*) muscle of porkers, taking into consideration their breed and sex;
2) evaluation of the effect of chosen genes on the intramuscular fat content in the *LL* muscle;
3) analysing the value of the intramuscular fat content in the *LL* muscle for diagnosing properties and physico-chemical characteristics of pork, its technological value and sensory quality;
4) verification of the determined and preferred in Europe limiting values for the content of intramuscular fat basing on mean values for selected meat quality traits.

The objective of studies undertaken within II research was the analysis of nutritional behaviour of consumers in relation to raw and processed meat, as well as determining the importance of visible fat for the selection of raw or processed meat. The objective was reached through an analysis of:

1) frequency of purchasing and consumption of raw and processed meat;
2) the types of meat most often purchased by consumers;
3) the consumer's expectations in relation to meat products;
4) elements determining the choice of raw (culinary) and processed meat;
5) degree of satisfaction with the meat products available.

4.1.3. Material and methods

The studies conducted within research I covered a total of 220 porkers from three breed groups: landrace (L), landrace x duroc (LxD), (landrace x yorkshire) x d uroc [(LxY)xD], free of the stress susceptibility gene *RYR1* allele $RYR1^T$. The analysis was conducted on animals uniform as regards HCW and meatiness so as to eliminate the effect of those factors on the intramuscular fat content and remaining meat quality traits.

Studies referring to research I were conducted in four stages:

Stage I – comprised a characteristic of breed groups analysed as regards the physico-chemical properties of meat, its technological value and sensory quality and included determining the

range of variability of the intramuscular fat in the *Longissimus lumborum* muscle, taking into consideration the breed and sex groups.

As the material was uniform as regards meatiness and hot carcass weight (no significant differences between breed groups and the variability coefficient < 10 %), those two sources of variability were not taken into consideration in further analysis.

Stage II – covered the evaluation of the effect of chosen genes on the intramuscular fat content in the muscle tissue of porkers. Within this stage the following research were identified:

1. evaluation of relations between intramuscular fat content and the polymorphism of chosen genes linked with lipogenesis, cell growth and differentiation and determining the *in vivo* and *post mortem* muscle tissue metabolism (*MYOG/Msp* I, *HFABP/Hae* III, *HFABP/Msp* I, *HFABP/Hinf* I, *ACSL4*/*Rsa* I, *PRLR/Alu* I, *GH/Msp* I, *GH/Hae* II, *GHRH/Alu* I, *IGF-1R/Sac* II, *PIT1/Rsa* I, *DECR1/Bfa* I, PKM2, *PRKAG3/BsrB* I, *GLUT4/Hae* I, *CAST/Hinf* I, *CAST/Msp* I, *CAST/Rsa* I);
2. evaluation of interaction between the genes analysed in relation to intramuscular fat content;
3. determining the relations between the expression level of genes *PKM2* and *CAST* and the intramuscular fat content. Those genes are coding enzymes participating in the process of glycolysis (*PKM2*) and proteolysis (*CAST*) and the final meat quality depends on both the glycogen level, its accumulation in the muscle tissue and breakdown rate after slaughter and the level of *post mortem* proteolytic metabolism.

Stage III – covered an estimation of the value of the intramuscular fat content in the *LL* muscle for diagnosing the properties and physico-chemical characteristics of pork, together with its technological value and sensory quality through:

- analysing the relations between intramuscular fat content in the *LL* muscle and a wide range of meat quality traits;
- analysing the efficiency of the given parameter, *i.e*. the intramuscular fat content for diagnosing the technological value and sensory quality against the background of methods most popularly used for classifying the quality variations in pork.

Stage IV – covered the verification of the determined and preferred in Europe limiting values for the intramuscular fat content on the basis of mean values of the meat quality traits analysed.

Basing on the optimum intramuscular fat content (IMF) in pork, indicated by numerous authors as ranging from 2 to 3%, three groups were identified within this stage:

- carcasses containing less than 2% IMF in the *LL* muscle,

- carcasses containing 2 – 3% IMF in the *LL* muscle,
- carcasses containing more than 3% IMF in the *LL* muscle,

The quality of fresh and cooled meat, as well as its consumer desirability and technological value was estimated after slaughter on the basis of the muscle tissue from the *Longissimus dorsi* (in the *Longissimus lumborum* part - *LL)* muscle and samples of the *LL* taken behind the last vertebra, basing on the basic chemical composition, glycolytic potential, pH_{35}, pH_{24}, R_1, EC, meat colour lightness, water holding capacity, drip loss, technological yield of cured meat in the process of cooking (TY), cutting force and parameters of the sensory meat evaluation.

In order to identify the polymorphism of the genes analysed blood samples were taken at slaughter for the isolation of genome DNA. The polymorphism of the genes (with the exception of gene *PKM 2*) was examined using the PCR-RFLP technique. In turn, the polymorphism of gene *PKM 2* was determined using the PCR-SSCP method. The level of expression of *PKM2* and *CAST* genes was determined in the *Longissimus lumborum* (LL) muscle tissue, taken 30 minutes after slaughter, placed in liquid nitrogen and subsequently stored at -80 ^{0}C, applying the Real-Time PCR technique and using the fluorescent stain SYBR Green (Power SYBR Green PCR Master Mix) and the Applied Biosystem 7500 Real Time PCR System. As reference gene the β-actine gene was used.

The results obtained were analysed statistically using the statistical software STATISTICA 6.0 PL and applying, depending on the type of research, a single or double-factor analysis of variance, analysis of simple phenotypic correlations, canonical analysis and cluster analysis. Moreover, the frequency of genotypes and alleles for the genes analysed was determined, together with the genetic equilibrium for the animals examined, in accordance with Hardy – Weinberg's law of genetic equilibrium, using test χ^2.

Within Research II a questionnaire survey was conducted in order to examine the behaviour and attitudes of consumers in relations to raw and processed meat, paying special attention to the effect of the content of visible fat on the choice of raw and processed meat. The studies were conducted in the town of Siedlce in year 2011, in distribution centres for raw and processed meat, in the consumers' places of work or apartments, as well as within the University. The group of 311 respondents consisted of persons who agreed to participate in the research.

The studies were conducted by the questionnaire method, using a specially elaborated questionnaires consisting of a part containing essential questions, related to the theme of the survey and of a part containing socio-demographic questions. The material collected was analysed statistically using the statistical software PASW 18. For the description of the

population and individual variables a frequency analysis was used with cross tables. For the comparison of data the χ^2 test was used on one sample in order to confirm the trends observed in the answers obtained from respondents. The probability at a level of 0.05 was accepted as the significance level.

Applying an analysis of the empiric data a characteristic was elaborated of those consumers who indicated visible fat (marbling) as the principal element considered by them while choosing culinary meat for purchase. Moreover, a characteristic was elaborated of those consumers who declared a conscious decision to consume meat with a lowered fat content. In order to examine and determine the relations between the traits selected the χ^2 test and V-Cramer coefficient were used.

4.1.4. Results obtained

The studies conducted on the priority research problem demonstrated, that the porkers of the three breed groups analysed (n=220), with a mean content of lean in carcass amounting to 55.84 % and mean hot carcass weight reaching 85.85 kg, were characterised by a low mean intramuscular fat content in the *Longissimus lumborum* muscle (1,89 ± 0,73 %), a considerable variability of this trait – from 0.61 to 5.01 % (coefficient of variation = 38,62 %) and a high frequency of carcasses containing less than 2% IMF (close to 62 %).

Among the porker breeds analysed – landrace, landrace x yorkshire and (landrace x yorkshire) x duroc – the lowest intramuscular fat content was observed for meat obtained from the landrace (1.48 %) animals, while meat from the three breed crosses, with a 50 % share of the duroc breed, were characterised by a significantly ($p \leq 0.01$) highest IMF (2.28 %) in the *Longissimus lumborum* muscle. It was also observed, that a 50% share of the duroc breed on the paternal side has a favourable effect of the intramuscular fat content and frequency of carcasses with meat characterised by an optimum content of this component (2–3 %) preferred by consumers and the meat industry, though on the other hand it leads to an increased variability of the IMF in the muscle tissue.

A common opinion has also been confirmed that gilts, compared with boars, are characterised by a lower intramuscular fat content in the *Longissimus lumborum* muscle. However, there was observed no statistically significant interaction between the factors examined, *i.e.* breed group and sex of porkers on the parameter studied, that is the intramuscular fat content. The lack of such an interaction indicates that changes in the intramuscular fat content in breed groups aim in the same direction, irrespectively of the sex of the animal.

Analysing the frequency of genotypes and alleles of the genes analysed in individual breed groups of porkers, as well as the genotype frequency expected according to the Hardy – Weinberg law, it was observed that the group of landrace porkers, as well as the landrace x duroc crosses, remained in a state of genetic equilibrium as regards 12 out of the 18 genes analysed. A majority of significant deviations from the genetic equilibrium was observed in the group of three breed porkers – (L x Y) x D. According to the Hardy – Weinberg law this group remained in a genetic equilibrium only as regards genes *HFABP/Hae* III, *GH/Msp* I, *GHRH/Alu* I, *PIT1/Rsa* I, *DECR1/Bfa* I, *PKM 2, GLUT4/Hae* I and *CAST/Msp* I.

An analysis of the polymorphism of the chosen genes demonstrated a statistically significant relation between the polymorphism of genes *MYOG*/*Msp*I (L x D), *HFABP/Hae*III [(LxY)xD], *HFABP/Msp*I (landrace), *HFABP/Hinf*I (landrace), *ACSL4/Rsa*I (landrace), *PRLR/Alu*I [(LxY)xD], *GHRH/Alu*I (landrace and (L x Y) x D), *DECR1/BfaI* (L x D), *PRKAG3/BsrB*I (landrace), *CAST/Hinf*I as well as *CAST/Msp*I (landrace) and the intramuscular fat content in the *Longissimus lumborum* muscle of porkers. One should emphasise, that the effect of genes *PRLR/Alu*I and *CAST/Hinf*I on the intramuscular fat content proved considerable, as the effects of these genes, expressed as the share of the difference between mean values for extreme homozygotes, amounted to 1 and -1.13 SD, respectively, in standard deviation units. Moreover, the results obtained in the landrace group confirm that gene *CAST/Hinf* I is a candidate gene for a major gene for this trait and could be used in selection of the breeding material. This is fully justified by the low, unacceptable for consumers, IMF content in this breed group of animals, confirmed both in own research work and by numerous authors throughout the world.

Analysing the polymorphism associations between the genes examined and the intramuscular fat content in individual groups of porkers, differing in the IMF content, a significant effect on the parameter examined was observed only for the polymorphism of genes *HFABP/Msp*I ($p \leq 0.01$) and *HFABP/Hinf*I ($p \leq 0.05$). It is worth emphasising, that a significant relation of both those genes with the IMF was demonstrated only for the group of animals with a low fat content – not exceeding 2%. The results obtained confirm the presented above significant relations between genes *HFABP/Msp*I and *HFABP/Hinf* I and the parameter examined in the landrace breed group, characterised by the lowest mean intramuscular fat content in the *LL* muscle. The relations recorded for the polymorphism of gene *HFABP/Msp* I, which are not fully understandable (the highest IMF value for heterozygous animals) may arise from the activity of another activator (various genes are active in the cell) or from a specific biochemical mechanism responsible for the phenotypic variability of this trait. Moreover, beside the effect of a single gene on the intramuscular fat

content, one should also take into consideration other genes and the process of gene expression regulation.

Analysing the whole research material as regards intramuscular fat content, interactions between genes were observed for the following pairs: *MYOG/Msp*I and *Cast/Msp*I, *HFABP/Hinf*I and *GH/Msp*I, *GH/Hae*II and *CAST/Hinf*I, *GH/Msp*I and *GLUT4/Hae*I, *IGF-1R/Sac*II and *GLUT4/Hae*I, *GHRH/Alu*I and *PIT1/Rsa*I as well as *DECR1/Bfa*I and *PRKAG3/BsrB*I. The most favourable effects ($p \leq 0.01$) were observed in the case of interaction between genes *MYOG/Msp*I and *CAST/Msp*I, *GLUT4/Hae*I and *IGF-1R/Sac*II as well as *DECR1/Bfa*I and *PRKAG3/BsrB*I.

An analysis of the interaction between gene *MYOG/Msp* I and *CAST/Msp* I in relation to the intramuscular fat content demonstrated that in the case of gene *MYOG* the most favourable effect was observed in animals with genotype *AB* at *locus MYOG/Msp* I and *AA* as regards gene *CAST/Msp* I. Porkers with genotypes *ABAA (MYOG/Msp* I / *CAST/Msp* I) were characterised by a IMF content higher by almost 0.5 pp when compared with double homozygotes and by about 0.6 pp when compared with double heterozygotes *ABAB*. The results obtained, difficult to interpret, point to the necessity of conducting further studies on the genotype effect of interaction between genes as regards the intramuscular fat content and mechanisms responsible for disturbances in the expression of those genes.

In 2010, the periodical *Science* published an article by Rappaport and Smith presenting the opinion that the environment in which the genes function is of greater importance than the genes themselves. Of the same opinion is Kamińska-Kaczmarek [2011], who conducted with a group of co-workers studies on cancerous transformations of the human cell. According to her, changes occurring in the chemical environment inside a cell and in its surroundings may affect the way in which the genetic information is read.

The analysis conducted for the interaction between gene *GLUT4/Hae* I and *IGF-1R/Sac* II in relations to the IMF level, demonstrated that the homozygotes *BB* for gene *GLUT4* were significantly differentiated by gene *IGF-1R*, what was expressed in an IMF content higher by 0.57 and 0.62 pp. in animals with genotype *BB* at *locus IGF-1R*, when compared with homozygotes *AA* and heterozygotes *AB*, which were uniform as regards this trait. Moreover, gene *GLUT4/Hae* I significantly differentiated homozygotes *BB* of gene *IGF-1R/Sac* II, as it was observed that porkers with genotype *AA* at *locus GLUT4/Hae* I, were characterised by a lower intramuscular fat content by over 1 pp when compared with homozygotes *BB* – 1.45 *vs*. 2.49 %, respectively. The associations obtained, as well as the results of the analysis of polymorphism of individual genes *GLUT4/Hae* I and *IGF-1R/Sac* II, indicates that selecting

animals for a high level of intramuscular fat on the basis of interaction between the genotypes of those genes may be more effective than when basing on each gene separately.

In turn, the analysis conducted for the interaction between genes *DECR1/Bfa* I and *PRKAG3/BsrB* I, in relation to the parameter examined, demonstrated that gene *DECR1/Bfa* I differentiated significantly ($p \leq 0.01$) the *AG* heterozygotes of gene *PRKAG3/BsrB* I. It was observed that porkers with genotype *CG* at *locus DECR1/Bfa* I, were characterised by a higher IMF level in the *LL* muscle, when compared with homozygotes *CC* and *GG*, (2.84, 1.96 and 1.05%, respectively). The interaction obtained was most probably random and the small number of animals with genotype *CCAG* and *GGAG* for genes *DECR1/Bfa* I and *PRKAG3/BsrB* I (n = 2 and 3, respectively) rendered impossible conducting a detailed statistical analysis and comparison of the genotypes identified as regards meatiness and meat quality traits.

The two-factor analysis of variance performed for the expression of genes *PKM2* and *CAST* in relation to the breed group and classes differing in the intramuscular fat content, demonstrated the existence of a statistically significant ($p \leq 0.01$) effect of both factors only on the level of expression of gene *PKM2*. There was observed no effect of either the breed group or the IMF level on the expression of calpastatin gene (*CAST*). Significant interactions have also not been proved between the two factors in relation to the expression level of genes *PKM2* and *CAST*.

A statistically significantly ($p \leq 0.01$) lower level of the expression of gene *PKM2* was observed for landrace porkers when compared with (L x Y) x D crosses (1.61 and 3.17, respectively). An intensified expression was observed in the (L x Y) x D group, what shows that a share of duroc pigs, with a proven higher IMF level in meat, on the paternal side in crossbreds, significantly modifies the level of expression in relation to gene *PKM2*.

The analysis of expression of gene *PKM2* in the groups identified, differing in the intramuscular fat content, confirms that the higher ($p \leq 0,01$) IMF content in meat is connected with the intensified expression. In groups of porkers with an intramuscular fat content ranging from 2 to 3% and over 3%, preferred by the contemporary consumer, the expression of gene *PKM2* was considerably higher than in the group of animals with a fat content not exceeding 2% (3.22, 5.69 and 1.79, respectively).

One should emphasise, that the relation between the level of expression of gene *PKM 2* and IMF content was not confirmed by the earlier performed analysis of the association of the polymorphism of the gene and the parameter examined in the present study. This may be explained by the fact that the gene expression may occur at different levels, depending on the environment and conditions. Georges [2011], referring to the research results reported by

other authors, states that there may occur a strong expression of a given gene, irrespectively of its genotype. The author suggests that causative variants may rather be regulatory than structural and indicates, that the road between relations and causation is long and winding.

Moreover, as stated by Kamińska–Kaczmarek [2011], the regulation of gene expression is based on complex relations between transcription factors and respective sequences in the genome and research into the mechanisms regulating gene expression is currently one of the most interesting areas in biology.

The subsequent objective of the present work, related to research I, was the estimation of the value of the intramuscular fat content in the *LL* muscle for diagnosing pork quality.

It was observed, that intramuscular fat content in porkers is significantly related to the content of protein, water and dry matter, the value of the glycolytic potential and pH_{24}, the indicator of energy metabolism R_1, drip loss, yield of cooked cured meat (TY), cutting force as well as meat tenderness and aroma. The importance of analysing the IMF content in relation to the traits examined was confirmed by the relations demonstrated, basing on an evaluation of the dendrogram structure and using the cluster analysis on the basis.

From the point of view of the technological and culinary meat value of interest are the significant correlations observed between the IMF content and the drip loss from the *LL* muscle tissue ($r = -0.24^{**}$, $b_{xy} = -0.88$). An increase in the IMF content in pork by 1 % results in a decrease in the volume of drip loss by 0.88 per cent point. The results obtained indicate that it is possible to diagnose the volume of the drip loss from the muscle tissue by measuring *in vivo* the intramuscular fat content using the USG technique or, directly after slaughter, using quick „*on-line"* methods, such as near infrared (NIR), computer image analysis, ultrasound or computed tomography. This is of considerable importance, both for the meat processing industry and for consumers, because meat with an intensive drip loss shows a poor water holding capacity and the products obtained are poorly accepted by consumers, due to the presence of meat juices in the wrapping [Huff-Lonergan and Lonergan 2007].

It has been proved that meat with an intramuscular fat content below 2 % is characterised by a significantly higher water content, lower dry matter content, higher acidity 24 h *post slaughter*, a higher rate of energy metabolism (R_1), greater drip loss from the muscle tissue, lower yield in curing and cooking and requires the use of a greater cutting force. The observed undesirable properties of meat characterised by a low level of intramuscular fat content were reflected in the lower evaluation of the taste of cooked meat.

A canonical analysis was used to evaluate to what degree the intramuscular fat content may explain the variability of a set of meat quality traits. As the canonical analysis renders it possible to estimate the relations between sets of traits an analysis was performed of the joint

and simultaneous effect of intramuscular fat content and other easily measurable „*on line*" parameters, describing pork quality, on the culinary and sensory quality of meat, as well as its technological value.

The significant (at $p \leq 0.01$) complex coefficient of determination $R_c^2 = 0.79$ indicates that IMF and pH_{24} are responsible for 79% of the observed variability in meat quality traits. Using for the estimation of meat quality only the pH_{24} measurement, the overall variability in meat quality traits could be explained in only 49 %. Moreover, the high values obtained for the coefficient of canonical correlation ($C_R = 0.86^{**}$) and the complex coefficient of determination ($R_c^2 = 0.74$) between the set comprising IMF and pH_{35}, and the set comprising a wide range of meat quality traits, confirm that it is possible to diagnose meat quality deviations within 45 min *post mortem, i.e.* in a very short period of time..

The analysis of consumer behaviour, conducted within research II demonstrated that among meat from five animal species, within the group of respondents tested, the most frequently purchased was poultry meat (61.5 %) and pork (33.3 %). Almost half the respondents examined declared that they consume meat 3-4 times a week. In the opinion of respondents among the most important factors deciding about the choice of meat were: colour (25 %), freshness and aroma (almost 21 %), amount of visible fat (about 17 %) and price (15 %). This shows, that over half the respondents, analysed as to their choice of culinary meat, are guided by elements related to meat quality.

Moreover, the observed considerable interest of consumers (almost 60%) in meat products with a lowered fat content, *i.e.* food with a favourable effect on health, probably arises from the fact that consumers treat their health seriously and assume that the consumption of such products will be beneficial.

The statistical analysis, conducted using the coefficient of V-Cramer, demonstrated that the importance of visible fat content for the choice of fresh meat, as well as the frequency of consumption of fatty products, is statistically related to the sex, age, education and employment of the respondents, while being completely unrelated to respondents' place of living. Women demonstrated both a greater interest in the marbling when selecting fresh meat and more frequently purchased meat products with a lowered fat content. Moreover, the study conducted shows that the interest in visible fat and frequency of consumption of fatty products were the highest in the case of young people (below 25the year of life), with a high-school or university level education, being students of white-collar workers.

4.1.5. Summary of the results obtained

1. The results obtained univocally indicate that stronger, more favourable relations between the intramuscular fat content and meat quality traits were observed in the landrace breed group, characterised by a low intramuscular adiposity and high glycolytic store, as shown by the value of the glycolytic potential, and as result a high drip loss.
2. Among the three groups of analysed pedigree porkers of Danish origin bred in Poland [L, L x D, (L x Y) x D)], three breed crosses with a 50% share of genes of the duroc breed should be preferred for the commercial production of porkers with a high lean deposition. Their meat is characterised by an optimum level of intramuscular fat (2.28 %), high protein content (22.53 %), the lowest glycogen content (44.84 μmol/g) and value of the glycolytic potential (129.87 μmol/g), a lower rate of energy metabolism (R_1 = 0.85), the lowest acidity of the muscle tissue 24h *post mortem* (5.70), the lowest value for electrical conductivity (2.57 mS/cm) and the lowest drip loss from the muscle tissue (5.46 %). Moreover, the meat obtained from those crosses requires a lower cutting force (34.12 N/cm^2) and is characterised by a very high sensory attractiveness expressed by juiciness (7.35 i.u.) and tenderness (7.25 i.u.) estimated 144 h after slaughter.
3. Gene *PRLR/Alu*I may be accepted as a major gene for IMF due to the observed in the (Landrace x Yorkshire) x Duroc group of porkers high share of the difference between the mean intramuscular fat content in homozygotes *AA* a *BB* of this gene in the value of the standard deviation (1,0 SD). Retaining the meat quality acceptable for consumers is possible animals used for crossing have the preferred *AA* genotype *at locus PRLR/Alu*I.
4. In turn, in pure bred landrace porkers the effect of gene *CAST/Hinf*I was observed for the IMF content, expressed by the share of the difference between the mean value for extreme homozygotes in the standard deviation units reaching 1.13 SD, what indicated a considerable effect of this gene on intramuscular adiposity in porkers with a low level of this trait. Thus, this gene is also a candidate for major gene for IMF content. Moreover, this indicates a possibility of directing selection work conducted in the landrace breed for an increased intramuscular fat level by preferring animals with genotype *BB* for gene *CAST/Hinf*I.
5. The analysis conducted for correlations between the genes examined demonstrated that as regards intramuscular fat content, the most favourable and statistically highly significant ($p \leq 0,01$) effects were obtained for animals with the following genotypes:
   - *AB* at *locus MYOG/Msp*I and *AA* at *locus CAST/Msp*I,
   - *BB* (*GLUT4/Hae*I) and *BB* (*IGF-1R/Sac*II),

- *CG* (*DECR1/Bfa*I) and *AG* (*PRKAG3/BsrB*I).

6. The expression level for gene *PKM2*, determining the intensity of glycolytic metabolism in the muscle tissue, depends on the breed group and decides about the intramuscular fat content in the *Longissimus lumborum* muscle of porkers, what is confirmed by the almost twice as high level of the expression of this gene in (L x Y) x D porkers, with a proven higher IMF level, when compared with the landrace group, as well as a clearly higher expression level in groups of porkers with an IMF level ranging from 2 to 3 % or over 3% when compared with the group of porkers with a content of IMF in meat below 2%. This is confirmed by the fact that the intramuscular fat content was observed to be highly dependent on the expression level of the gene examined – r = 0.64**.
7. The interesting data presented as regards the role of genetic associations in the intramuscular fat content, as well as the fact that there have not been many works undertaken to elucidate these relations pointing to the necessity of conducting further studies on the genotypic effect of gene correlations and aiming at explaining their mechanism, using new possibilities as regards functional genomics, proteo-genomics, epi-genomics and bio-IT. One may expect that studies on the polymorphism of other genes, interactions between genes and between genes and environmental factors, will explain the variability of the intramuscular fat content in the muscle tissue of porkers.
8. Results obtained in the presented studies indicate also that there is a possibility of a quick diagnosis of both qualitative meat properties, characterising the intensity of glycolytic metabolism 45 min. *post mortem*, and traits showing its technological, culinary and sensory quality, through measurements of the intramuscular fat content *in vivo* or over a short period of time after slaughter. IMF and pH_{24} are responsible for 79 % of the observed variability of meat quality traits. The measurement of IMF content may also constitute a valuable indicator of the methods in which meat is used in the meat industry.
9. Poultry meat, in the presented studies, was indicated by consumers as the meat consumed most frequently, despite the fact that it is pork that in the overall meat consumption has the highest share throughout the country. This was probably caused by such factors as: a marked, slow but systematic, increase in consumption of poultry meat, competitive prices of poultry meat, high unemployment and changes in consumer preferences.
10. The considerable interest of respondents (almost 60%) in the consumption of products with a decreased fat content, *i.e*. food having a favourable effect on health, indicates on one hand an increased interest in health and the advantages arising from the consumption of such meat and on the other this confirmed the declarations of respondents as regards factors decisive in the choice of culinary meat – almost 17% indicated marbling as an

important factor considered while purchasing meat. On the basis of the characteristic of those consumers one may assume that those persons prefer meat with less marbling as this group was comprised principally of young women who purchase and consume meat with a decreased fat content, mostly poultry meat.

5. Presentation of the remaining scientific achievements

In the years 1990 – 1994 I attended the Królowa Jadwiga High School in Siedlce. In 1994, after passing the entrance examinations, I started studying at the Faculty of Food Technology of the Warsaw University of Life Sciences. In 1999 I defended a Masters thesis prepared at the Chair of Meat Technology, being granted the title of Master of Sciences of Food Technology, with a speciality in meat technology.

After graduation I returned to my home town and on March 1, 2000, I started work at the Podlasie University (currently Siedlce University of Natural Sciences and Humanities) at the Department of Pig Breeding (currently Department of Pig Breeding and Meat Science), as a technical worker. On February 1, 2001 I was appointed to the post of assistant in the Department of Pig Breeding. On September 22, 2006 I defended with honours my doctoral thesis entitled „ *Usefulness of electrical conductivity in the diagnosis of pork meat quality*", prepared under the direction of Professor Maria Koćwin – Podsiadła. The Council of the Agricultural Faculty granted my PhD in Agricultural Sciences, in the field of Animal Breeding, on October 4, 2006.

Since March 1, 2007, I am employed as lecturer – till February 28, 2011, at the Department of Pig Breeding and Meat Science, between 01.03.2011 and 30.09.2013 at the Inter-Faculty Dietetics Department and from 01.10.2013, after a reorganisation of the Faculty, at the Department of Dietetics and Food Evaluation.

I began my research activities in year 2000 on the determinants of the quality of raw pork, while being a technical worker, assisting in the realisation of statute studies conducted by the team of the Department of Pig Breeding. I would like to emphasise that the whole of my work and development as a scientist took place under the direction of Professor Maria Koćwin – Podsiadła, head of the Department of Pig Breeding and Meat Science. My scientific interests concentrate principally on the determination, diagnostic possibilities and improvement of the quality of pork. Due to the wide range of research, as well as the complexity and multiplicity of required scientific methods, a majority of my work was conducted as member of research teams.

Work in the team of Professor Maria Koćwin–Podsiadła lead me to undertake research in several fields:

1. Evaluation of the pork quality in mass production from the Central and Eastern regions of Poland;
2. Analysis of the genetic and environmental determinants of pork quality used as raw meat and for processing;
3. Methods of diagnosing pork quality (direct and on the molecular level).

The objective of the research which I conducted within the first research field, *i.e*. evaluation of the quality of porkers from mass production from the Central and Eastern regions of Poland, was to analyse the situation as regards pork quality in relation to the slaughter value, carcass adiposity as well as degree of lean meat deposition in carcasses obtained in a given region, against the background of the country mass population, together with a characteristic of the meat quality and frequency of occurrence of faulty meat (**II.D.2.1.2, II.D.2.1.3, II.D.2.1.10, II.D.2.1.11, II.D.2.1.14, II.D.2.1.15, II.D.2.1.16, II.D.2.1.17, II.D.2.1.28, II.D.2.1.30, II.D.2.3.1, II.D.2.3.2, II.D.2.4.1, II.D.2.4.27, II.D.2.4.28, II.D.2.5.2**).

The need for such research was indicated by the considerable losses incurred by the meat processing industry due to the presence of quality defects in the meat obtained from animals with a high meatiness, as well as the fact that the technological possibility of reaching a high quality final product is definitely dependant on the properties of the raw material used for production. The results obtained demonstrated that a considerable increase in the meat deposition in porkers resulted in a deterioration of meat quality, decreasing its technological value and consumer desirability, expressed by a lighter colour, excessive drip loss and lowered water holding capacity.

Moreover, the studies I conducted analysing the relations between hot carcass weight and lean meat content in carcasses of porkers obtained from mass production, demonstrated that 80-90 kg is an optimum hot carcass weight, guaranteeing the best economic effect for both the pig breeder and the meat processing plant. This comprised the essential justification for system of financial settlements with the pig producers by some slaughter houses, a system based on favouring lean meat content in pig carcasses and taking into consideration the hot carcass weight (**II.D.2.1.27**).

Simultaneously, I participated actively in work aiming at the elaboration of a reference method for estimating the percent content of meat in pig carcasses, based exclusively on linear carcass measurements and measurements of ham meatiness. The idea was to apply this method for testing classification equipment, used by the meat industry on production lines.

Evaluation of the precision and usefulness of the elaborated regression equations was performed by way of comparison between the meat deposition calculated on the basis of the reference method and that obtained from carcass dissection. Among the methods proposed the most precise, concordant with the European Union requirements, proved to be the combined reference method, taking into consideration seven linear measurements and the lean meat content in ham, expressed as weigh of ham without fat and skin (**II.D.2.1.4, II.D.2.5.1**).

The second field of my research work concentrated on the analysis of genetic and environmental determinants of the quality of raw pork. Those studies were conducted taking into consideration such factors as breed, crossing variant, carcass weight and meatiness, effect of polymorphism, expression of major genes and what is known as candidate genes. Moreover, part of the research work included also interactions between genes, environmental factors and post slaughter treatment of carcasses.

Results obtained from the analysis of the situation as regards quality of porkers obtained from mass production constituted a premise for undertaking a search for the genetic and environmental determinants of pork quality. Those results indicated the presence of meat of a lowered quality arising from breeding work aimed at increasing the meatiness in pigs through the introduction of the highly meaty pietrain breed, which is burdened by the stress susceptibility gene (*RYR1*^{T}). Moreover, the recorded considerable consumption of pork in Poland, Europe and the USA, together with the growing nutritional awareness of consumers, also led to an intensification of research work in scientific centres throughout the world, concentrating on the search for factors affecting meat quality.

The breed of animals or the crossbreeding variation is one of the significant genetic factors affecting the technologic, processing and sensory meat properties. The studies conducted by the research team, of which I was an active member, covered the evaluation of the quality of carcasses and meat obtained from pure bred landrace and duroc porkers, breed groups originating from various variants of commercial crossing, using boars of breeds and lines from the national pedigree breeding centres (polish landrace, polish large white, pietrain, hampshire, duroc, line 990) and of breeds imported from Denmark (landrace, duroc, yorkshire) (**II.A.1.4, II.D.2.1.5**, **II.D.2.1.8, II.D.2.1.12, II.D.2.1.18, II.D.2.1.19, II.D.2.1.20, II.D.2.1.29, II.D.2.4.2, II.D.2.4.7, II.D.2.4.8, II.D.2.4.29).** On the basis of the results obtained it was ascertained that to improve meat quality one should resign from using in commercial crossing the pietrain and hampshire breeds, as well as crosses with those breeds, as those animals are burdened by the stress susceptibility gene *RYR1*^{T} (responsible for the PSE type of meat) and the acid meat gene *RN*$^{-}$ (**II.A.1.5, II.A.2.5, II.D.1.1, II.D.2.1.6, II.D.2.1.13, II.D.2.4.9, II.D.2.4.10, II.D.2.4.11).** In turn, due to the high culinary and sensory

quality, as well as technological value of meat from duroc pigs and their crosses, it is advisable to use duroc animals for crossing, especially those carrying the gene of intramuscular fat content (*HFABP*) (**II.A.1.3, II.A.2.2, II.A.2.7, II.A.2.9, II.D.2.1.9, II.D.2.1.24, II.D.2.1.25).**

Within this field of research I conducted also an analysis of the effects of other genetic factors, so as to explain the high variability observed for pork quality. The negative correlations between degree of meat deposition and meat quality traits, obtained in earlier studies on porkers from mass production, were confirmed in analyses conducted on animals of different breed groups, both those burdened by and free of the stress susceptibility gene *RYR1*^{T}, recognised as the meatiness gene (**II.A.1.1, II.A.1.6, II.D.2.1.1, II.D.2.1.26).** It was observed, that the balance of benefits as regards meat deposition and content of meat in the carcass, arising from the presence of gene *RYR1*^{T}, and losses caused by the negative effect observed as regards the quality traits of meat and its culinary and technological value, proved to be unfavourable and for this reason it is necessary to limit crossbreeding with pig breeds burdened by this gene.

The variability in pork quality is decided principally by the intensity and range of glycolytic and proteolytic metabolism taking place *post mortem*. The knowledge of metabolic paths related to the development and physiology of the muscle tissue *in vivo*, together with the metabolism taking place *post mortem* during the period of meat maturation, may indicate which genes should be examined as regards their effect on those traits. For this reason, together with the whole research team, I undertook studies aiming at explaining the genetic background, at the level of the polymorphism of genes responsible for the metabolic profile, for the meat deposition traits, culinary and sensory quality, as well as the technological value of pork. Those studies comprised part of analyses conducted within the research project PBZ-KBN-036/P06/2000/04 entitled *„The effect of polymorphic forms of selected genes on meatiness and functional and physico-chemical properties of the muscle tissue of porkers*", for which I was the executor.

While implementing this research work I participated in short-term scientific practices (2 months in total) at the Department of Immunogenetics of the Polish Acedemy of Sciences Institute of Genetics and Animal Breeding, Jastrzębiec, where under the direction of Professor Jolanta Kurył I perfected my knowledge of the use of the PCR/RFLP technique, as well as other scientific techniques from the field of molecular genetics, for the identification of genes determining the performance traits in pigs. Moreover, I participated in a training session on "Methods of DNA isolation and STR polymorphism in genotyping", organised by the Warsaw University of Life Sciences.

In a series of works published on this theme, a significant relation was demonstrated between the polymorphism of genes responsible for the development of the muscle tissue and genes participating in the glycolytic and proteolytic metabolism and the traits characterising the quality of pig carcasses and pork:

- A significant relation was observed between the calpastatin *CAST* gene and the values for both meatiness and meat quality. Genotype *AA* of gene *CAST*, in the case of mutations identified by endonucleases *Hinf* I and *Msp* I (in case of mutation identified by endonuclease *Rsa* I genotype *BB* is preferred) has a positive effect on the morphological composition of the carcass expressed by the weight of the most valuable basic cuts (sirloin and sirloin without fat and skin) and fat thickness, as also on the basic traits characterising the intensity of glycolytic metabolism throughout the period of meat maturation: glycolytic potential and glycogen content (*CAST/Hinf* I), content of lactic acid and EC_{24} (*CAST/Msp*I) as well as the energy store (IMP/ATP), protein content and technological yield during curing and cooking (*CAST/Rsa* I) (**II.A.1.2, II.A.1.7, II.A.2.4, II.D.4.3, II.D.4.4)**.
- A significant correlation was observed between phenotype *RN* and genotype *CAST/Msp* I for the volume of drip loss from the muscle tissue 144 h *post mortem*, what is of importance for the consumer as during that time culinary meat reaches the retail stores **(II.A.2.6, II.D.2.2.1).**
- Among the series of the analysed associations of the gene polymorphism and carcass and meat quality traits a significant relation was observed between the polymorphism of gene *HFABP* for fat thickness on the cross I and weight of the *LD* muscle (in the case of *locus HFABP/Hae* III); fat thickness and lean meat content in carcass (*locus HFABP/Msp* I and *HFABP/Hinf* I) as well as weight of spare rib and loin eye area (*locus HFABP/M*sp I) **(II.A.2.1, II.A.2.8).** Moreover, in breed groups without the share of duroc blood, a relation was demonstrated between the polymorphism of gene *HFABP* and the content of water and protein, yield of cured meat in cooking (TY) (in case of polymorphism identified by endonuclease *Hae* III) and with the energy metabolism indicator R_1, EC_2, meat colour lightness and drip loss (*HFABP/Msp* I). In turn, breed groups obtained with the share of the duroc animals are carriers of the gene controlling intramuscular fat content – genotype *dd* at *locus HFABP* identified by endonuclease *Hae* III (**II.A.2.2, II.A.2.7, II.A.2.9**).
- A significant effect was observed of gene PRKAG 3 on fat thickness, weight of ham and sirloin (**II.A.2.10, II.A.2.11**). Moreover, there were observed no relations between the polymorphism of gene *PRKAG*3 – in year 2000 announced by Milan *et al*. as the gene of acid meat *RN* — and phenotype RN^-. The results obtained from five groups of porkers point to the necessity of conducting studies on a more numerous population of animals of various

breeds and searching for other genes determining the level of glycogen in the muscle tissue and the occurrence of acid meat (**II.D.2.2.5**).

- A significant relation was recorded between the polymorphism of gene *ACSL* 4 (beside gene *HFABP*) and the intramuscular fat content, what indicates that as regards this parameter preferred are animals with genotype *GG* **(II.A.2.19)**.

Participating in works of the research team led by Professor Koćwin–Podsiadła I took also part in an analysis of interactions between genes for carcass and meat quality traits. Analysing the interaction between genes *GLUT* 4 and *PKM* 2, that means genes from the starting and finishing stages of the glycolytic metabolism path, their interaction was observed with slaughter value traits. It was shown that animals with genotype *TT*/*BB*, at *locus PKM* 2 and *GLUT* 4, respectively, are characterised by a content of meat in carcass higher by 2,55 % and mean fat thickness smaller (by 0.28 cm) than animals with genotype *TT/AA* **(II.D.2.2.3).** Moreover, gene *GLUT4*, in interaction with gene *PKM* 2, differentiates the value of the glycolytic potential in porkers being *TT* homozygotes for gene *PKM* 2. It was also shown that within animals with genotype *TT* at *locus PKM* 2, there exist two groups with the same, high values for glycolytic potential (genotype *AA* and *BB* at *locus GLUT* 4, respectively), but significantly differing in intramuscular fat content, pH_{45}, pH_{24}, pH_{144}, drip loss from the muscle tissue 96 h *post mortem* and indicator TY, in favour of pigs with genotype *BB* at *locus GLUT* 4. The results obtained initiated further research work on the expression of gene *PKM* 2.

In turn, the significant interaction between myogenin *MYOG* and calpastatin *CAST/Rsa* I genes, observed for the weight of sirloin, may be used in selection aimed at increasing the share of sirloin weight in the overall carcass weight (genotype *BB* at *loci MYOG* and *CAST/Rsa* I) **(II.A.2.15).**

My contribution to the studies referring to the problems discussed consisted of analysing the polymorphism of the genes examined as well as interpretation and essential analysis of the relations between those genes and the quality properties of the porkers' meat, together with the effect of their interaction.

Part of my studies were also conducted within research project No. PBZ-KBN-113/06/2005/14 entitled: „*Polymorphism and expression of genes responsible for the profile of glycolytic metabolism and the calpastatin gene as an endogenous inhibitor of the protease system in porkers differing in meat quality*", for which I was the executor. Within this project we analysed relations between the polymorphism and level of expression of genes *PKM* 2 and *CAST* and the quality and technological value of the porkers' meat. With this aim I completed a course on Real Time PCR techniques and their uses, organised by the DNA-Gdańsk company in co-

operation with the Gdańsk University of Technology, improving my knowledge of research methods as regards quantitative and qualitative DNA and mRNA determination in the muscle tissue of pigs. On the basis of the studies conducted it was observed that the polymorphism of gene *PKM* 2 is in porkers related to the content of lean cuts, lean meat content in carcass and fat thickness. Moreover, it was proven that genotype *CC*, compared with genotypes *CT* and *TT* of gene *PKM* 2, determined a significantly lower content of glycogen, lactic acid and value of the energy metabolism indicator 45 min *post mortem*, as well as a higher value of pH_{24} and lower drip loss during storage 24-96 and 24-144 h *post mortem* **(II.A.2.17)**. It was also observed that there exists a significant interaction between gene *PKM* 2 and the genetic group as regards the glycolytic potential and glycogen content. The statistically confirmed interaction between gene *PKM* 2 and the breed group for the glycolytic potential and glycogen content clearly indicates that the relation with the polymorphism of the gene discussed refers principally to landrace pigs. What is important cognitively is the observed in this group high (almost 89%) conformity between the genotype of gene *PKM* 2 with the *RN*$^-$ phenotype **(II.D.2.1.22).** Moreover, it was demonstrated that the level of expression of genes *PKM* 2 and *CAST* does not explain the relations between meat quality classes, differentiated by the glycolytic potential and drip loss, irrespectively of the breed group and within groups (**II.A.2.18**). In turn, analysing relations between the level of expression of genes *PKM* 2 and *CAST* and the quality properties and technological value of meat, the only significant correlations observed were between the level of expression of gene *PKM* 2 and the water and intramuscular fat content between the expression of gene *CAST* and pH_{35} (**II.D.2.2.6).**

As a member of the research team headed by Professor Maria Koćwin-Podsiadła, and in co-operation with the team headed by Professor Stanisław Kamiński from the Olsztyn University of Warmia and Mazury, I participated in studies conducted with the use of the SNiPORK type genomic microarray, one of the first in Poland. As result of those studies, using the method of genomic microarray analysis, groups of determinant genes were identified, the polymorphism of which is related to the extreme differentiation of drip loss (*CYP21, SFRS1*) and glycolytic potential (*DECR1, PPARGC1, MC4R*) in the *Longissimus lumborum* muscle of porkers or the intramuscular fat in meat (*ACSL4)* (**II.A.2.16).**

Meeting the growing requirements of consumers in relation to the quality of meat and meat products is also determined by appropriate management of animals before and during slaughter.

Among the environmental factors a significant effect on the quantitative and qualitative meat losses is observed for slaughter procedures and *post slaughter* treatment of carcasses. Within this problem research aimed at analysing the effect on selected quality meat

properties of the use of concentrated CO_2 in the pharmacological method of stunning pigs. For some time now one may observe an increasing share of pigs stunned by this method as it meets the requirements referring to animal welfare and consumer protection to a greater degree than stunning by mechanical or electrical methods. It is also worth noting that in the meat of pigs, and also sheep and lambs, stunned pharmacologically one observes less blood effusions and the pork is characterised by smaller weight loses caused by drip loss [Christensen 2008].

Conducting studies within this field I ascertained that this method of stunning pigs, and specifically the level of CO_2, concentration, has a significant effect on the *post slaughter* physico-chemical and functional properties of pork. The majority of cases of PSE and DFD meat was observed in the population of porkers stunned with a 92% CO_2 concentration (respectively 16 and 7% *vs*. 9 and 1% for those stunned with 88% CO_2). In turn, the occurrence of carcasses with acid meat was observed only in the case of porkers stunned with an 88 % concentration of CO_2 – among those animals 17% were not sufficiently stunned **(II.D.2.1.32)**. The obtained results are a basis for conducting a detailed investigation on material of a known genotype, uniform hot carcass weight and meatiness, because the response of pigs to CO_2 to a considerable degree depends on these factors.

Another aspect of by scientific work, related to the environmental determination of pork quality, was an analysis of relations between the carcass chilling system and meat quality traits. With this aim, right carcass-sides was subjected to traditional chilling at a temperature of 4ºC over a period of 24 h, while the left carcass-sides were subjected to a rapid chilling in a three-phase tunnel (-10ºC for 15 min., -15ºC for 25 min., -5ºC for 40 min. with an air velocity of 3 m/s) and next, until 24 hours *post slaughter*, cooled at a temperature of 4ºC. The studies, conducted jointly with a research team demonstrated, that rapid chilling significantly slows down the decrease of pH in the *LL* muscle in the period between 2 and 96 hours after slaughter. A significant interaction was also observed between the value of the glycolytic potential and acidity of the *LL* muscle, which proved to be more pronounced in the group of carcasses subjected to rapid chilling. The studies conducted by the team of which I was a member, demonstrated also, that a rapid chilling of carcasses of duroc pigs may lead to a slight increase in the drip loss from the *LL* muscle 48 h *post mortem* (**II.A.2.21, II.D.2.1.23, II.D.2.2.7)**.

Analysing the determinants of pork quality, the research team, of which I was a member, undertook studies aimed at comparing two methods of analysing the basic chemical composition of meat, that means the model analytical method by Soxhlet and the method of near infrared transmission (NIT). The need for such investigations arises from the fact that the

Soxhlet method, though still used in laboratories, is not suitable for routine analyses in meat processing plants, because it is time consuming (fat extraction may last even a whole day) and laborious. For this reason it is necessary to search for other methods, rendering possible a quick evaluation of pork marbling – for instance using near infrared transmission (NIT). Studies, in which I participated, demonstrated a small precision of intramuscular fat content determination using the NIT method, when compared to the reference analytical method (Soxhlet) **(II.A.2.3, II.D.2.4.18)**.

The third theme of my research work and an object of special interest, was the search and estimation of the value of physico-chemical meat indicators for diagnosing pork qualitative variations. The considerable interest in the search for methods determining meat quality variations arises from the high frequency of faulty meat, increased consumer demands and losses of the world, including national, meat industry arising from lowered meat quality. The need for a precise, quick and economic diagnosis of pork defects, contributed to the search for and elaboration of methods aiming at the determination and detection of quality variations.

Together with the research team of the Department of Pig Breeding and Meat Evaluation of the Siedlce University of Natural Sciences and Humanities, I participated in investigations on the estimation of the value of selected physico-chemical properties of meat, as well as *post slaughter* measurements, for diagnosing the culinary and technological value of meat. The research work conducted demonstrated a significant relation between pH_1, R_1, pH_{24}, electrical conductivity, glycolytic potential and its components (lactic acid and glycogen) and drip loss and the meat quality properties determining the culinary and technological value of pork (**II.A.1.8, II.A.2.20**, **II.D.2.1.7, II.D.2.1.11, II.D.2.1.30, II.D.2.1.31, II.D.2.2.8, II.D.2.2.9, II.D.2.2.10, II.D.2.2.11, II.D.2.4.5, II.D.2.4.25, II.D.2.4.26, II.D.2.5.3, II.D.2.5.6, II.D.2.5.7**).

As regards the research conducted it was observed, that meat with the smallest pH decrease during the period examined, *i.e.* ≤0.88 unit, was characterised by the lowest content of glycogen and the highest concentration of lactic when acid compared with the group characterised by a significantly higher level of glycogen and the lowest concentration of lactic acid. It was also observed, that from 3 hours after slaughter the meat of porkers classified to the group with the lowest pH decrease between 45 min. and 48 h *post mortem*, was characterised by a significantly lower rate and scope of pH decrease in comparison to the meat obtained from porkers of the remaining groups. However, there was observed no effect of the rate of pH changes on meat colour lightness and drip loss (**II.A.2.22**).

Moreover, I participated in studies on the elaboration and verification (using the achievements of molecular genetics) of the efficiency of diagnosing faulty meat for the meat processing industry, basing on the physico-chemical traits, easily measured *on line* (pH_1 and R_1; pH_1 and pH_{24}; EC_{120} and pH_{24}), value of the glycolytic potential (PG) and the glycolytic and glycolytic-energy resources up to 45 min *post mortem* (**II.D.1.1, II.D.1.2, II.D.1.3)**. It was observed that parameter pH_1 is determined by two genes (*RYR*1 and *CAST/Rsa*I), R_1 – by 4 genes (*RYR*1 *CAST/Hinf*I, *CAST/Rsa*I and *HFABP/Msp*I), EC_{120} – by 3 genes (*RYR*1, *RN*-, *HFABP/Msp*I), while pH_{24} – by 5 genes (*PRKAG3, RN*-, *CAST/Hinf*I, *CAST/Rsa*I and *CAST/Msp*I). This means that the method of classifying qualitative variations on the basis of pH_1 and R_1 is determined by 6 genes, pH_1 and pH_{24} – by 7 genes, while EC_{120} and pH_{24} – by 8 genes.

The search for methods of meat quality evaluation, possible to use *on line* soon after slaughter, were the theme of my PhD thesis entitled „ *Usefulness of electrical conductivity in the diagnosis of pork meat quality*", which was a comprehensive estimation of the value of electrical conductivity (EC) measurements, performed after slaughter and applied together with other meat quality indicators, for diagnosing meat properties and its culinary and technological quality. The work aimed also at verifying the efficiency of a chosen, most favourable set of meat quality indicators, including the EC, for the determination of pork quality in comparison with three methods most often used in practice. In my PhD thesis I pointed to the exceptionally high usefulness of electrical conductivity, measured 120 min. *post mortem* and pH_{24} for diagnosing a wide spectrum of meat quality traits, its culinary and technological value. I observed that both the parameters mentioned determine in as much as 81% of the meat quality properties, 72% of the technological value of meat, 64% of its culinary value and 41% of the meat's water holding capacity. The results obtained univocally showed the justification for applying those parameters to the diagnosis of meat quality properties and classifying quality variations. Moreover, a comparative analysis of four methods of classifying defective meat, *i.e.* based on the criteria examined EC_{120} and pH_{24}, as compared with three most commonly used (pH_1 and R_1, pH_1 and pH_{24} as well as pH_1, pH_{24} and colour lightness L*), confirmed the high value of the method analysed for diagnosing meat quality properties, thus rendering it possible to apply it for selection of a wider range of meat defects, including dripping meat, both in industrial and laboratory conditions. I would like to emphasise, that the PhD thesis was distinguished by both reviewers, that is by Professor Józefa Gardzielewska – from the Faculty of Biotechnology and Animal Breeding, West Pomeranian University of Technology, Szczecin, and Professor Władysław Migdał – from the Faculty of Food Technology, University of Agriculture in Cracow. The results

obtained were presented among others, during the international conference *„Safe food. Plant production, animals production, management”*, which took place in Bydgoszcz in year 2008 (**II.D.2.4.22, II.D.2.4.23, II.D.2.4.24**).

After obtaining the doctoral degree my research interest (beside the continuation of problems presented above) turned to the content of intramuscular fat in pork as an indicator of culinary quality and technological value of meat, both from the consumers' and the processing point of view, as well as an analysis of the nutritional behaviour of meat consumers. The low intramuscular fat content observed in pork by both the Polish and foreign meat industry, is not accepted by the contemporary consumer. As result of my interest in this problem I elaborated the scientific treaties entitled "***Genetic determinants of intramuscular fat content and its usefulness in diagnosing pork quality”*** which I present as my scientific achievement.

Currently, owing to the co-operation of the research team headed by Professor Koćwin–Podsiadła, of which I am a member, with the team headed by Professor Abramczyk from the Inter-faculty Institute of Radiation Technique of the Lodz University of Technology, my research interests have concentrated on the use of rapid methods of diagnosing meat quality *post mortem*, directly during the production process by way of absorption spectroscopy and Raman spectroscopy, on the basis of glycolytic and energy parameters as well as parameters characteristic for proteins, lipids, fatty acids and water. The significance of the innovative method lies in the fact that the carcass, placed on the production line and prepared for the production process, will be, after refining the method and construction of the apparatus, subjected to non-invasive examinations consisting of an early, fast and objective determination of metabolites and the protein-lipid profile, which decide about the final meat quality and its consumption and technological value. The metabolites and the protein-lipid profile will be determined through an spectrometric analysis and tests using the Raman scattering technique. Refinement of this method will render it possible ti identify classes of meat quality and reaching better economic results by the meat plants and also increase the amount of meat.

Summarising, as result of my research work I have elaborated and published 73 original scientific papers, 30 of which (22 after receiving the PhD) have been published in scientific periodicals of worldwide coverage, placed on the JCR list, such as Meat Science, Journal of Animal Breeding and Genetics, Animal Science, Fleischwirtschaft, Animal Science Papers and Reports, Annals of Animal Science, Żywność. Nauka. Technologia. Jakość, and in periodicals from the B MSHE list, such as Polish Journal of Food and Nutrition Sciences, Journal Central European Agricultural and in materials from international conferences.

Moreover, the results of investigations in which I was personally engaged and actively participated in the performance of tasks, statistical and essential elaboration of results, rendered it possible to elaborate practical recommendations for meat processing plants and were introduced into practice in the meat plants belonging to the SOKOŁÓW S.A. company: *„Usefulness of the INFRATEC apparatus for analysing the basic composition of meat in production conditions of the meat industry”* and *„The value of porkers from different commercial crossing variants for the production of high class pork”.*

6. Specification of publications

Yet I have published 116 papers, including:

- 73 original scientific papers, 30 of which were published in periodicals distinguished by the Journal Citation Reports,
- One monograph and three chapters in two books,
- Two reviews articles.
- 30 scientific communications of a local and international character,
- 7 popular science works,

and two implementations introduced at the meat processing plant belonging to the SOKOŁÓW company.

Scientific value of publications:

- Total score for publications according to the list of scientific periodicals of the Ministry of Science and Higher Education, according to year of publication – **655 point** (including 503 points after being granted the PhD)
- Total score for publications according to the current list of scientific periodicals of the Ministry of Science and Higher Education (dated 17.12.2013) – **1077 points** (including 702 points after being granted the PhD)
- Summary *impact factor* (IF) according to the Journal Citation Reports list (JCR) consistent with the year of publication – **17,84**
- Citation number according to Web of Science – 33 (excluding self-citing 29)
- Hirsch index according to Web of Science for cited publications – 3
- Hirsch index according to Web of Science for indexed publications - 4

A complete list of scientific and popularising publications, of which I am the author or co-author is presented in Appendix 3 and 4, respectively

Summary scientific achievements divided into original scientific creative publications, review articles, monographs and chapters in books, scientific communications and popular science articles

Scientific achievements	Number of publications	IF [a)]	MSHE *	MSHE **
Original scientific creative publications including:				
● in journals in the *Journal Citation Reports* database	**30**	**17,84**	**490**	**780**
-in the peer-reviewed scientific papers in supplements	14	5,105	210	350
● in other journals	**32**	-	157	**278**
- in the peer-reviewed scientific papers in supplements [b)]	8		36	120
● in materials of congresses and conferences	**11**	-	-	-
Summary original scientific creative publications	**73**	**17,84**	**647**	**1058**
Monographs and chapters in books	**4**	-	-	-
Review articles	**2**	-	4	15
Scientific communications	**30**	-	-	-
Popular science works	**7**	-	4	4
Summary scientific achievements	**116**	**17,84**	**655**	**1077**

IF [a)] – summary impact factor according to the Journal Citation Reports list (JCR) consistent with the year of publication

MSHE * - number of points according to the Ministry of Science and Higher Education (MSHE) list of journals in line with the year of the publication

MSHE ** - number of points according to the current MSHE list of scientific journals (dated 17.12.2013)

[b)] - applies to works published before the doctorate, which are currently in the JCR database, while in the publication were not highlighted by the Journal Citation Reports

List of journals

Journals	Number of publications	IF [a)]	MSHE point in years	MSHE *	MSHE **
Meat Science	4	9,696	2008 – 24 pkt, 1 pr. 2010 -32 pkt, 2 pr. 2011 – 40 pkt, 1 pr. 2013 – 40 pkt	128	160
Journal of Animal Breeding and Genetics	1	1,574	2010 – 27 pkt, 1 pr. 2013 – 35 pkt	27	35
Animal Science	5	5,105	2006 – 24 pkt, 5 pr. 2013 – 25 pkt	120	125
Fleischwirtschaft	1	0,129	2005 – 10 pkt, 1 pr. 2013 – 15 pkt	10	15
Animal Science Papers and Reports	16	0,306	2004 – 10 pkt, 7 pr. 2006 - 10 pkt, 7 pr. 2007 – 10 pkt, 2 pr. 2013 – 25 pkt	160	400
Annals of Animal Science	5	0,84	2002 – 6 pkt, 2 pr. 2003 - 6 pkt, 1 pr. 2013 – 15 pkt, 1 pr. 2014 – 15 pkt, 1pr.	48	75
Żywność.Nauka. Technologia.Jakość	7	0,190	2003 – 4 pkt, 2 pr. 2005 - 4 pkt, 4 pr. 2013 – 15 pkt, 1 pr.	39	105
Journal Central European Agricultural	1	-	2010 – 9 pkt, 1 pr. 2013 – 8 pkt	9	8
Polish Journal of Food and Nutrition Sciences	4	-	2001 – 6 pkt, 1 pr. 2004 - 6 pkt, 1 pr. 2009 – 8 pkt, 1 pr. 2011 – 8 pkt, 1 pr. 2013 – 10 pkt	28	40
Roczniki Naukowe PTZ	13	-	2005 – 4 pkt, 1 pr. 2007 - 4 pkt, 2 pr. 2008 – 6 pkt, 4 pr. 2009 – 6 pkt, 2 pr. 2010 – 6 pkt, 4 pr. 2013 – 7 pkt,	72	91
Roczniki Naukowe Zootechniki	1	-	2001 – 4 pkt, 1 pr. 2013 – 4 pkt	4	4
Prace i Materiały Zootechniczne	1	-	2002 – 2 pkt, 1 pr. 2013 – 0 pkt	2	-
Przegląd Hodowlany	1	-	2004 – 4 pkt, 1 pr. 2013 – 4 pkt	4	4
Zeszyty Naukowe Przeglądu Hodowlanego	2	-		-	-
Zeszyty Naukowe AR Wrocław	1	-		-	-
Trzoda Chlewna	1	-		-	-
Magazyn Przemysłu Mięsnego	4	-		-	-
Mięso i Wędliny	1	-		-	-
Monographs and chapters in books	4	-		-	-
Scientific communications	30	-		-	-
Works in materials of congresses and conferences	11	-		-	-
Review articles	2	-	2003 – 4 pkt, 1 pr. 2013 – 15 pkt.	4	15
Summary	**116**	**17,84**		**655**	**1077**

IF [a)] – summary impact factor according to the Journal Citation Reports list (JCR) consistent with the year of publication

MSHE * - number of points according to the Ministry of Science and Higher Education (MSHE) list of journals in line with the year of the publication

MSHE ** - number of points according to the current MSHE list of scientific journals (dated 17.12.2013)

Summary scientific achievements before and after PhD degree

Lp.	Scientific achievements	Before PhD degree			After PhD degree			Total		
		Number of publications	MSHE*	MSHE**	**Number of publications**	MSHE*	MSHE**	**Number of publications**	MSHE*	MSHE**
1	**Original scientific creative publications including:**	**26**	**144**	**356**	**47**	**503**	**702**	**73**	**647**	**1058**
1.1	in journals in the *Journal Citation Reports* database	8	80	190	22	410	590	30	490	780
1.2	in other journals	17	64	166	15	93	112	32	157	278
1.3	in materials of congresses and conferences	1		-	10	-	-	11	-	-
2	**Other achievements including:**	**27**	**8**	**19**	**16**	**-**	**-**	**43**	**8**	**19**
2.1	Monographs and chapters in books	1		-	3	-	-	4	-	-
2.2	Review articles	2	4	15	-	-	-	2	4	15
2.3	Scientific communications	21		-	9	-	-	30	-	-
2.4	Popular science works	3	4	4	4	-	-	7	4	4
3.	**Summary scientific achievements**	**53**	**152**	**375**	**63**	**503**	**702**	**116**	**655**	**1077**

MSHE * - number of points according to the Ministry of Science and Higher Education (MSHE) list of journals in line with the year of the publication
MSHE ** - number of points according to the current MSHE list of scientific journals (dated 17.12.2013)

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