SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS OF THE SCIENTIFIC AND RESEARCH ACTIVITIES

APPENDIX 2

ANDRZEJ PÓŁTORAK PhD, Eng.

DEPARTMENT OF TECHNIQUE AND FOOD DEVELOPMENT

FACULTY OF HUMAN NUTRITION AND CONSUMER SCIENCES

WARSAW UNIVERSITY OF LIFE SCIENCES

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1. PERSONAL DATA

1.1. Name and surname

Andrzej Półtorak

1.2. Obtained diplomas (degrees)

2003	**Doctor of Philosophy** in the field of agricultural engineering, Faculty of Production Engineering, Warsaw University of Life Sciences, thesis topic: "Analysis of the production process of filled products using a automating forming machine"; promoter: Andrzej Neryng, Professor, PhD habillitated
1993	**Master of Science** of agriculture mechanization, Faculty of Agricultural and Forestry Technique, Warsaw University of Life Sciences, thesis topic: "Determination of the thickness of a thin layer depending on the speed of the drying air", promoter: Małgorzata Jaros, PhD, Eng.

1.3. Information about employment in scientific units

Since 03.2016	Warsaw University of Life Sciences, Faculty of Human Nutrition and Consumer Sciences, Department of Technique and Food Development Division of Food Research and Development – **head of Division**
01.2013	Warsaw University of Life Sciences, Faculty of Human Nutrition and Consumer Sciences, Department of Technique and Food Development Division of Food Research and Development – **assistant professor**
07.2011 – 11.2015	Warsaw University of Life Sciences, Faculty of Human Nutrition and Consumer Sciences, Division of Engineering in Nutrition, Project "Optimization of beef production in Poland, according to the strategy "from fork to farm"" (POIG.01.03.01-00-204/09-00)– **head of research task no. 4**
01.2010 – 12.2010	Warsaw University of Life Sciences, Faculty of Human Nutrition and Consumer Sciences, Department of Functional Food and Commodities – Project "BIOFOOD – innovative, functional products of animal origin" Project (POIG.01.01.02-014-090/09) – **evaluator**
01.2010 – 12.2010	Warsaw University of Life Sciences, Faculty of Human Nutrition and Consumer Sciences, Department of Functional Food and Commodities – **assistant professor**
09.2004 – 12.2009	Warsaw University of Life Sciences, Faculty of Human Nutrition and Consumer Sciences, Department of the Technique and Technology in Gastronomy– **assistant professor**
02.1994 – 09.2004	Warsaw University of Life Sciences, Faculty of Human Nutrition and Consumer Sciences, Department of the Technique and Technology in Gastronomy – **assistant**

2. ACHIEVEMENTS UNDERLYING THE PROCEDURE FOR GRANTING A HABILITATION DEGREE

2.1. Title of a scientific achievement

Pursuant to article 16 sec. 2 of the Act of 14 March 2003 on scientific degrees and scientific titles, and on degrees and titles in Arts (consolidated text: Journal of Laws of 2014, item 1852 and of 2015, item 249 and 1767) the scientific achievement that underlies the procedure for granting the habilitation degree is a cycle of six scientific publications and two patents that are thematically related, titled "Study of a relation of meat and meat products composition, and packaging and storing conditions to the quality of finished products".

2.2. Publication presenting the research results that constitute habilitation achievements

I.B.1. **Półtorak, A**., Marcinkowska-Lesiak, M., Lendzion, K., Onopiuk, A., Moczkowska, M., Wojtasik-Kalinowska, I., & Wierzbicka, A. (2018). The effect of bioactive components of plant origin on the physicochemical and sensory characteristics of functional sausages. *Food Science and Technology*, Epub September 21, 2018. https://dx.doi.org/10.1590/fst.03018 **(IF 1.084; MNiSW Min. of Sci. & Hghr Edu *[Ministry of Science and Higher Education]*: 20 points).**

My contribution in this paper consisted in co-creation of the concept of the article, setting the objective, co-participation in literature review, performance of some experiments, development of some methodologies, co-participation in the discussion of results and preparation of a manuscript. My percentage contribution is ***55%****.*

I.B.2. **Półtorak, A**., Marcinkowska-Lesiak, M., Lendzion, K., Moczkowska, M., Onopiuk, A., Wojtasik-Kalinowska, I., & Wierzbicka, A. (2018). Evaluation of the antioxidant, anti-inflammatory and antimicrobial effects of catuaba, galangal, roseroot, maca root, guarana and polyfloral honey in sausages during storage. *LWT – Food Science and Technology*, 96, 364-370. doi.org/10.1016/j.lwt.2018.05.035 **(IF: 3.129; Min. of Sci. & Hghr Edu: 40 points).**

My contribution in this paper consisted in co-creation of the concept of the article, setting the objective, co-participation in literature review, performance of some experiments, development of some methodologies, co-participation in the discussion of results and preparation of a manuscript. My percentage contribution is ***55%.***

I.B.3. Marcinkowska-Lesiak, M., Poławska, E., **Półtorak A**., & Wierzbicka, A. (2017). The effect of varying gas headspace to meat ratio on the quality of pork stored in high O_2 modified atmosphere. *Cyta – Journal of Food*, 15, 226-233. doi.org/10.1080/19476337.2016.1240237 **(IF: 1.371; Min. of Sci. & Hghr Edu: 20 points).**

My contribution in this paper consisted in co-creation of the concept of the article, setting the objective, co-participation in literature review, performance of some experiments, development of some methodologies, co-participation in the discussion of results and preparation of a manuscript. My percentage contribution is ***51%.***

I.B.4. Lipińska, A., **Półtorak A**., Wierzbicka, A. & Wyrwisz J. (2016) The effect of packaging method and dietary vitamin D_3 supplementation on the quality of beef in rectus femoris, gluteus medius, and adductor femoris beef muscles. Turkish Journal of Veterinary and Animal Sciences, 40, 505-513. doi:10.3906/vet-1507-7. **(IF: 0.449; Min. of Sci. & Hghr Edu: 20 points).**

My contribution in this paper consisted in co-creation of the concept of the article, setting the objective, co-participation in literature review, performance of some experiments, development of some methodologies, co-participation in the discussion of results and preparation of a manuscript. My percentage contribution is ***45%.***

I.B.5. Łopacka, J., **Półtorak, A**., & Wierzbicka, A. (2016). Effect of MAP, vacuum skin-pack and combined packaging methods on physicochemical properties of beef steaks stored up to 12 days. *Meat Science*, 119, 147–153. doi:10.1016/j.meatsci.2016.04.034. **(IF: 3.126; Min. of Sci. & Hghr Edu: 40 points).**

My contribution in this paper consisted in co-creation of the concept of the article, setting the objective, co-participation in literature review, performance of some experiments, development of some methodologies, co-participation in the discussion of results and preparation of a manuscript. My percentage contribution is ***25%.***

I.B.6. Łopacka, J., **Półtorak, A.,** & Wierzbicka, A. (2017). Effect of reduction of oxygen concentration in modified atmosphere packaging on bovine M. longissimus lumborum and M. gluteus medius quality traits. *Meat Science*, 124, 1–8.doi:10.1016/j.meatsci.2016.10.004. . **(IF: 2.821; Min. of Sci. & Hghr Edu: 40 points).**

My contribution in this paper consisted in co-creation of the concept of the article, setting the objective, co-participation in literature review, performance of some experiments, development of some methodologies, co-participation in the discussion of results and preparation of a manuscript. My percentage contribution is ***25%.***

I.B.7. Wierzbicka, A., Gutkowska, K., Horbańczuk, J., Guzek, D., Poławska, E., **Półtorak A.,** Marcinkowska-Lesiak, M., Wyrwisz, J., Tomasik, C., Blicharski, T. (2016). Sposób wytwarzania wieprzowych wyrobów mięsnych. (Method of producting pork meat products). **Patent no. 221480; (Min. of Sci. & Hghr Edu: 30 points).**

My contribution in the patent development consisted in the analysis of technical and patent literature, co-participation in setting the objective and preparation of scientific methodologies, indication of the patent range and patent reservations. My percentage contribution is ***10%****.*

I.B.8. Wierzbicka, A., Gutkowska, K., Horbańczuk, J., Marcinkowska-Lesiak, M., Poławska, E., **Półtorak A**., Wyrwisz, J., Guzek, D., Tomasik, C., Kuboń, M. (2016). Zastosowanie folii trójwarstwowej i modyfikowanej atmosfery do pakowania prozdrowotnych wyrobów wieprzowych. (The use of three-layer foil and modifed atmospheres for packing health supporting pork products). Patent no. 221874 **; (Min. of Sci. & Hghr Edu: 30 points).**

My contribution in the patent development consisted in the analysis of technical and patent literature, co-participation in setting the objective and preparation of scientific methodologies, indication of the patent range and patent reservations. My percentage contribution is ***15%.***

The total Impact Factor (IF) for 6 publications and 2 patents is **IF=11.980.** Total number of points, according to uniform evaluation of the journal within 2013-2016 published on 26 January 2017 by the Ministry of Science and Higher Education, is **240 points**. Copies of papers contained in the mono-subject cycle of publications that constitutes the scientific achievement along with the co-authors statements determining their contribution in writing the publication constitute Enclosure.

2.3. Discussion on the scientific objective of the above-mentioned papers and achieved results, and their possible use

2.3.1. Introduction

Many factors influence decisions on the purchase of meat and meat products. Conventionally, there are three groups of factors i.e., factors related to health criteria, sensory attractiveness, and availability. Taking into consideration the nutritive value of meat, consumers are aware, that it is a very precious source of nutritive elements, although, sometimes reasons for its consumption are undermined and various counter indications are indicated. When talking about eating, attention is often paid to the increased fat content in meat with a considerably high amount of saturated fatty acids, high content of cholesterol, sodium chloride, a considerable amount of which can be found in preserved food, and to varied functional additives which are used in the meat industry (McAfee et al., 2010).

Quality of meat and meat products

A pork quality, its dietary values, tastiness, and technological usefulness depend on both genetic and environmental factors (Moczkowska et al., 2015; Onopiuk et al.., 2016; Wyrwisz et al., 2016). The concept of meat quality includes inherent properties that have impact on the possibilities of pork application for further processing and storing, including storing during trade turnover. The main properties of pork meat include a nutritive value, texture, water content, colour, fat content, and composition (the fatty acids profile, stability of oxidation processes and repeatability of those features). A technological quality of meat is a complex and multidimensional feature that shapes many factors and interactions between them (Rosenvold and Andresen, 2003; Wood et al., 2004; Bonneau and Lebret, 2010).

The quality of meat products depends mainly on the quality of the used meat raw material and technological processes applied in their production. Supplementary additives, taste, and structure shaping substances of this type of products have a key meaning (compositions of seasonings, sodium chloride, protein hydrolysate, meat tastiness potentiates, aromas, and smoke curing preparations (Krzysztofiak and Uchman, 2008).

Meaning of meat and meat products composition impact on the quality of finished products.

Muscular tissue, the participation of which in carcass is fundamental for their price evaluation, decides on the nutritional, commercial, and technological value. Meat constitutes a mixture of over a few dozen of chemical compounds that occur there permanently but in various amounts. A chemical composition of meat depends greatly on the survival factors, namely on: species, race, gender, age, feeding manner, confirmation degree of the animal carcass and on a part of carcass from which a particular culinary element of meat comes from, and on the degree of post-mortem changes. On the other hand, a utility value of meat depends on the percentage content of muscular, connective, and fatty tissue, which depends on the race property, feeding conditions, and maintenance of animals (McAfee et al., 2010). Moreover, meat has a high biological value, which is preconditioned mainly by the content and composition of protein as well as intramuscular fat. A high biological value of meat is also influenced by the fact that it is a rich source of many other, important components. It has a high content of vitamins, in particular from B group (in particular B_1, B_2, B_6, B_{12}, PP), vitamins soluble in fat (A, D and E) and mineral components that belong to the antioxidant group (ferric, zinc, copper, magnesium, selenium (Williamson et al., 2005). A technological quality and usefulness for meat processing are greatly affected by the water, protein and fat content (Kristensen and Purslow, 2001).

Presently, one aims at production of meat products with a repeatable and at the same time high quality. Basic mechanisms of muscle spoilage of cured and processed finished products include development of microflora and oxidization changes that are responsible for, inter alia, changes in physical properties, including changes in colour and deterioration of the product texture. Thermal processing used during production should destroy, inter alia, vegetative bacteria cells, deactivate catabolic enzymes, and preserve a colour of the produced product. Problems with a lack of repeatability of the meat products quality may occur as a result of a wrongly applied technological process or unsuitable for a given product packaging and storing process. Oxidative rancidity of products may be prevented by elimination of oxygen from the protective atmosphere. Oxygen-free atmosphere is recommended also in case of curing products. Since, addition of nitrite inhibits the growth of majority of bacteria that cause food poisoning. However, in reactions with myoglobin, it creates nitrate myoglobin which is susceptible to oxygen blooming (particularly under the influence of light). Moreover, application of sodium chloride influences not only the improvement of the meat product taste, but also extension of its shelf life (bacteriostatic activity), inactivation of proteolytic enzymes and increase of water absorption by increasing solubility of myofibril proteins and a shift of isoelectric point. Table salt increases also emulsification ability of protein and influences the improvement of juiciness and consistency causing expansion of muscle protein. Technological and commodity necessity of ensuring meat products with attractive colour and elimination of pickling effects that are harmful for human health at the same time lead to even more popular use of natural extracts, which results in achieving a stable and attractive colour.

However, recipes with a reduced salt, nitrites, or other preservatives content limit their inhibitory properties. Thus, in unsuitable storing conditions, meat products without preservatives may be exposed to the growth of one of the most dangerous bacteria i.e. *Clostridium botulinum,* which can produce botulinum toxin. Therefore, changes in recipes of products should be introduced with a great care and individual packaging and storing methods of meat products should be selected with attention to possible effects (Pietrasik et al., 2003; Vandendriessche, 2008). Meat products including natural antibacterial and antioxidant elements may be of potential in this case (Flawo et al. 2014; Lu et al. 2016). Unfortunately, so far this type of products have included usually single selectively acting bioactive components (Kerry and Kerry, 2011; Alvarez and Barbut, 2013; Zychnowska et al., 2015)

Packing and storing of meat and meat products with a varied composition

The greatest challenge for food producers and sellers is to maintain a relevant quality and shelf life of food products, in particular of meat and its products (Cayuela et al., 2004; Garcia-Esteban et al., 2004; Brody et al., 2008).

Majority of animal raw materials are perishable. Therefore, maintenance of their natural properties requires fast processing or protection from spoilage. Spoilage and a short shelf life of meat and meat products is the main problem of the meat industry. Unpleasant smell and taste, as well as formation of slime and changes in colour, and deterioration of the texture cause raw material losses, namely economic ones. The main reason of meat spoilage is the growth of bacteria and formation of products of their metabolism (Tomovic et al., 2009). In case of red meat, its shelf life in retail sale is additionally limited by colour changes, which usually occur before the product is spoiled caused by the growth of microorganisms. Discolouration and processes of spoilage usually start on the surface that has a contact with oxygen, which considerably limits the possibility of distribution of culinary elements of red meat (Viana et al., 2005).

Application of the relevant method of packaging enables maintenance of a natural appearance of a product, protects it from changes in colour and texture and formation of foreign aroma and aftertaste, and extends its shelf life, which ensures higher acceptance of the product. Properties that determine the shelf life of meat and its products are water absorption, microbiological quality, stability of fat oxidation processes, colour, and tastiness. The shelf life is also influenced by numerous factors, including a product type, composition of the gases mixture used for packing, packing material or storage conditions (Damaziak et al., 2016; Marcinkowska-Lesiak et al., 2016).

Meat and meat products shelf life is presently extended by the use of modified atmosphere including vacuum (Ripoll et al., 2013). VP-Vacuum Packing guarantees protection of meat products against aerobic microorganisms. Moreover, it limits the mass losses and eliminates the impact of the atmosphere conditions from the outside (oxygen, moisture, etc.) (Cayuela et al., 2004). MAP - Modified Atmosphere Packing consists, on the other hand, in packing in different conditions than the outside conditions (surrounding atmosphere). In packing with this method, air is replaced with another gas or gas mixture, the most often it is oxygen, carbon dioxide, and nitrogen. The composition of the mixture depends on the product type and requirements set before recipients, packing method and storing conditions (McMillin, 2008; Zhou et al., 2010, Bingol and Regun, 2011). In case of red meat, maintenance of a relevant colour and limitation of microorganism's growth is indispensable. In order to maintain a proper colour or to induce a red colour of meat, a mixture with oxygen above 50% is applied. On the other hand, application of carbon dioxide prevents development of microorganisms. In case of meat products, considerable extension of the shelf life in comparison to vacuum packing may be reached in case of the nitrogen mixture with 20-50% participation of carbon dioxide (Jeremiah, 2001; McMillin, 2008).

A relevant packing system is thus, besides the use of a high quality of raw material and development of a relevant recipe composition, one of the tools that helps both to maintain the quality of the product at a relevant level, its effective appearance, safety and guarantees a reasonable total cost. A suitable packing enables also to individualize the offer helping to reach even a narrower group of consumers. Meat industry is now searching for alternative solutions - methods that expand the shelf life of products, which enable the sale of final products on distant markets.

Therefore, the collection of publications and patents titled "Study of a relation of meat and meat products composition, and packaging and storing conditions to the quality of finished products" presented as the scientific achievement, includes new cognitive elements not only within the scope of meat and meat products production with addition of bioactive components or a raised nutritive value and reduced fat and salt content (without polyphosphate). The paper also presents the impact of varied packing systems on the selected quality determinants of meat and meat products including such factors as packaging method, packaging type, and the size of filling the package with raw material.

2.3.2. Scientific objective

The main scientific objective of the achievement that is a basis of application for the scientific habilitation degree pursuant to Article 16 sec. 2 of the Act of 14 March 2003 on scientific degrees and scientific title, and degrees and titles in Arts, is **the Study of a relation of meat and meat products composition, and packaging and storing conditions to the quality of finished products**.

Pursuant to the requirements of the Act of 14 March 2003 on scientific degrees and scientific title, and degrees and title in Arts (Journal of Laws of 2003, No. 65, item 595 as amended) and pursuant to the requirements of the act of 27 July 2005 Law on Higher Education Act (Journal of Laws No. 164, item 1365 as amended), and pursuant to the Resolution of the Minister of Science and Higher Education as of 26 September 2016 on detailed mode and terms of procedure of PhD studies, habilitation and granting the professor title (Journal of Laws 2016, item 1586).

Detailed objectives:

- investigation of the impact of meat and meat products composition on the quality of finished products (**article: I.B.4.; I.B.1.; I.B.2.; patent I.B.7.**) - Numbering in accordance with Annex 3;

- investigation of the impact of packaging and storing systems on the quality of finished products (**article**: **I.B.3.; I.B.4.; I.B.5.; I.B.6.; patent I.B.8.**) - Numbering in accordance with Annex 3;

2.3.3. Discussion on the paper results

2.3.3.1. Impact of the meat and meat products composition on the quality of the finished product

A decision on the purchase of meat and meat products is mainly influenced by a subjective assessment of the quality carried out by a consumer. It is mainly related to sensory attractiveness, which consists of, inter alia, colour, and texture of the product, particularly its tenderness (Ramamoorthi et al., 2009; MSa, 2010). Both those features depend, inter alia, on the meat and meat products composition.

A degree of a relation between the colour, mechanical texture determinants, and a nutritive composition of meat was presented in numerous studies (Brewers et al., 2001; Van Laack et al., 2001; Rincker et al., 2008; Pogorzelska-Nowicka et al., 2018). The area that has been described by me and the team is the analysis of the colour and texture parameters of beef meat as a result of feeding animals with fodder including vitamin D_3 according to the schematic representation in Table 1 (**article I.B.4.**). Since, this vitamin, as a result of the regulation of calcium-phosphorus metabolism in a body, may influence the increase of Ca^{2+} ions concentration, that are indispensable for activation of calpains - enzymes responsible for meat tenderness (Carnagey, 2008).

Table 1 Scheme of supplementation (**article I.B.4.)**.

PARAMETERS	**EXPERIMENTAL GROUP**			
	control	*II*	*III*	*IV*
dose of vitamin d_3 (M IU/daily/animal)	0.0	3.5	7.0	10.0
supplementation time (days)	0	6	3	3
feeding time without supplementation	10	4	7	7
total time of feeding (days)	10	10	10	10

Material for the study consisted of *m. Rectus Femoris, m. Gluteus Medius,* and *m. Adductor Femoris* obtained from cross-breeds of Holstein-Fresian and Limousin. The research focused on the selection of a dose of a vitamin D_3 powdered mixture together with the fodder and time of administration to obtain the best possible quality parameters of beef meat that decide on its tenderness. Therefore, instrumental measurement of the meat colour parameters was carried out in the L*a*b* system and share force with INSTRON 5965 test machine with the use of Warner-Bratzler blade. Statistical analysis of the obtained results was carried out with a one - way analysis of variance and the lowest significant differences were determined with Tukey's test at the level of significance of α=0.05.

The obtained results show that doses of vitamin D_3 in the amount of 3.5 and 10 M IU significantly (*P≤0.05*) improved tenderness of beef meat and thus shortened the time of its ageing which directly may result in limitation of costs related to storage of meat raw material by entrepreneurs. Also other authors observed the increase of tenderness in case of meat obtained from animals which were given vitamin D_3 few days before slaughtering (Gonzales et al., 2010; Hansen et al., 2012). However, in own research it was proved that supplementation with vitamin D_3 may be related to deterioration of colour parameters which as a result may have a considerable impact on consumer's purchase decisions. The observed results are contrary to the results achieved in the paper by Lawrence et al., (2006). Since, the author showed that meat supplementation with vitamin D_3 has no significant impact on the intensity of red colour in the investigated meat. On the other hand Hansen et al., (2012) reported a considerable increase of the parameter value a* as a result of administering vitamin D_3 to animals. Therefore, selection of the meat packing system that combined with a relevant ageing time will improve tenderness and desired parameters of colour of meat from animals that were given vitamin D_3 is significant. This aspect of the paper will be discussed in the detailed objective no.2.3.3.2. (Impact of packaging and storing systems on the quality of finished products).

Due to the increasing customers' expectations, meat products with specific pro-health properties are more and more popular. A customer can pay a higher price for the functional product but he expects a high and repeatable quality and a relevantly long shelf life. Expectations related to textural and sensory properties of products - its colour, taste, or aroma are very significant. As long as the literature knows the research on the impact of single selectively acting components on the quality of meat products (Hayes et al., 2011; Kim et al., 2013; Fan et al., 2014), the research that determines the impact of the group of bioactive components with strengthening, supporting and protective activity on the human body (catuaba, galangal, roseroot, maca and polyfloral honey) on the quality determinants of meat products (**article I.B.1.**) and their shelf life (**article I.B.2.**) constitutes a considerable contribution to the field of food sciences.

The material for the study in both papers (**article: I.B.1.**;**I.B.2.**) consisted of medium minced pork and beef products, the composition of which was presented in Table 2.

Table 2 Composition of the analysed variants of sausages.

	COMPOSITION	EXPERIMENTAL GROUP			
		C	*E1*	*E2*	*E3*
CURED MEAT MATERIAL AND FAT (∑100 %)	pork class I (ham)	42.850	42.850	42.850	42.850
	pork class I (paddle)	12.790	12.790	12.790	12.790
	pork class II (porkneck)	18.410	18.410	18.410	18.410
	pork fat (back fat)	11.650	11.650	11.650	11.650
	beef class II (lard)	14.300	14.300	14.300	14.300
OTHER (%)[2]	(mixture of seasonings; black pepper, marjoram, garlic, lovage, allspice)	0.683	0.683	0.683	0.683
	ice (C) or decoction from catuaba (A, B, C)	20.000	20.000	20.000	20.000
BIOACTIVE COMPONENTS (%)[2]	catuaba cut bark	-	0.867	1.301	1.734
	galangal minced root	-	0.011	0.017	0.022
	minced roseroot	-	0.229	0.344	0.458
	maca root extract (4:1)	-	0.307	0.461	0.614
	minced guarana	-	0.300	0.450	0.600
	polyfloral honey	-	0.573	0.860	1.146

[1]C – control group; E_1, E_2, E_3 – groups with added bioactive components (E2=1.5 x E1, E3=2 x E1);
[2]amount in relation to meat raw material and fat (100%);

All analysed variants were produced according to the technological scheme indicated in Figure 1.

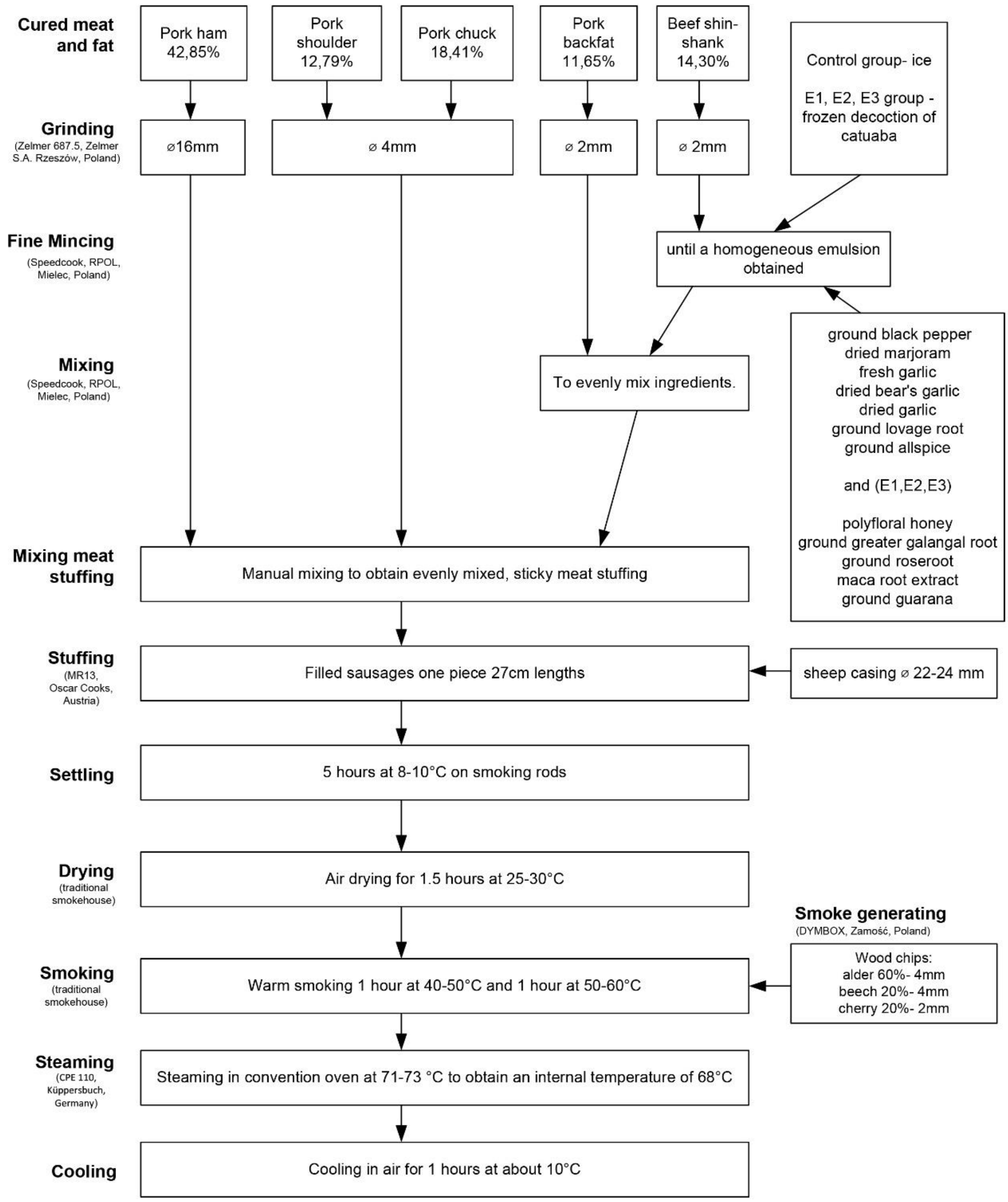


Figure 1. Technological scheme of medium minced pork-beef products. (**article I.B.2.)**.

Meat products made in the own research (**article I.B.1.**; **article I.B.2.**) intend to be an innovative approach in elimination of negative symptoms of degenerative diseases related to ageing through the use of natural elements in food and herbs with confirmed pro-health and stimulation properties. Reasons of diseases, such as cancer, cardiovascular disease, atherosclerosis, and diabetes include oxidization damage caused with particles, which include one or more uncoupled electrons. However, free radicals may be related or neutralized by natural antioxidants that occur in medical plants, fruit, or vegetables (Mouhoubi-Tafinine et al., 2016). Catuaba, galangal, roseroot, maca root, guarana or honey. It is proved that these products show antioxidant, antibacterial, anti-inflammatory or antidepressant properties mainly due to high amounts of phenolic compounds, which were more extensively described in literature (Viana et al., 2011; Lonni et al., 2012; Tang et al., 2017).

Firstly, (**article I.B.1.**) the impact of bioactive components on the pH value, colour parameters, texture, consumer's acceptance, and selected chemical parameters (the total content of phenols, total antioxidant ability, and anti-inflammatory ability) of meat stuffings and finished products were described. Statistical analysis of the obtained results was carried out with a one-way analysis of variance. The lowest significant differences were determined with Tukey's test at the level of significance. Medium fragmented pork and beef products from E1, E2, and E3 group had not only pH values and textural properties comparable with control samples, but also good sensory properties and higher antioxidant and anti-inflammatory properties (that grow along with the amount of added bioactive components). Nonetheless, added components statistically significantly influenced ($P<0.05$) the lightness and participation of yellow colour of the analysed meat products. The reduction of L* parameter value of finished products along with the increase of addition of bioactive elements was reported. Products from experimental groups (E1, E2, E3) were also more yellow and had a higher degree of colour intensity (C) with reference to the control.

Based on the obtained results (**article I.B.1.)** it was assumed that the same set of components (Table 2; Figure 1) with antioxidant and anti-bacterial properties may also improve the quality of stored meat products (**article I.B.2.**). As a result, each of the variants of medium fragmented pork and beef products (C, E1, E2, E3) was tested with regard to the total phenolic content, total antioxidant ability, anti-inflammatory ability, substances reacting with tiobarbiturate acid, fatty acids profile and the total number of mesophilic aerobic bacteria on the day of packing, on the 10th and 20th day from packing. Statistical analysis of the obtained results was carried out with two-way analysis of variance, while the smallest significant differences were determined with Tukey's test at the level of significance $\alpha=0.05$.

According to Vaquero et al., (2010) phenols included in products show antioxidant and antibacterial activity. In the own research it was observed that the used components slowed down the oxidation changes and limited the growth of the total number of bacteria in comparison to the control group. Group E1, E2 and E3 had also a higher anti-inflammatory activity (Table 3). In order to limit the oxidation process of pork-beef sausages and its negative impact on their nutritive value, it is recommended to use a recipe including 17.3 g/kg of catuaba bark, 0.22 g/kg of the minced galangal root, 4.58 g/kg of minced roseroot, 6.14 g/kg maca root extract, 6.00 g/kg of minced guarana and 11.46 g/kg of polyfloral honey.

Table 3. Selected quality characteristics of the analyzed sausage variants (**article I.B.2.**).

PARAMETRS	GROUP[1]	STORAGE TIME (DAYS) 0	10	20
TBARS [mg/kg]	C	1.09^{aA2}±0.05	4.53^{bD}±0.19	6.85^{cD}±0.21
	E1	0.99^{aA}±0.04	3.99^{bC}±0.21	6.12^{cC}±0.18
	E2	0.83^{aA}±0.05	3.49^{bB}±0.15	5.68^{cB}±0.10
	E3	0.73^{aA}±0.07	3.06^{bA}±0.03	5.02^{cA}±0.02
Total number of microorganisms [log]	C	2.48^{aA**}±0.02	3.15^{bC}±0.03	3.46^{cB}±0.02
	E1	2.49^{aA}±0.04	2.72^{bB}±0.02	2.86^{cA}±0.02
	E2	2.48^{aA}±0.04	2.69^{bAB}±0.01	2.83^{cA}±0.02
	E3	2.47^{aA}±0.01	2.62^{bA}±0.01	2.81^{cA}±0.01
Antioxidant activity [% of hyaluronidase inhibition]	C	0.09^{aA**}±0.02	0.09^{aA}±0.01	0.08^{aA}±0.01
	E1	0.77^{aB}±0.15	0.68^{aB}±0.04	0.66^{aB}±0.08
	E2	0.99^{bB}±0.14	0.78^{abB}±0.06	0.75^{aBC}±0.02
	E3	1.30^{bC}±0.13	1.01^{aC}±0.03	0.95^{aC}±0.02

[1]C – control group; E1, E2, E3 – groups where bioactive components were added (E2=1.5 x E1, E3=2 x E1);

[2]a,b,c – the average values that were marked with lowercase letters in the lines differ significantly at *P ≤0.05*; A,B,C,D – the average values that were marked with capital letters in the columns, differ statistically significantly at *P ≤0,05*;

Despite meat products are enriched with bioactive substances, they me be perceived still as products with a high caloric value, high content of animal fat and high participation of sodium chloride and phosphorus added in the technological processes. To recognize this type of products as a favourable alternative for typical products, together with the team I developed a manner of production of fragmented pork meat products with a raised nutritive value, reduced fat and salt content, which do not contain polyposphorates and at the same time meet the expectations related to their quality, consumer's acceptance and the shelf life (**patent I.B.7)**.

So far, the highest number of papers has concerned replacement of animal fat with substitutes in this type of products (Muguerza et al., 2003; Jiménez- Colmenero et al., 2010). The developed technology of production of fragmented meat products (**patent I.B.7.**) enables a significant reduction of the fat content level which still enables obtaining a desired consumer's acceptance. Based on numerous own research, recipes with no fat, fat and skin emulsion or substances that rise the product efficiency were prepared. These components were replaced with pork collagen and extract from red sea algae, while a part of pickling salt was replaced with a natural extract with seasonings (basil, coriander, rosemary, oregano, bay leaf, thyme, juniper, and garlic, single or mixed, possibly with addition of black pepper and red pepper). An exemplary composition of poultry sausages finely, medium and coarsely minced were presented in Table 4.

Table 4 Composition of exemplary variants of sausages with a increased nutritive value, reduced fat, and salt content, which do not contain polyphosphates (**patent I.B.7.**).

COMPONENTS		*A**	*B***	*C****
CURED MEAT MATERIAL	miced meats with water holding capacity (WHC) 4-5%, lightness of colour (L*) 43-56 (colour component measured in the system L*a*b*), pH 5,6, 3% of intramuscular fat content, at the selenium content in the amount of 40μg Se/100g of meat and the relation of fatty acids omega 6 to omega 3 within 4:1	100%	100%	100%
OTHER	water/ice	7%	6%	5%
	curring salt	1.5%	1.5%	1.4%
	collagen protein	0.5%	0.9%	1.2%
	modified starch	1.5%	0.9%	0.6%
	powdered sea algae	1.2%	0.8%	1.2%
	basil extract	0.03%	0.07%	0.06%
	coriander extract	0.03%	0.07%	0.06%
	rosemary extract	0.03%	0.07%	0.06%
	oregano extract	0.03%	0.07%	0.06%
	bay leaf extract	0.03%	0.07%	0.06%
	thyme extract	0.03%	0.07%	0.06%
	juniper extract	0.03%	0.07%	0.06%
	garlic extract	0.03%	0.07%	0.06%
	black pepper extract	0.03%	0.07%	0.06%
	red pepper extract	0.03%	0.07%	0.06%

*A- thin minced sausages (full participation of minced fraction with particles dimensions of 0.01≤ Ø ≤2.00mm);
**B – medium minced sausages (full participation of minced fraction with particles dimensions of 5≤ Ø ≤20mm);
***C – roughly minced sausages (full participation of minced fraction with the dimension of particles of 25≤ Ø ≤45mm);

To conclude the discussed publication and patent (**I.B.4.; I.B.1.; I.B.2.; I.B.7.**) that constitute the first part of the scientific achievement, one may state that the composition of meat and meat products significantly influences the quality of the finished products**.** Therefore, there is an option to modify the meat and meat products composition to make products with a high, repeatable quality that include bioactive components, including also products with the limited fat content and limited caloric value.

Summarizing the results presented in the publication and the patent **(I.B.4; I.B.1; I.B.2; I.B.7.)** provide the first part of the scientific achievement, it can be concluded that the composition of meat and the composition of meat products significantly affect the quality of finished products. There was carried out an activity to adapt meat and meat products to the needs of consumers who expect functional products. The primary objective was the need of creating meat products which cover a deficit of complete protein, vitamins, minerals and bioactive substances. Particular, it was important to prepared with raw materials produced products of high nutritional value, pro-health, low-fat, calorie-reduced additives.

2.3.3.2. The effect of packaging and storing systems on the quality of finished products

An appropriate choice of packaging system influences the quality of meat and meat products to no lesser extent as the composition of raw material or finished product. Therefore, in the discussed scientific achievement I have focused on the determination of a differentiated means of storage for red meat and meat products, taking into consideration the following: packaging method (**article I.B.5.; I.B.6.; I.B.4.**), (gaseous) atmsphere space to packaged product volume ratio (**article I.B.3.**), type of used packaging material (**article I.B.8.**).

Based on those, I have decided to define the effect of a packaging method on the quality of red meat stored under cooling conditions (**article I.B.5.**). The study material was beef (*m. Longissimus Lumborum*), originated from the Holstein-Friesian (HF) and Limousine cross-breeds, packed using either a modified atmosphere (MAP: 80% O_2, 20% CO_2), vacuum skin package (VSP), or a technology constituting the combination of both the aforementioned methods with an additional internal use of foil partially permeable towards oxygen (VSP-MAP). The samples were next stored at 2°C for 12 days. On the day of packaging, on the 4th, 8th, and 12th days of storing the following were determined: colour parameters, the percentage of heme pigments, the content of substances reacting with tiobarbiturate acid, storage and thermal (leakages) drip loss, texture, and the content of general number of microorganisms in the stored roast beef. A statistical analysis of results was made using variance analysis. The smallest significant differences were determined based on Tukey's test, assuming significance level as α=0.05. In turn, correlation coefficients between variables were found using Pearson's correlation procedure.

Packaging technologies used with **article I.B.5.** significantly affected the majority of the tested parameters, and the greatest diversity has been observed in the case of meet colour parameters, and as to the degree of intramuscular fat oxidation, which was directly connected to a different oxygen content in the atmosphere surrounding the product. Meat stored in MAP and VSP-MAP featured statistically significantly ($P<0.01$) higher values of L* parameter not only in relation to initial values, but also to this parameter values measured in meat stored in VSP. The influence of the discussed system on the remaining colour parameters has also been found (Table 5).

Table 5. Colour parameters (mean ± SEM) of *m. Longissimus Lumborum* muscles (**article I.B.5.)**.

Para-meter	Packaging method	Storage period (days) D0	D4	D8	D12
L* [-]	VSP	37.8 ± 0.31	38.1 ± 0.45[B1]	37.6 ± 0.43[B]	36.2 ± 0.75[B]
	MAP	37.8 ± 0.31[b]	41.0 ± 0.49[aA]	41.2 ± 0.46[aA]	41.2 ± 0.59[aA]
	VSP-MAP	37.8 ± 0.31[b]	40.8 ± 0.45[aA]	41.1 ± 0.48[aA]	40.6 ± 0.55[aA]
a* [-]	VSP	19.3 ± 0.55[a]	17.2 ± 0.21[bB]	16.3 ± 0.31[bB]	17.6 ± 0.38[abB]
	MAP	19.3 ± 0.55[b]	22.8 ± 0.36[aA]	20.5 ± 0.29[bA]	20.5 ± 0.42[bA]
	VSP-MAP	19.3 ± 0.55[b]	22.2 ± 0.51[aA]	20.3 ± 0.41[abA]	20.1 ± 0.49[bA]
b* [-]	VSP	7.3 ± 0.34[a]	3.4 ± 0.19[bB]	2.8 ± 0.09[bB]	3.6 ± 0.17[bB]
	MAP	7.3 ± 0.34[c]	11.5 ± 0.17[aA]	10.4 ± 0.12[bA]	10.5 ± 0.13[baA]
	VSP-MAP	7.3 ± 0.34[c]	11.4 ± 0.20[aA]	10.5 ± 0.15[baA]	10.4 ± 0.15[bA]

[1] a, b, c – mean values denoted with lower-case letters in lines demonstrate statistically significant differences at *P ≤0.05*; A, B, C, D – mean values denoted with capital letters in columns demonstrate statistically significant differences at *P ≤0.05*.

An observed decrease of a* parameter value in meat stored under modified atmosphere conditions (MAP) was related to the transformation of oxymyglobin into metmyoglobin (Murphy et al., 2013). The highest content of oxymyoglobin and the lowest content of metmyoglobin during storage were represented by vacuum-packed samples (Figure 2).

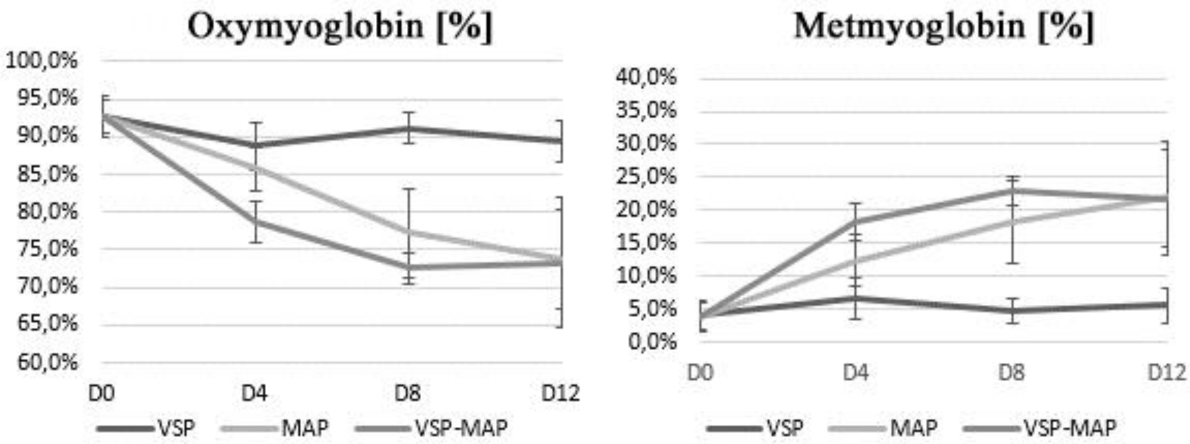


Figure 2. The effect of packaging system on the percentage (mean ± SEM) of oxymyoglobin and metmyoglobin in the stored beef (**article I.B.5.)**.

A high oxygen level in the (gaseous) atmosphere mixture has also made an impact on reaching the highest values of TBARS index in samples stored in MAP (Cruzen et al., 2015). The degree of intramuscular fat oxidation in the case of samples stored both in VSP-MAP and VS systems did not significantly differ throughout the storage period (*P≥0.05*). High values of correlation coefficients both between oxymyoglobin content and TBARS value (R^2=-0.73), and between metmyoglobin content and TBARS value (R^2=0.73) demonstrate that the conversion of oxymyoglobin into metmyoglobin might have been initiated by the action of fat oxidation products (Faustman et al., 2010).

Analysed of colour parameters, the share of heme pigments and the TBARS index values, it can be stated that, from the meat quality point of view, the VSP-MAP is the most beneficial system. This is the technology that has enabled us to reduce the degree of fat oxidation with a simultaneous preservation of an attractive meat colour due to the use of oxygen semi-permeable foil.

Based on findings published in **article I.B.5.** I can conclude that the confinement of exposure to oxygen in the case of red meat packed in the modified atmosphere could possibly exert a positive effect on its qualitative parameters including its shelf life. The study described in **article I.B.6.** was therefore aimed at determining the effect of the modified atmosphere of diverse oxygen concentrations (MAP1: 50% O_2, 20% CO_2, 30% N_2; MAP2: 65% O_2, 20% CO_2, 15% N_2; MAP3: 80% O_2, 20% CO_2) on colour parameters, the percentage share of heme pigments, the content of substances reacting with tiobarbiturate acid, storage and thermal (leakages) drip loss, texture, and the content of general number of muscular microorganisms of high (*m. Longissimus Lumborum*) and average (*m. Gluteus Medius)* colour stability. Furthermore, a percentage content of gaseous mixture was determined during the storage. The analyses were carried out on the day of packaging and on the 4th, 8th, and 12th day of storage. Results were subjected to statistical processing using variance analysis. The lowest significant differences were determined using Tukey's test at the significance level of α=0.05, and correlation coefficients between variables were determined with the use of Pearson's correlation procedure.

Similarly to **article I.B.5**, given the acquired results (**article I.B.6.**), we have observed an increase in L* parameter value regarding both stored muscles. However, a particular type of muscles played a more relevant role in the determination of the lightness and the remaining parameters of the muscular colour (a*,b*) compared to the used oxygen levels (Table 6).

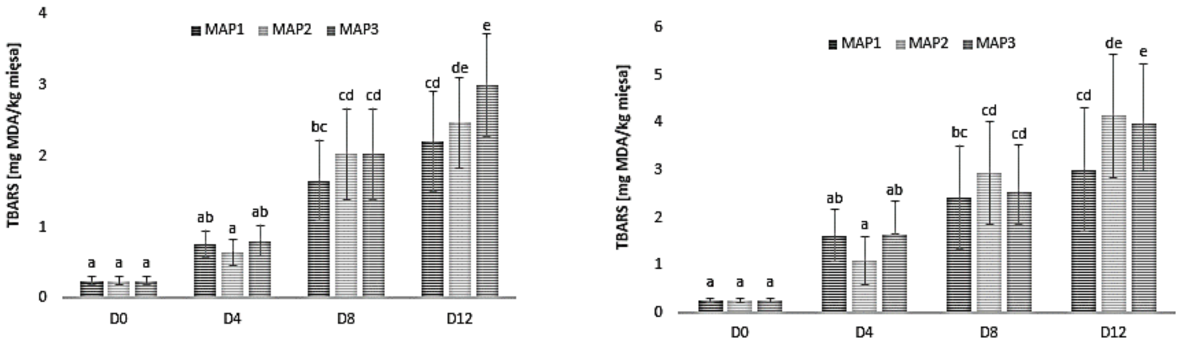
Table 6. Colour parameters (mean ± SEM) of *m. Longissimus Lumborum* and *m. gluteus medius* muscles (**article I.B.6.**).

day	MAP	***m. Longissimus Lumborum***			***m. Gluteus Medius***		
		L*	**a***	**b***	**L***	**a***	**b***
D0	-	37.3±1.4^{a1}	17.8±1.7^{ab}	2.9±1.4^{a}	40.7±1.4^{a}	20.1±1.8^{abcd}	4.4±0.7^{a}
D4	**MAP1**	41.2±1.9^{b}	21.6±2.0^{c}	10.1±0.9^{b}	42.0±1.3^{ab}	25.6±1.0^{e}	12.1±0.7^{c}
	MAP2	40.5±2.0^{b}	21.5±1.8^{c}	9.8±0.8^{b}	41.8±1.2^{ab}	24.6±1.6^{de}	11.9±1.1^{bc}
	MAP3	40.6±1.6^{b}	21.8±1.7^{c}	9.9±0.7^{b}	41.9±1.8^{ab}	24.5±1.9^{de}	11.8±1.2^{bc}
D8	**MAP1**	41.7±2.4^{b}	19.2±2.4^{bc}	9.4±1.2^{b}	42.5±1.2^{abc}	21.0±1.4^{abcde}	10.9±0.6^{bc}
	MAP2	41.9±2.1^{b}	19.4±2.0^{bc}	9.5±0.9^{b}	43.0±1.2^{abc}	21.8±0.9^{bcde}	11.7±0.7^{bc}
	MAP3	41.5±1.4^{b}	19.3±1.8^{bc}	9.3±0.8^{b}	43.4±1.4^{bc}	21.9±1.7^{cde}	11.6±0.4^{bc}
D12	**MAP1**	42.6±2.0^{b}	15.9±1.7^{a}	8.6±0.8^{b}	44.1±1.0^{bc}	16.5±2.0^{a}	10.7±0.9^{b}
	MAP2	42.1±2.1^{b}	16.9±1.4^{ab}	8.7±0.7^{b}	44.4±1.5^{c}	17.0±2.3^{abc}	11.0±0.6^{bc}
	MAP3	42.2±1.5^{b}	17.1±1.4^{ab}	8.9±0.5^{b}	43.7±1.4^{bc}	16.9±2.9^{ab}	11.1±0.9^{bc}

[1] a, b, c – mean values denoted with lower-case letters in columns demonstrate a statistically significant difference at $P \leq 0.05$.

Having analyzed the percentage of heme pigments, a significant increase of metmyoglobin content ($P<0.05$) with concomitant reduction of oxymyoglobin percentage was recorded in both stored muscles irrespective of whether the meat was packed under MAP1, MAP2 or MAP3 atmosphere option.

As it could have been assumed, based on the obtained results presented in **article I.B.5.**, the degree of intramuscular fat oxidation in both the analyzed muscles increase along with storage time period due to oxygen contained in the atmospheres used for the packaging (Figure 3).



m. longissimus lumborum *m. gluteus medius*

Figure 3. The effect of modified atmospheres of various oxygen concentrations on the fat oxidation levels in the studied muscles (**article I.B.5.)**.

In the case of muscles of high colour stability (*m. Longissimus Lumborum*) on the last storage day the increase of TBARS values was least intensive for samples wrapped in MAP1, and the most intensive for samples packed in MAP3. A lower oxygen level in the closest vicinity of the product resulted in the reduction of oxidative processes in that instance, thereby affecting the quality of the finished product. This fact was also confirmed by studies conducted by Zakrys et al. (2008). In turn, in the case of TBARS values for muscles of average colour stability (*m. Gluteus Medius)* no statistically significant differences were observed with respect to the level of fat oxidation dependent on oxygen concentration in the gaseous mixture.

To sum up findings presented in **article I.B.6.,** due to the lack of differences in the colour parameters among samples stored in MAP1, MAP2 and MAP3, and due to a reduced degree of intramuscular fat oxidation on the last day of storage for *m. Longissimus Lumborum*, it is recommended to use an atmosphere composed of 50% O_2, 20% CO_2 and 30% N_2.

Taking into consideration the fact that in shaping the quality of a stored product its content is of importance, study material and methods specified in **article I.B.4.** (described in detail in 2.3.3.1.) also served to determine the effect of a packaging method on the quality of beef meat originated from animals who used to be fed with feed containing D_3 vitamin according to model presented in Table 1. For that reason, the analyzed muscles were packed in two variants of modified atmosphere containing 80% O_2 and 20% CO_2 (MAP1), and 60% O_2 and 40% CO_2 (MAP2), respectively, and also using skin-pack technology (VSP). Samples were then stored under cooling conditions for 14 days.

I have observed that in all the experimental groups both MAP1 and MAP2 atmospheres statistically significantly affected (*P<0.05*) the increase of L* parameter of the stored beef (L*,a*,b*). Yet, muscles stored in VSP technology were characterized by comparable or lower lightness than on the day of packaging regardless of the fact, which group they were derived from. Nevertheless, based on the obtained results, we can conclude that the modified atmosphere of an adequate concentration of gases (MAP1) in connection with an appropriate D_3 vitamin dose (10 M IU) makes an impact on the reduction of L* parameter value in the stored beef. This phenomenon had not been demonstrated earlier in the studies of Montgomery et al., (2002), and Reiling & Johnson (2003). Importantly, in my own studies I have found that only on the 10th day the VSP vacuum packaging technology exerted a statistically significant effect on the obtainment of lower values of a* parameter in all the tested muscles and at all the levels of vitamin D_3 supplementation compared to MAP1 and MAP2.

Having analyzed beef muscles tenderness, I confirmed that all the tested packaging methods exerted a statistically significant effect (*$P<0.05$*) on the improvement of the discussed parameter after 10 and 14 days of storage. Additionally, we have demonstrated that, due to its tenderness it is beneficial to store beef either for 14 days under vacuum-packaged conditions (VSP) or for 10 days in the atmosphere containing 60% O_2 and 40% CO_2, and the meat should originate from animals fed with 10 MU vitamin D_3-containing feed. At higher levels of oxygen in the atmosphere surrounding the packaged beef, a growth in the hardness of beef takes place due to ongoing processes of myofibrillar and enzymatic protein oxidation (Clausen et al., 2009; Lagerstedt et al., 2011).

Summarizing findings presented in **article I.B.4.**, manufacturers who want to guarantee the provision of their consumers with tender beef, besides the use of meat gained from animals fed with an appropriate dose of D_3 vitamin with feed, can make use of VSP or MAP2 technology provided they would indicate a proper meat shelf life.

From literature data it can be seen that to date the effect of gaseous mixture on the quality of meat and its secondary products stored in a modified atmosphere has been determined to the highest extent (Lund et al., 2007; Lukic et al., 2015; results presented in **articles I.B.4., I.B.5.** and **I.B.6.**). However, not only the atmosphere content but also the proportion of gaseous space volume to packaged product volume may influence selected quality determinants and a packaged product shelf life. Yet, the effect is not unambiguous. Moreover, it might have seemed that due to an increase in the degree of package filling with a product, costs related to the purchase of package or its transport would be reduced. Hence, in **experimental paper I.B.3.** I have determined changes in physical, chemical and microbiological parameters of pork meat as a result of using three distinct proportions of gaseous space to packaged product volume. Pork (*m. Longissimus Dorsi)* was packaged in a modified atmosphere containing 80% oxygen and 20% carbon dioxide. The gaseous space volume – product volume ratio inside the used packages (PP/EVOH/PP) was 1:3, 1:1 and 3:1, respectively. On the day of packaging and on the 8th, 10th and 12th day of storage inside packages with stored meat the measurements of gas composition were taken, and the analysis of meat physico-chemical properties (the measurements of pH, colour components and cutting force, storage and thermal (leakages) dripp loss, fatty acid profile) and microbiological analyses of selected groups of microorganisms (*Salmonella*, *E. coli*, *Enterobacteriaceae*, general microorganism count, *Pseudomonas spp*., lactic acid fermentation mesophilic bacteria count, general number of psychrotrophic microorganisms, yeast and mould counts) were made. Mean values of the obtained results were compared using a two-way analysis of variance. On the other hand, Tukey's test served for testing the significance of differences between studied parameters at the significance level α=0.05.

Based on the obtained results, we have found that the excess of meat in packages with modified oxygen-highly enriched atmosphere contributed to a faster growth of microorganisms. It was connected to an insufficient amount of carbon dioxide in relation to the product volume. Carbon dioxide is commonly known to provide meat product microbiological stability as it exerts an inhibitory effect on the growth of the majority of aerobic bacteria and moulds (Bingol & Ergun, 2011). On the other hand, an insufficient product volume in relation to the gaseous space volume in the package led to undesired changes of pork meat colour parameters. Furthermore, I have observed that on the last day of its shelf life meat stored at the highest proportion of gaseous space volume to product volume (3:1) featured a lighter colour and a higher absolute colour difference (ΔE) compared to the remaining samples (Table 7). Undoubtedly, the modifications were related to a stronger effect of free oxygen radicals that provoked a higher degree of heme group oxidation in the meat pigment (Insani et al., 2000).

Table 7. The parameters of pork stored at diverse proportions of gaseous space volumes to packed product volumes (**article I.B.3.)**.

COLOUR PARAME-TERS	STORAGE TIME PERIOD (DAYS)									
	0	**8**			**10**			**12**		
	THE PROPORTION OF GASEOUS SPACE VOLUME TO THE PACKED PRODUCT VOLUME									
	-	**3:1**	**1:1**	**1:3**	**3:1**	**1:1**	**1:3**	**3:1**	**1:1**	**1:3**
L* [-]	52.92^{d}	60.24^{b}	54.95^{c}	53.56^{c}	61.02^{ab}	56.91^{c}	54.03^{c}	62.01^{a}	58.49^{b}	55.85^{c}
a* [-]	8.81^{a}	6.96^{ab}	7.39^{ab}	7.24^{ab}	6.34^{b}	6.53^{b}	6.72^{ab}	5.68^{b}	6.20^{b}	6.52^{b}
b* [-]	6.41^{ab}	6.87^{ab}	6.23^{b}	6.03^{b}	7.07^{ab}	6.32^{b}	5.95^{b}	7.48^{a}	6.88^{ab}	6.97^{ab}
C [-]	10.90^{a}	9.80^{ab}	9.67^{ab}	9.43^{ab}	9.51^{ab}	9.09^{b}	8.98^{b}	9.41^{a}	9.27^{ab}	9.54^{ab}
ΔE [-]	-	7.67^{a}	2.97^{d}	2.17^{d}	7.77^{a}	5.32^{b}	4.61^{b}	8.96^{a}	5.67^{b}	3.77^{c}

[1]a, b, c – mean values denoted with lower-case letters in lines demonstrate a statistically significant difference at *P ≤0.05*.

Samples of the lowest degree of filling the package with the product distinguished themselves by the highest values of cutting force in the case of meat applied to thermal processing. Given that, due to the preservation of the highest possible qualitative parameters of meat after 12 days of storage in the modified high oxygen-enriched atmosphere, it is advisable to use the proportion of gaseous space volume to packaged product volume at the level of 1:1. Findings presented in **paper I.B.3.** can be implemented directly into the manufacture practice as the red meat is most often packed in the atmosphere containing from 75% to 80% O_2 and from 20% up to 25% CO_2 (Resconi et al., 2009). This indicates to a high applicability of the above-mentioned paper in the production practice.

Also, the choice of packaging seems to be a key factor of packaging meat and meat-derived products in the modified gaseous atmosphere. The preferable one should enable manufacturers to limit the effects of external factors and the rate of changes in respective ingredients of the packed product. Packaging materials with reduced permeability towards vapours and gases appear to be a promising solution guaranteeing, a high quality of stored products and the excention of their shelf lives. Bearing in mind the aforementioned, our research team decided it would be necessary to conduct studies regarding the effect of using barrier three-layer foil and the modified atmosphere on the quality of culinary pork meats of enhanced nutritional value (**patent I.B.8.**). An innovation in **patent I.B.8.** consisted in the fact that the packed products were characterized by an improved nutritional value (an elevated content of selenium and polyunsaturated fatty acids, a reduced fat content, a reduced caloric value, a diminished content of salts, the lack of polyphosphates, and limited allergenicity). As a result, due to their limited inhibitory potential, the discussed products were exposed to negative effects of environmental factors to a greater extent. Based on the conducted studies, I have observed that elaborated products of an increased nutritional value and stored in barrier packages, demonstrated lower drip losses. Moreover, although the storage time period affected microorganism counts in the analysed culinary meats, packages made of tri-layer foil (polypropylene/ethylene and vinyl alcohol/polypropylene copolymer) presented a less intensive growth of respective microorganisms. However, an excessive drop in the package permeability might had induced adverse alterations in the colour of meat stored in the modified atmosphere of high oxygen concentration (Marcinkowska-Lesiak et al., 2017). In order to retain desired colour parameters, packages based on tri-layer foil, with inner and outer layer made of polypropylene (PP) and with the central layer made of ethylene and vinyl alcohol copolymer (EVOH) and of oxygen permeability equalling from 0.03696 cm^3/package/24 hours up to 0.00616 cm^3/package/24 hours and of the thickness of EVOH layer within the range of 18-30 μm, were used for the packaging of healthy pork products. Such a solution finds its use in the case of packing products in the atmosphere of gases containing from 20% to 40% CO_2 and from 60% to 80% O_2. The developed raw material content of culinary meats possessing an enhanced nutritional value has been specified in Table 8.

Summarizing the analysed results contained in publications (**I.B.5.; I.B.6.; I.B.4.; I.B.3.**) and a patent (**I.B.8.**), comprising the second part of the presented scientific achievement, it can be stated that also a packaging method (**article I.B.5.; article I.B.6.; article I.B.4.**), the proportion between the gaseous space volume and packed product volume (**article I.B.3.**), and the type of used packaging material (**patent I.B.8.**) play a pivotal role in the shaping of a finished product quality. Therefore, it is necessary to modify the above-mentioned factors in order to launch products of high and repeatable quality that contain bioactive ingredients and feature a reduced content of fat and limited caloric value.

Table 8. An elaborated raw material resource content of the culinary meats, manifested by a boosted nutritional value (**patent I.B.8.)**.

INGREDIENTS		CULINARY MEAT
CURED MEAT RAW MATERIAL	The elements of pork meats of water holding capacity (WHC) 4–5%, colour lightness (L*) 43–56 (colour component measured in the L*a*b* system), pH 5.6, 2.0–3.0% intramuscular fat content, with selenium content of 40 μg Se per 100 g of meat, and with omega-6 to omega-3 fatty acids ratio equalling 4:1.	100%
SUPPLEMENTARY RAW MATERIALS	Water/ice	6%
	Salt	1.4%
	Collagen proteins	0.5%
	Powdered sea algae	0.5%
	Basil extract	0.08%
	Coriander extract	0.08%
	Rosemary extract	0.08%
	Oregano extract	0.08%
	Bay leaf extract	0.08%
	Thyme extract	0.08%

2.3.4. Summary

Presented results fully correspond to the main aim of my accomplishment entitled "A study testing the relationship between meat content and its secondary products, packaging and storing conditions and the quality of finished products".

A series of papers and patents presented in the achievement allowed to broaden the knowledge on factors affecting the quality of meat and meat products, and was characterized by, a high degree of applicability. Among strategic priorities in the meat sector the following deserve our attention: an improvement in the quality of the manufactured products, extention of their shelf life, an increase in competitiveness, widening a range of sold products, and the diminution of production costs at unchanged profitability. Based on the findings of this scientific achievement I can state that it is possible, among other things, by means of the modifications in meat raw material content, reformulations of marketed meat product content (using healthy ingredients, reducing the contents of fat, salt and additives) and using appropriate packaging systems (including the selection of a packaging method adjusted to a particular meat product, the choice of proportion of gaseous space volume to packaged product volume, and the type of used packaging material).

The result of the scientific achievement implies an offer of sample ready-to-use solutions directed to the meat sector, e.g. high quality meats and their secondary products, including more and more popular healthy products packed in adequately selected packaging systems. I assert that the implementation of our findings will allow for the minimization of costs associated with product line returns, and also for consumers' greater satisfaction and higher trust towards products packaged in such, a peculiar way.

2.3.5. References

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3. DESCRIPTION OF OTHER RESEARCH AND SCIENTIFIC ACHIEVEMENTS

In the years 1988-1993, I was a student in the field of agriculture mechanization, Faculty of Agricultural and Forestry Technique, Warsaw University of Life Sciences. I completed this stage of my education with my master's thesis entitled: "Determination of the thickness of a thin layer depending on the speed of the drying air" promoted by Małgorzata Jaros, PhD, Eng.

From February 1994, I worked as an assistant at the Department of the Technique and Technology in Gastronomy Faculty of Human Nutrition and Consumer Sciences.

In 2003, I obtained the title of Doctor of Philosophy in the field of agricultural engineering at the Faculty of Production Engineering. Doctoral thesis entitled: "Analysis of the production process of filled products using a forming device" and promoter was prof. dr hab. Andrzej Neryng. The doctoral thesis was assessed very well and was awarded by both reviewers, as well as the Council of the Faculty gave award with mention for the high application value.

From September 2004 I have been employed as professor assistent at the Faculty of Human Nutrition and Consumer Sciences. At the beginning I worked at the Department of the Technique and Technology in Gastronomy and from January 2010 in the Department of Functional Food and Commodities.

My experience and work contribution have let to take part in 3 projects in cooperation with german company Teka Küppersbusch Großküchentechnik (years 2005-2007). The aim of the projects was to provide guidelines for designing a combi steamer oven to obtain high-quality products, as well as to develop a specialized thermal treatment program for product groups commonly used on the Polish market.

From January 2010 I was an evaluator of the Project at Warsaw University of Life Sciences "**BIOFOOD** – innovative, functional products of animal origin" realised by Scientific and Industrial Consortium established by the Institute of Genetics and Animal Breeding of the Polish Academy of Sciences and scientific and industrial partners in the years 2009-2015.

Project was co-financed by the European Union from the European Regional Development Fund within the Innovative Economy Operational Programme in 1.1 operation "Support for scientific research for building a knowledge-based economy", Sub-operation 1.1.2 "Strategic research and development programs".

In July 2011, I became a head of task 4 of the Project entitled: "Optimization of beef production in Poland, according to the strategy "from fork to farm"" (***ProOptiBeef***) co-financed from the European Regional Development Fund as part of the Innovative Economy Operational Program, as part of the Innovative Economy Operational Program, Priority 1. Research and development of modern technologies, Operation 1.3. The Project was realized at the Division of Food Engineering in Nutrition.

During my work at the Faculty of Human Nutrition and Consumer Sciences, I also took part in the Project entitled: „Bioproducts, innovative technologies to produce pro-healthy bakery products and pasta with reduced caloric value"

From January 2013 until now I am employed as an professor assistent at the Department of Technique and Food Development and where from March 2016 I am a head of Division of Food Research and Development.

Among my scientific interests, the following research topics can be specified (numbering publication in accordance with point II) List of other (not included in the achievement mentioned in point I) published scientific papers and scientific performance indicators) of Appendinx 3:

Thematic group 1. Analysis of beef tenderness development depending on protein degradation degree

Article: II.A.13., II.A.5., II.A.4., II.A.10., II.A.15., II.A.6. - Numbering in accordance with Appendinx 3;

Thematic group 2. Non-invasive (non-destructive) methods to extend the shelf life

Article: II.A.8., II.A.7., II.A.2. - Numbering in accordance with Appendinx 3;

Thematic group 3. The effect of packaging methods on the quality of semi-finished and food products

Article: II.A.18. II.A.11. II.A.13. – Numbering in accordance with Annex 3;

Thematic group 4. Effect of thermal treatment on the structure and texture of food products

Article: II.A.23., II.A.17., II.A.22., II.A.12., II.A.9., II.A.14., II.A.21. - Numbering in accordance with Appendinx 3;

Thematic group 5. The effect of bioactive substances on health-promoting properties of food

Article: II.A.3., II.A.20., II.A.19., II.A.1. – Numbering in accordance with Appendinx 3;

Discussion of the articles in thematic groups

3.1. Thematic group 1. Analysis of beef tenderness development depending on protein degradation degree

The improvement in the quality of raw material from a slaughterhouse which lives up to the requirements of contemporary consumers is among the key purposes of my studies. It is related to growing expectations of consumers and meat processing companies who look for very high quality meat with relevant suitability for processing (Lian et al., 2013; Marino et al., 2015). In relation to the above I have carried out a number of studies in recent years to improve beef tenderness at a simultaneous reduction of its ageing time.

There are many factors which affect beef quality, including genetic features (breed, sex), environmental conditions (age, farming conditions, feeding system) and intracellular biological processes which occur after slaughtering. During the multi-stage process of muscle conversion into meat, different biochemical and structural modifications take place in the muscle tissue, which enable obtaining specific taste and physical and chemical parameters of the meat. With regard to the meat suitability for consumption and processing, the meat tenderness is among its most important quality parameters. The meat tenderness depends on the structure of two basic protein ingredients of muscles - proteins of the intramuscular connective tissue (mainly collagen) and myofibrillar proteins (Chriki et al., 2013; Modzelewska-Kapituła et al, 2015).

Breaking the life metabolism as a result of animal slaughter and exsanguination causes decomposition of the majority of organic substances. Cells, tissues and consequently whole organs are deprived of the supply of oxygen and other metabolically indispensable chemical compounds, while energy transformations are hindered. The directions of enzymatic reactions change from synthesis to decomposition under the influence of tissue enzymes. The process of muscle glycogen decomposition to lactic acid begins. Further transformations and development of the meat characteristics depend on the glycogen level and its decomposition rate in a process called anaerobic glycolysis, which was described on **article II.A.13**. Glycogen content greatly determines the final pH of the meat and affects its characteristics such as hydration properties, tenderness, colour and drip loss. Due to the complexity of transformations which occur in the muscle tissue after slaughtering, my studies focused on determining the kinetics of glycogen transformations, because modifications of the energy compound determine the speed of further post-slaughter changes and affect the meat tenderness.

Ageing is among the most effective methods to improve meat tenderness. Changes in the microstructure of all muscle fibres occur during ageing process. Myofibrils are subject to fragmentation into smaller structural units composed of different numbers of sarcomeres. Scientists believed for many years that ageing mainly depends on the action of proteolytic lysosomal enzymes from a cathepsin group. Nowadays a greater role in meat tenderisation during storage (ripening) is assigned to a proteolytic calpain system, which was described in detail in my **article II.A.5 and II.A.4**. The calpain system, which consists of μ-calpains, m-calpains and their endogenous inhibitor - calpastatin, requires the presence of Ca^{2+} to be activated. Decomposition of macromolecular proteins leads to occurrence in the muscle tissue of polypeptide extracts with lower molecular weight, which are good indicators of post-mortem proteolysis advancement. The results of my work complete the knowledge of myofibrillar protein transformations occurring during the first few post-mortem hours. Together with my team I developed a detailed method for identification and quantitative analysis of muscle proteins profile, i.e. SDS-PAGE gel electrophoresis combined with Western blotting enzyme method.

During ageing myofibrils are subject to fragmentation into smaller structural subunits composed of different number of sarcomeres. Traponin T degradation products observed on electrophoretic gels are regarded as an indicator of proteolytic processes progress. An ingredient with the molecular mass of 30 kDA is the basic polypeptide formed as a result of degradation, which was described in detail in **article II.A.10**. Based on the studies I managed to obtain high correlation between the slice force (WBSF) and activity of desmine, troponine T and proteins with a lower molecular mass, i.e. 45 and 30 kDa. The ripening time, heat processing type and muscle type had a significant impact on the physical, chemical and textural characteristics of beef. The animal genotype was another factor which affected the proteolysis dynamics (**article II.A.15**). Studying the meat from Belgian Blue x Holstein Friesian (BB x HF) and Simental x Holstein-Friesian (SM x HF) genotypes I demonstrated a significantly higher level of MHC, TMP and Tn-I proteins in the case of the BB x HF genotype. The relationship can be attributed to higher protein content in meat from animals revealing a hypertrophic effect. An analysis of muscle proteins during ripening is necessary to understand biological bases for changes in meat tenderness and differences between muscles.

Gradually higher requirements for meat products, including beef, require searching for new, objective and quick methods to improve their tenderness. Supplementation of animal feed with vitamin D_3 turned out to be an effective method, which was described in detail in **article II.A.6**. An addition of vitamin D_3 to animal feed in the last period of kettle fattening, i.e. 7 - 10 days before slaughtering, is a natural and highly effective way to increase activity of calcium ions in the muscle tissue, which leads to an increase in the activity of the aforementioned proteolytic enzymes in the calpain system. Vitamin D_3, contributes to Ca^{2+} increase and accelerates biological processes responsible for proteolysis of myofibrillar proteins. This way it is possible to reduce beef ageing time. The studies helped to improve meat tenderness and reduce its proteolysis time, which in turn improves raw material quality and reduces the costs related to maintaining the cold storage temperature during ageing. The knowledge of factors which affect meat quality as well as practical use of the knowledge during beef production is indispensable for breeders and meat processing specialists.

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3.2. Thematic group 2. Non-invasive methods to extend the shelf life

The life of fruit and vegetables is an important feature affected by a number of factors, including agrotechnical, climate and processing ones. Genetic features such as the species and variety play the primary role. They are followed by climate conditions and horticulture: cultivation method, irrigation, fertilisation, plant protection, using special treatment to extend the crop life and the harvesting period. Consumers' requirements are increasing for quality and shelf life at the highest degree of preserving natural condition of products available on the market. The knowledge of the beneficial impact of fruit and vegetables on the human body makes consumers aware of the need to include them in everyday diet (Oliveira et al., 2012).

Fruit and vegetables are characterised by a high nutritive, pro-health and dietary value at simultaneously low caloric values. They are also a rich source of minerals, vitamins, ascorbic acids, phenolic acids and flavonoids. The compounds deactivate reactive forms of oxygen and free radicals, which has a beneficial impact on the human health. Regular consumption of fruit and vegetables helps to prevent diabetes type 2, arterial hypertension, atherosclerosis, obesity and other diet-dependent diseases as well as a number of cancer types (Nuñez-Mancilla et al., 2013). Fruit and vegetables characterised by a rich and diversified profile of bioactive compounds demonstrate strong anti-inflammation effect and support normal function of the heart and cardiovascular system (Aaby et al., 2012; Mazur et al., 2014).

With regard to seasonality of fruit and vegetables and short expiry date caused by high content of water in their tissues, it is necessary to seek new methods to extend their shelf life. Ozonisation is an innovative food storage method, which applies to berry fruit in particular. I described the method in detail in **article II.A.8.** and **II.A.7.** alongside with a modern packaging system based on modified gas atmosphere (**article II.A.2.**). Three papers were devoted to the methods to extend shelf life of strawberries, raspberries and mushrooms.

Storage losses related to ripening, storage conditions and perishing occur during berry fruit storage. Weight loss during storage of strawberries and raspberries is caused by water loss due to evaporation and a loss of carbon reserve due to respiration. The speed of losing water depends on the pressure gradient between the fruit tissues and its surrounding atmosphere. The use of ozone gas in food industry as a factor which extends the shelf life and has bactericidal action helps to limit the use of standard chemical compounds having a negative impact on the natural environment, and extends the period of consumers' high acceptability of the fruit. Ozone gas acts superficially on the bacterial flora occurring naturally on fruit and affects the chemical composition of the fruit. The results I achieved suggest a relationship between stability of anti-oxidation ingredients and the ozone dose and ozonisation time of strawberries and raspberries. The fruit exposed to ozone gas concentrations from 0.3 to 2.5 ppm had a higher content of soluble solids and statistically significantly higher level of phenolic compounds, and revealed a greater anti-oxidant capacity as compared to non-ozonised fruit. The use of ozone resulted in reduction of weight loss in strawberries and raspberries with no negative impact on their pro-health-promoting quality. Laboratory tests helped to select the right ozonisation conditions depending on the fruit type. In the case of *Honeoye* strawberries ozonisation for 120 minutes and ozone dose of 0.6 mg/l turned out to be the most favourable treatment, while for *Polka* raspberries it was 60 minutes and ozone concentration of 0.9 mg/l. The obtained results may turn out to be useful for optimisation of distribution systems of berry fruit intended for consumption.

Food producers are constantly looking for ways to extend the shelf life of products without interfering in their physical and chemical properties or adding some auxiliary substances. Modified atmosphere packaging (MAP) is the technology which satisfies the criteria perfectly. That is why my next study within the reference study group was to identify the impact of the composition of gas mixtures and type of packaging foil on the quality changes in mushrooms during chilling storage. The use of relevant composition of gases and appropriate permeability of foil can have a positive impact on the quality parameters of mushrooms (colour and firmness), and also helps to extend their shelf life. According to the results I obtained, the most favourable composition of gases is 20% O_2 and 80% N_2, at the foil thickness of 44 μm.

It can be concluded that there are effective methods to extend the shelf life of fruit and vegetables. The protective methods help to limit the weight loss of fruit and vegetables and enable maintaining their high sensory quality. The directions of studies I have described will contribute to the development of the fruit and vegetable industry in Poland and worldwide owing to the reduction in unfavourable changes and weight losses.

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3.3. Thematic group 3. The effect of packaging methods on the quality of semi-finished and food products

Food packaging is among factors which determine the quality of products launched. Nowadays there is a wide array of solutions which ensure high product quality for its microbiological safety, reduction in weight loss and product protection in distribution. In the case of red meat, the packaging should also ensure an attractive colour of the meat. Atmosphere with a high oxygen content, i.e. containing 80% O_2 and 20% CO_2 is used in the meat industry to pack beef with regard to oxymyoglobin formation, which maintains bright red and stable colour on the meat surface (O'Grady, Monahan, Burke and Allen, 2000). On the other hand too high oxygen concentration may have a negative effect on oxidative stability of proteins and lipids (Clausen et al., 2009, Kim et al., 2010, Lagerstedt et al., 2011), which may adversely affect meat quality because products formed during lipid oxidation induce oxidative degradation of myoglobin (Kim et al., 2010).

With regard to the above it was purposeful to carry out analyses concerning evaluation of meat quality characteristics variability depending on selected packaging parameters (**II.A.18., II.A.16., II.A.11.**).

The purpose of my studies was to evaluate physical characteristics and fatty acids profile in ostrich meat obtained from animals whose feed was enriched with n3 fatty acids. The samples were packed with either of two methods - VAC versus SP (skin-pack) or stored for 14 days under cold store conditions (**II.A.18**). No statistically significant differences were observed in SFA content in meat during the whole storage period in the case of both packaging methods. A tendency was observed towards higher MUFA values during meat storage in VAC packaging. A significant decrease in PUFA content after 7 and 14 days of storage was observed in vacuum-packed meat as compared to fresh meat, while no differences in PUFA content were observed for skin-packaging. Summing up it can be concluded that SP method can be successfully used for ostrich meat packaging.

Within the thematic group I also carried out studies in the application area of MAP with the objective to optimise beef packaging process.

Another study (**II.A.16.**) was designed to analyse physical and chemical changes and consumer acceptance of *M. Infraspinatus* and *M. Supraspinatus* muscles during 7 days of meat ageing in vacuum followed by 12 days' storage in MAP. It was demonstrated that the abovementioned packaging conditions contribute to meat colour stability but are insufficient for reducing beef toughness. The packaging method can be used in retail but will not necessarily be applied in catering where meat hardness is far more important than its appearance before heat processing.

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3.4. Thematic group 4. Effect of thermal treatment on the structure and texture of food products

The cycle of 10 scientific publications with thematic covers (G 4.1, G 4.2, G 4.3, G 4.4, G 4.5, G 4.6, G 4.7, G 4.8, G 4.9, G 4.10) regarding the effect of thermal treatment on the structure and texture of food products includes an analysis of the essential factors of heat and mass exchange, which affect the development of physicochemical properties, nutritional value, pro-health-promoting properties, and sensory features of thermally treated meat products containing beef meat, as well as bakery products and vegetables. The action of temperature on food products takes place in defined conditions of thermal treatment. The dynamics of the process of heat exchange intensity depends on, i.a., the initial temperature, time, as well as the planned degree of product processing, and processing method. The level of heat exchange intensity depends on the environment where processing takes place, and on basic ingredients, e.g. on water, protein, carbohydrate and fat content, distribution and location, as well as the method of water binding in cellular and intercellular structures of the products, which constitutes a conglomerate of many components in various quantitative relations, which are characterized by changeable and diversified properties of heat and mass exchange. All actions in terms of thermal treatment of food products are performed in such a manner which improves their expiry date and sensory attractiveness, allows the obtaining of the best possible nutritional value and pro-health-promoting properties, and in order to maximize safety of consumption, not only from the microbiological point of view, but also due to products obtained as a result of the 1st, 2nd, and 3rd stages of the Maillard reaction which are produced under these conditions.

The effect of temperature and environmental conditions in the location where the ageing process of bovine muscles takes place within the scope of the conducted scientific process was evaluated in several areas that are important for the physicochemical properties of processed beef (**II.A.23.**) in order to obtain the lowest possible losses of mass and geometric dimensions in processed muscle, as well as to achieve the lowest possible losses in nutritional and pro-health-promoting properties. Various conditions of selected processing methods were controlled (grilling, frying, roasting at a temperature of 180^{O}C, and roasting with constant temperature difference until achieving a maximum of 180^{O}C) in order to evaluate the effect of these methods on texture parameters. In particular, the analysis included the effect of the aforementioned thermal treatment method on the tenderness, colour components, and high sensory attractiveness (juiciness and taste) of thermally treated muscles (m. *Longossimus Lumborum* (LL); m. *Semimembranosus* (SEM); m. *Semitendinosus* (SET); m. *Psoas Major* (PSM) and m. *Triceps Brachii* (TRI)).

Based on the obtained results and their analysis, it was established that the roasting process with constant difference of temperatures, when a temperature of 71^{O}C was achieved inside of the processed product, provided a less favourable effect on the suitable level of brightness and intensity of the red colour of processed muscles compared to rapid thermal treatment methods conducted at a temperature of 180^{O}C, because the level of myoglobin denaturation under these conditions provided a less favourable effect on the brightness and intensity of colour on a cross-section sample due to the process extantion of the temperature effect. Under the influence of temperature, the completely natural and most durable primary structure of proteins was transformed into a changed spatial layout. There was no excessive destruction of protein structures and without the production of complex conglomerates with the participation of proteins. Intensive heat exchange as a result of conduction (e.g. grilling) at higher temperature ranges caused significantly lower losses of the product's mass by reducing loss of water in processed beef, which directly influences the juiciness and acceptability of processed meat. The dynamic process of protein denaturation, which is in direct contact with heating elements during heat exchange by conduction, results in higher tenderness of meat, as well as higher intensity of red colour in the cross-section sample. Therefore, based on the obtained results, it was determined that rapid heat exchange by conduction results in significantly lower losses during the process, provides increased process efficiency, and allows the achieving of higher acceptability in terms of tenderness and juiciness as well as better colour in the cross-section sample, and attractiveness of the surface-overall colour.

Summarizing the obtained results of the studies regarding the effect of thermal treatment on the structure and texture of the beef, it should be stated that the selection of suitable methods and temperature ranges significantly influences the quality and acceptability of steak tenderness, as well as the level of losses of mass and geometric changes of the muscles during thermal treatment, and the nutritional value of proteins and fatty acids caused by temperature processes. There is a dependence of the level of losses of mass with geometric dimensions corresponding to the thermal treatment method, temperature, and its long lasting. It should be emphasized that the obtained study results allowed an improvement of knowledge about the effect of using various thermal treatment methods on the structure and texture of the beef meat.

The next stage of the study included an analysis of the effect of processing with microwave heating compared to convective heat transfer in reference to the *Gluteus Medius* muscle on selected physical properties of the final product, and process and product effectiveness (G4.2). It was established that duration and temperature play the main roles in obtaining the final quality of processed meat. It was proven that a combination of processing with convective heat transfer and microwave heating significantly shortens the duration of the temperature effect in order to obtain the assumed level of meat processing. However, the use of high intensity microwave heating negatively influences the quality of the final product. After microwave processing with prior roasting, the beef demonstrated a high result in the Warner-Bratzler shear force (WBSF) and texture profile analysis (TPA). During evaluation of consumer preferences, this beef was characterized by low tenderness. It was proven that microwave intensity reduced to 30% during roasting improves tenderness and reduces contraction compared to standard roasting at a temperature of 180^{O}C.

In addition, I was observed that using 30% microwave heating intensity significantly produced an even distribution of the red colour in the cross-section sample (parameter a* is responsible for its intensity) compared to conventional roasting at a high temperature of 180^{O}C. Furthermore, using high temperature within the whole thermal treatment significantly affects the lasting of the temperature effect and causes higher losses of mass, so lower process and product efficiency is achieved and, which is especially important, it significantly lowers the quality of the final product, which is less tender and tougher. Summarizing, the combination of standard convective roasting with low intensity microwave heating may be successfully used in catering due to reduced processing duration and lower energy consumption. Therefore, this study confirmed the high applicability of this combined method of thermal treatment under conditions of manufacturing practice, which is an important aspect of the conducted studies and the obtained results because these processing parameters (loss of mass, duration of the processing, and reduced caloric value consumption) have a significant impact on the economy of the process, and it is desirable not only from the point of view of the manufacturer, but also that of the consumer.

Studies included an analysis of the effect of the dependence between the basic composition, pH and physical properties of selected bovine muscles (**II.A.22.**), and I extended knowledge within the area of interrelations among the studied parameters. I have proven that the properties of the beef meat depend on many factors, i.a., : genotype, age, sex, feeding method, transport conditions, slaughter, ageing, and temperature of the process during the maturation process. These component variables affect beef quality (colour, tenderness, taste, juiciness). Meat pH level, content of connective tissue, and amount of intramuscular fat determine the colour of the meat, its tenderness and toughness, as well as the level of water loss, i.e., they affect product performance. The basic composition of the beef (water, protein, fat and connective tissue content) depends on the type of muscle, its location in the carcass, and its role in the level of muscle work intensity in animals under intravital conditions. Muscles which performed less intensive work under intravital conditions contained more fat and less connective tissue compared to muscles performing larger effort in the motor function. It was confirmed that loss of its own water is significantly negatively correlated with the pH level of the beef. Loss of its own water is moderately correlated with the connective tissue content in the studied bovine muscles. Toughness and tenderness are strongly positively correlated with content of intramuscular fat, i.e. they significantly affect muscle marbling. Colour parameters are most closely dependant on pH level and, to a lesser extent, on the content of connective tissue.

Summarizing this experiment, the conducted instrumental studies determined the effect of dependence among the basic composition, pH, and physical properties of the studied bovine muscles, the composition, as well as the product and process effectiveness by reference to its own water loss. The results obtained in this design of scientific system demonstrate the consistent and consequent integrity of the properties evaluated in the planned experiment related to effect of the studied features of the basic composition, as well as product and process effectiveness in terms of the level of its own water loss in reference to the possible use of these results by the industry, which pays special attention to the effect of intravital factors and basic composition, as well as process effectiveness on the applicability of technology and beef processing. In particular, the conclusions from the conducted studies are important for industrial practice in terms of the technological properties and sensory attractiveness of the muscles depending on the role which they played under intravital conditions, on the connective tissue content, and the level of marbling, as well as red colour attractiveness and intensity.

Components of the muscle colour, such as brightness, stability and intensity of cherry red colour measured in the L*a*b* system in relation to the percentage of oxymyoglobin, were stabilized more rapidly than in the muscle after 21-day ageing during exposure. Furthermore, muscles which were ageing over at least 14 days were characterized by better tenderness (lower level of WBSF), but they did not fall into the range of tenderness acceptable by consumers. Loss of mass during thermal treatment after 7-day ageing was significantly higher, and it increased together with extended ageing. The dependence between the content of oxymyoglobin and components of texture (WBSF) means that the higher the dynamics in the stabilization of a light cherry red colour during exposure outside of vacuum conditions, the better the meat tenderness, and the lower its hardness. Therefore, observing this dependence allows the informing of customers that the more tender the meat is, the faster the meat outside of vacuum packaging during exposure achieves a stable light cherry red colour. These results of the studies may constitute the basis for the system of labelling aged beef meat.

Determining the dependence of the sensory quality of smoked goose meat (półgęsek) in reference to volatile compounds and chemical composition was an important research area within the scope of the effect of thermal treatment on the structure and texture of food products, which included an analysis of the essential factors of heat and mass exchange affecting the development of the physicochemical properties, nutritional value, health-promoting properties, and sensory features of thermally treated meat products (G4.5). Sensory analysis demonstrated that traditional smoked goose meat (półgęsek) was characterized by a high diversity of volatile compounds, chemical composition and specific sensory profile, taste, flavour, and texture. This diversity was caused by the effect of the production technologies used by various manufacturers. Summarizing, it should be stated that there is high diversity in the physicochemical, sensory and textural properties of the smoked goose meat (półgęsek) produced by manufacturers, which is determined by the applied manufacturing technologies. In order to unify and standardize sensory quality and physicochemical properties, as well as textures, differences in the manufacturing technologies of smoked goose meat (półgęsek) should be overcome in order to unify quality, accompanied by nutritional and sensory value.

The analysis of the dependence of the fat content in selected cheeses on components of texture and colour, which were evaluated with instrumental research methods, as well as on selected attributes of quality, colour and taste, which were evaluated with sensory studies, constituted an important research aspect within the area of the effect of the textural features on achieving high consumer acceptability of physicochemical properties, nutritional value, pro-health-promoting properties, and sensory features (G4.6). In the conducted experiment I analyzed the effect of fat content on changes in components of the cheese colour, including the brightness and intensity of yellow colour. The analyses also included the effect of used substitutes of the milk fat in the form of vegetable oils (canola oil) on the colour and texture of cheeses The results of instrumental and sensory evaluations demonstrated that low-fat cheeses were characterized by higher hardness, adhesiveness, cohesiveness and elasticity, but cheeses containing rapeseed oil were comparable with the majority of full-fat cheeses in terms of texture properties. Strong correlations occurred in reference to results regarding the hardness and elasticity of cheeses based on instrumental and sensory evaluations. The obtained results indicate that instrumental analysis of the cheese texture, including texture profile analysis (TPA) and results of the cut and penetration tests, may be potentially used for the determination of the sensory properties of the cheese.

It can be concluded that increased fat content may result in higher meltability of the cheese, but cheese meltability may be lowered in the case of increased content of water and salt. Moreover, cheeses with reduced fat content demonstrate higher meltability during microwave heating than during convection of heating. In order to summarize, it should be stated that the obtained results may be used in the manufacture of convenience foods, i.a., frozen low-calorie pizza, by using low-fat cheeses, i.e. with low calorific value. This aspect of reducing the calorific value of manufactured food is an important and useful factor in the current search for technological solutions in manufacturing food with reduced calorific value, and it falls into the global trend of reducing the calorie density of manufactured products.

Research in the area of influence of the effect of thermal treatment on the structure and texture of food products, including the analysis of essential factors of heat and mass exchange, which affects the forming of physicochemical properties, nutritional value, pro-health-promoting properties, and sensory features of thermally treated beef meat products, included the analysis of the effects of frying and grilling processes on the dynamics of changes in colour depending on the achieved final temperature in the processed product **(II.A.21.)**. I found that the thermal treatment leading to denaturation of myoglobin, which starts at a temperature of 55°C, is most intensive at temperatures of 75-80°C. It is important that during thermal treatment of the beef meat, all three forms of myoglobin undergo transformation and degradation, which influence the change of the meat colour. The selection of a suitable method of meat processing is very important in determining the final quality of the product. It was established that the largest differences in the brightness and intensity of red colour occurred in two evaluated types of thermal treatment, i.e. frying and grilling conducted until achieving an internal temperature of 65°C during frying – for average degree processing, and achieving an internal temperature of 60°C during grilling – for low-degree preservation. The lowest differences between the evaluated components of colour were observed in a cross-section sample of thermally treated muscles to an internal temperature of 70°C and 75°C, and it is important that in this case the lowest qualitative difference of processed muscles was identified due to the elimination of differences in terms of the brightness and intensity of red colour in the cross-section sample.

The obtained results within the scope of the effect of thermal treatment on the structure and texture of food products, including the analysis of essential factors of heat and mass exchange, which affect the development of physicochemical properties, nutritional value, pro-health-promoting properties, and sensory features of thermally treated meat products and bakery products as well as vegetables demonstrated high application value, which may be analyzed in a few aspects. The first aspect includes using a suitable processing method and adequate ranges of temperature for correctly designed and performed processes of temperature effect which do not lower its nutritional value, pro-health-promoting properties, or sensory features. The second aspect includes the significantly reduced formation of unfavourable chemical compounds produced in the extended action of excessively high temperatures, which leads to obtaining the 3rd and 4th stages of the Maillard reaction, including local overheating, and intensive browning leading to the occurrence of polycyclic aromatic hydrocarbons (WWA) and heterocyclic aromatic amines (HAA), which strongly reduces the nutritional value and pro-health-promoting properties of such thermally treated products.

These achievements clearly increased the scientific value and application usability of conducted analysis within the area of the applied studies. The results of these studies are original, and they constitute an important contribution to science in the discipline of food and nutrition engineering. Considering the fact of the high innovation of the conducted studies and the obtained results, as well as the high potential of their application in business practice, they are especially valuable nowadays.

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3.5. Thematic group 5. The effect of bioactive substances on pro-health-promoting properties of food

Nutrition value of food products highly depends on the profile of fatty acids. An addition of plant oils to animal feed and directly to products can become an effective method to modify the profile of fatty acids (McNeill and Van Elswyk, 2012).

Plant oils do not contain cholesterol and have a higher UFA/ SFA ratio (Selani, Shirado, Margiotta, Saldaña et al., 2016) than animal fats. Rapeseed oil is characterised by high content of PUFA (28.14%) and low SFA level (7.37%) as compared to other plant oils (USDA, 2016). PUFA demonstrate a number of pro-health-promoting benefits in preventing e.g. cardiovascular diseases and are indispensable for proper structure of cellular membranes. Moreover, they reduce cholesterol level in the blood, strengthen the immune system and improve neural system functions (Siriwardhana, Kalupahana and Moustaid-Moussa, 2012).

Choosing the right doses of oils added to animal feed and directly to meat products is important mainly due to the need to improve the profile of fatty acids, but also with regard to the need for product acceptance by consumers.

In the recent years in Poland and worldwide there is observed an increase in the demand for products completely or partly free of ingredients which have a negative impact on the human body. β-glucan, which is a polysaccharide built of β-D-glucose particles, tends to be used as a fat substitute e.g. in meat products or other foodstuffs, including bakery or confectionery products. The purpose of my study (**II.A.3**) was to replace tallow added to beef burgers with a mixture or rapeseed oil and 30% concentrate of β-glucan, which resulted in development of beef burgers with reduced fat content. Based on the obtained results it was concluded that replacing tallow with oil and β-glucan helps to reduce cholesterol level and increase WHC value in the products. Tallow substituted with rapeseed oil and β-glucan does not affect the majority of texture parameters, while changing the profile of the product volatile compounds. It was demonstrated that low-fat beef burgers with an addition of oil and β-glucan are acceptable by consumers. Summing up it can be concluded that replacing tallow with rapeseed oil and β-glucan concentrate in burgers with reduced fat content has a positive effect on the nutritive value at simultaneous maintenance of texture parameters and consumer acceptability as compared to standard beef burgers.

In my studies (**II.A.20**) I made an attempt to reformulate the profile of ostrich meat fatty acids through animal feed supplementation with linseed and rapeseed oil. Breast fat (BF) and leg fat (LF) were analysed in the study for the composition of fatty acids. A higher content of n-6 fatty acids and PUFA and a lower content of n-3 were discovered for BF as compared to LF. In both cases a favourable PUFA/SFA ratio was observed at a fairly unfavourable n-6/n-3 ratio. A much higher PUFA/SFA ratio was observed in BF than in LF (0.69 and 0.55, respectively). Summing up it can be concluded that an addition of linseed oil to ostrich feed improves the nutritive value of fat by increasing the n-3 FA content, the total PUFA content.

Lipids oxidation is an important problem during food storage. Fat oxidation products appear already on the stage of semi-finished foodstuffs production, and then during their processing and storage. Secondary lipids oxidation products are particularly unfavourable and include e.g. low-molecular aldehydes and ketones which have a negative influence on human health and cause adverse sensory changes in food (Estevez and Cava, 2004) consumers perception and the changes as rancidity (Campo et al., 2006).

An addition of synthetic anti-oxidants such as butylhydroxyanisole (BHA) or butylhydroxytoluene (BHT) makes an effective way to reduce oxidative processes in food. However, due to their potential negative impact on human health, there is a search for natural sources of compounds with antioxidative character such as herbs or spices (Sampaio et al., 2012). That is why my studies (**II.A.19)** focused on an analysis of the effect that an addition of natural antioxidants has on sweet bakery products containing fats to extend their shelf life and improve consumer acceptance. The study compared antioxidative action of herbs extracts (thyme and rosemary) and a synthetic antioxidant on oxidative stability of the fat extracted from the cakes. The antioxidation properties were evaluated by means of differential scanning calorimetry (DSC). It was demonstrated that an addition of natural herbs extracts from to cakes as compared to cakes with no food additives reduced the oxidation degree, which is evidenced by, a higher initial oxidation point of samples which contained the antioxidant.

The antioxidant properties of natural green tea, black currant fruits and nettle extracts were also analysed (**II.A.1**) in cakes with oat flakes. The extracts used in the studies affected the oxidation rate of fats in the cakes after baking and during 3-month storage period. An addition of 1% green tea extract was the most effective inhibitor of lipids oxidation, while the most unfavourable changes were observed for sweet bakery products with a 0.5% addition of nettle extract. It was also observed that the applied herbs' extracts did not significantly deteriorate sensory values of the products. Sweet bakery products with 1% addition of green tea extract and sweet bakery products with the highest content of black currant fruit extract (1.5%) demonstrated the highest acceptability for sensory acceptance.

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4. Summary of the scientific and research work

Publication	Number of publications		Number of points according to Ministry*	Sum of points according to Ministry**	Impact Factor rom year	5-year Impact Factor
	Before Ph.D.	After Ph.D.				
A. Scientific publications in magazines in the journals in Journal Citation Reports (JRC)						
Animal Science Papers and Reports (2012)[1]	-	1	25	25	0,918	0,845
Animal Science Papers and Reports (2013)	-	1	25	25	0,814	0,845
Animal Science Papers and Reports (2014)	-	1	25	25	0,718	0,845
Bulletin of the Veterinary Institute in Pulawy (2012)	-	2	20	40	0,377	0,547
Bulletin of the Veterinary Institute in Pulawy (2015)	-	1	20	20	0,468	0,547
CYTA - Journal of Food	-	3	20	60	1,371	1,320
Food Science and Technology	-	1	20	20	1,084	1,268
International Journal of Food Science and Technology (2015)	-	2	25	50	1,504	2,173
International Journal of Food Science and Technology (2017)	-	1	25	25	2,383	2,173
Irish Journal of Agricultural and Food Research	-	1	30	30	0,706	0,973
Journal of Food Processing and Preservation	-	3	20	60	1,510	1,494
Journal of Food Process Engineering	-	1	20	20	1,955	1,545
Journal of Thermal Analysis and Calorimetry (2014)	-	1	25	25	2,042	1,917
Journal of Thermal Analysis and Calorimetry (2018)	-	1	25	25	2,209	1,917
Journal of Veterinary Research	-	2	20	40	0,811	0,973
LWT – Food Science and Technology	-	1	40	40	3,129	3,455
Meat Science (2016)	-	2	40	80	3,126	3,550
Meat Science (2017)	-	2	40	80	2,821	3,550
Polish Journal of Food and Nutrition Sciences	-	1	15	15	1,697	1,760
Turkish Journal of Veterinary and Animal Sciences	-	1	20	20	0,449	0,587
B. Scientific monograph						
Rozdziały w monografiach naukowych w języku polskim	-	1	5	5	-	-
Rozdziały w monografiach naukowych uznanych za dzieło wybitne w języku polskim	-	1	10	10	-	-
Chapter in scientific monography in English	-	3	5	15	-	-

C. Scientific publications in journals listed in part B of the list of scientific journals						
Inżynieria Rolnicza/Agriculture Engineering (2003)	-	6	5	30	-	-
Inżynieria Rolnicza /Agriculture Engineering (2013)	-	3	5	15	-	-
Polish Journal of Food and Nutrition Sciences	-	1	9	9	-	-
Postępy Techniki Przetwórstwa Spożywczego/ Advances in Food Processing Techniques	-	1	6	6	-	-
D. Scientific communicats						
At international conferences	-	23	-	-	-	-
At national conferences	-	17	-	-	-	-
E. Collective studies, catalogs of collections, documentation of research works, expert opinions, works and artistic works, and others						
International and national patents	-	6	30	180	-	-
Utility models and Industrial designs	-	3	10	30	-	-
Patent applications	-	10	-	-	-	-
F. Popular science publications						
Cheef Advisor	-	11	-	-	-	-
SUMMARY				**Sum of points according to Ministry**	**Impact Factor from year**	**5-year Impact Factor**
SUM OF PUBLICATIONS	**40**		**SUM OF POINTS**	**1025**	**44,493**	**48,705**

1 – in the case of two or more publications from different years, the year of publication is given in the same journal

* -The number of points according to the scoring list of journals Communications by the Minister of Science and Higher Education on the list of journals by year of publication or the latest available list of 26.01.2017. In the case of a monograph: Regulation of the Minister of Science and Higher Education of December 12,2016 on the awarding of a scientific category to scientific units and universities in which, according to their statutes, basic organizational units have not been separated -Annex 7

** -The sum of points according to the list of magazines scored by the Ministry of Science and Higher Education multiplied by the appropriate number of publications

- I am the author of **29 scientific publications** in journals indexed by the Journal Citation Report published in 2012-2018.
- The number of publications cited according to the **Web of Science database is: 118**, according to **Scopus 128.**
- Hirsch Index according to **Web of Science: 6**; according to **Scopus: 7**
- **The sum of points according to the lists of the Ministry of Science and Higher Education is 1025.**
- **The total Impact Factor of all publications is 44.493.**

Półtorak Andrzej