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Original article

The effect of supplementing organic diets with fish meal and premix on the performance of pigs and some meat and blood characteristics

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Abstract

The aim of this study was to determine the effect of fish meal and mineral-vitamin premix, supplementing organic diets, on the performance of pigs and some meat and blood characteristics. The experiment was conducted on an organic pig fattening farm. The study involved 120 pigs with an approximate 25 kg body weight. Animals were divided into 3 groups, kept in pens, 10 animals each. Group I (control) animals were fed with plant feedstuffs of organic origin. Diets for group II and III were enriched with fish meal or fish meal and vitamin-mineral premix, respectively. The experiment was carried out till pigs reached a weight of 115 kg. Feed samples were subjected to laboratory analyses. Body weight (3 times) and feed intake were recorded. Blood samples were collected (2 times) to determine hematological and biochemical indices. Some parameters in meat samples were also determined. The fish meal addition improved ($P \leq 0.05$) the average daily gains as well as feed conversion ratio during fattening period and mineral-vitamin premix significantly ($P \leq 0.05$) fortified fish meal influence. Fish meal supplement improved ($P \leq 0.05$) also some carcass characteristics. Supplementation of the diet with premix additionally decreased ($P \leq 0.05$) backfat thickness and increased share of meat in carcass. Fish meal improved ($P \leq 0.05$) some meat characteristics and elevated content of some polyunsaturated fatty acids. An increase in hemoglobin, red blood cell, white blood cell and cholesterol level in blood of animals from both experimental groups were also found. The results obtained proved the usefulness of fish meal and mineral-vitamin premix in the fatteners nutrition based on organic diets.

Key words: fattening pigs, organic feed, performance, carcass, meat, fatty acids, blood

Introduction

Feeding pigs in compliance with the organic farming regulations, imposed (in the opinion by Blair, 2007) too early, is a serious challenge. The biggest problem appears a collision of substantial dietary requirements of contemporary swine and the possibility of meeting them under conditions of organic farm (Grela and Semeniuk 2008). However, organic feeding, by definition, sets up an extensive production, nevertheless it cannot result in the worsening the quality of pork derived from swine suffering from

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the poor supply, since the quality of meat is considered the main goal of organic farming. This problem was noted as early as in 2002 by Jonsäll et al. (2002) and Sundrum (2005) who found organic pork quality to be inferior compared to conventionally reared pigs.

Organic feeding of swine is mainly limited by the supply of exogenous amino acids and some specific compounds, rare in feedstuffs grown at the farm. Balancing the demand-supply of amino acids, especially in piglets and lactating sows can only be achieved by means of some natural non-agriculture feeds (for instance fish meal), so far approved (up to 5%) in an organic diet. In accordance to EC Commission Regulation No. 889/2008, valid from January 1st 2012, these feeds will be forbidden, which might hamper organic feeding at the higher degree. Since the regulations proposed are controversial, a lot of research is actually in progress to reveal whether abandonment of non-agriculture feeds has a reverse effect on the main productive traits, especially on the pork quality (Grela and Kowalczuk-Vasilev 2010).

The aim of the experiment was to compare the results obtained by growing/finishing pigs fed organic mixtures with or without fish meal and mineral-vitamin premix. The traits examined were: performance, carcass and meat quality, some blood parameters and fatty acid profile in intramuscular lipids.

Materials and Methods

The Polish Regional Ethics Commission in Lublin (Poland) approved the experimental protocol, and the animals were handled and slaughtered in a humane manner in accordance with the guidelines established by this commission.

The experiment involved 120 crossbreed pigs (Polish Landrace x Polish Large White) x Duroc assigned into 3 groups (I, II and III), consisting of 20 gilts and 20 boars each. The animals were kept in pens (10 pigs each) with the outside run. Pigs of initial body weight of 25 kg were fattened until the slaughter weight of about 115 kg.

Experimental diets based on plant feedstuffs (grains and pulses) grown on organic farm, which were fed to animals as a ground mixture. The mixtures were fed *ad libitum* and the animals had free access to water. Animals of the group I were exclusively fed plant feedstuffs of organic origin. Animals belonging to the group II and III were given the same feedstuffs enriched with fish meal: 5% during growing and 2% during finishing period. The diet for the group III provided extra supplement of S-Bio, which was a special certified mineral and vitamin premix by Dolfos company.

The content of basic nutrients and amino acids was determined by AOAC (2000) methods in the feed samples that has been collected twice in a feeding period. Energy value of mixtures was calculated accordingly to the formula by Kirchgessner and Roth (1983). Composition and nutritive value of diets are given in Table 1.

During the experiment, blood samples from the branchial vein of 8 fatteners per group of 50 kg body weight and at the slaughter, were taken in order to determine hematological and biochemical indices. Hematocrit (Ht) value was established by the microhematocrit method, hemoglobin (Hb) content – following the Drabkin's method and both leucocytes (WBC) and erythrocytes (RBC) by the chamber technique (Pinkiewicz 1971, Feldman et al. 2000). The levels of total cholesterol (CHOL), HDL-cholesterol and triacyloglycerols (TG) were measured by test kits developed by Cormay company. The level of LDL-cholesterol was calculated using formula by Friedewald et al. (1972).

The animals were tagged and weighed individually three times: at the beginning of the experiment, at the time of changing grower mixture to the finisher and at the slaughter. Feed intake per pen was noted as well. After the slaughter, carcass composition of 8 animals from each group was established and the weight of the liver, heart and kidney was determined as well. The backfat thickness was measured over the shoulder, on the midback and on the rump at three points: over the cranial, medial and caudal edge of the *gluteus medius* muscle cross-section. The samples of *longissimus dorsi* muscle were examined in order to establish physicochemical properties including a fatty acid profile.

The pH and electrical conductivity of pork were measured by PQM – I KOMBI (Aichach, Germany). The measurements were performed 24 and 48 h post slaughter (pH_{24}, EC_{24} and pH_{48}, EC_{48}). Colour of meat was evaluated after 30 minutes-exposure using Minolta CR-310 device. The results were given according to CIE*a*b* (CIE 1986), where L*-Lightness, a*-Redness, b*-Yellowness, C*-Chroma, h°-Hue. Water-holding capacity of meat was expressed as a drip loss and thermal drip (Honikel 1998). A homogenized portion of meat subjected to filter paper method (Grau and Hamm 1953) giving amount of loose water (mg) and M/Tx100 proportion (Hofmann et al. 1982), using image analyzing computer program MultiScan Base v.14 for measurement of the total surface (cm^2) of leakage (T) and meat area (M). The TBARS value (oxidative stability of lipids in minced meat) was determined by Witte et al. (1970) method at 530 nm wavelength using Cary 300 Bio spectrophotometer. Meat tenderness evaluation

Table 1. Composition (%) and nutritive value of organic mixtures.

Item	Grower (25-70 kg)			Finisher (71-115 kg)		
	I	II	III	I	II	III
Wheat	30.0	30.0	30.0	20.0	20.0	20.0
Barley	32.0	27.0	30.0	32.0	30.0	28.0
Rye	10.0	10.0	10.0	20.0	20.0	20.0
Pea	25.0	25.0	25.0	20.0	20.0	20.0
Horse bean	–	–	–	5.0	5.0	5.0
Flax	3.0	3.0	3.0	3.0	3.0	3.0
Fish meal	–	5.0	5.0	–	2.0	2.0
Mineral-vitamin premix S-bio[1]	–	–	2.0	–	–	2.0
Nutritive value of 1 kg:						
ME MJ	13.56	13.62	13.37	13.44	13.47	13.22
Crude protein, g	139.8	162.3	160.7	140.5	149.5	148.4
Crude fiber, g	40.89	38.44	37.46	41.15	40.17	39.19
Lysine, g	6.70	8.59	8.58	6.85	7.60	7.60
Methionine + cystine, g	4.64	5.48	5.45	4.56	4.89	4.86
Tryptophan, g	1.44	1.69	1.68	1.44	1.53	1.52
Ca, g	0.68	2.84	8.43	0.70	1.56	7.15
P (total), g	3.62	4.72	5.85	3.64	4.08	5.20
Na, g	0.13	0.52	1.32	0.13	0.29	1.09

[1] – 1 kg of mineral-vitamin premix S-bio contained: vitamin A 225 000 i.u., vitamin D_3 22 500 i.u., vitamin E 900 mg, vitamin K 30 mg, vitamin B_1 30 mg, vitamin B_2 60 mg, vitamin B_6 60 mg, vitamin B_{12} 0.15 mg, nicotinic acid 300 mg, panthotenic acid 150 mg, folic acid 7.5 mg, biotin 0.75 mg, betaine 2660 mg, choline 1200 mg, 4 g lysine, 2.5 g methionine + cysteine, 0.7 g tryptophan, 2.5 g threonine, 280 g Ca, 60 g total P, 40 g Na, 3 g Fe, 3 g Zn, 2 g Mn, 300 mg Cu, 20 mg Co, 25 mg J, 10 mg Se.

(shear force) was carried out by means of Zwick/RoellProline BO.5 machine to define maximum shear force (N) and shear energy (J). Fatty acid profile of intramuscular lipids was determined according to the GC method using Varian CP-3800 unit. The chromatograph operating conditions were: capillary column CP WAX 52CB DF 0.25 mm, 60 m long, gas carrier – helium, flow rate – 1.4 ml/min, column temperature 120°C gradually increased by 2°C/min up to 210°C, determination time – 127 min., feeder temperature – 160°C, detector temperature – 160°C, other gases – hydrogen and oxygen.

The results obtained were analyzed statistically and the significance of differences of means characterizing experimental groups was performed by Duncan's test.

Results

The results of chemical analyses of feed mixtures (Table 1) indicate that the diets fed in group II and III were richer in crude protein (by about 15 and 6% in grower and finisher mixtures, respectively) as compared to group I (control). Fatteners' body weight depended significantly on the diet (Table 2). The addition of fish meal, as the sole supplement, improved ($P \le 0.05$) the daily weight gains (with exception of the pigs ranging 71-115 kg) and the mineral-vitamin premix was also significantly ($P \le 0.05$) beneficial. Fish meal decreased feed intake by the animals weighing 25-70 kg, but it has not affected considerably the older fatteners, whereas all the animals reacted significantly negatively ($P \le 0.05$) in this matter to the supplementation of the basal diets with fish meal and premix marriage. The highest feed conversion ratio (FCR) characterized the control group animals (Table 2). During whole fattening period they needed 3.64 kg feed mixture per 1 kg body weight gain, in comparison with 3.31 and 2.90 kg of feed in group II and III, respectively. The differences were confirmed statistically ($P \le 0.05$).

The post-slaughter investigations revealed that dressing percentage was similar, irrespective of the ex-

Table 2. Performance of pigs and some carcasses indices.

Item	Body weight, kg	Feeding groups			SEM
		I	II	III	
Average daily gain, g	25-70	576[a]	626[b]	689[c]	35.4
	71-115	692[a]	714[a]	772[b]	33.8
	25-115	634[a]	670[b]	731[c]	36.2
Feed intake, kg day^{-1}	25-70	1.84[a]	1.73[b]	1.62[c]	0.08
	71-115	2.82[a]	2.75[ab]	2.66[b]	0.09
	25-115	2.34[a]	2.24[ab]	2.14[b]	0.11
Feed conversion ratio kg kg^{-1}	25-70	3.19[a]	2.76[b]	2.35[c]	0.17
	71-115	4.08[a]	3.85[ab]	3.45[b]	0.22
	25-115	3.64[a]	3.31[b]	2.90[c]	0.18
Body weight (BW) at slaughter, kg		114.8	115.9	115.7	2.17
Dressing percentage (cold)		78.4	77.9	77.1	1.78
Ham weight, kg		8.96[a]	9.42[b]	9.53[b]	0.37
Lean of ham, %		60.8[a]	64.6[b]	65.2[b]	2.43
Loin eye area, cm^2		42.6[a]	45.3[b]	45.6[b]	1.12
Backfat thickness, mm		30.8[a]	24.5[b]	21.3[c]	1.08
Meat content in carcass, %		49.2[a]	51.8[ab]	54.4[b]	2.62
Liver weight, g/100 kg of BW		1589[a]	1605[a]	1504[b]	39.8
Heart weight, g/100 kg of BW		368.5	363.2	374.5	19.5
Kidney weight, g/100 kg of BW		158.9[a]	165.9[a]	173.5[b]	12.3

a, b – values with different letters in the same row differ significantly at $P \leq 0.05$.

Table 3. Hematological and biochemical indices of blood.

Indices	Body weight, kg	Feeding groups			SEM
		I	II	III	
Ht, l l^{-1}	50	0.23	0.24	0.28	0.05
	115	0.36	0.37	0.39	0.05
Hb, g l^{-1}	50	92.4	93.1	96.8	3.56
	115	124.4[a]	128.3[ab]	131.2[b]	4.28
RBC, 10^{12} l^{-1}	50	6.89	6.92	7.14	0.24
	115	7.47[a]	7.89[b]	7.99[b]	0.32
WBC, 10^9 l^{-1}	50	16.89	16.53	16.37	1.13
	115	17.21[a]	17.37[a]	18.12[b]	0.88
Total cholesterol, mmol l^{-1}	50	2.32[a]	2.77[b]	2.74[b]	0.21
	115	2.57[a]	2.91[b]	2.94[b]	0.25
Triacyloglycerols, mmol l^{-1}	50	0.33	0.36	0.35	0.06
	115	0.38	0.41	0.40	0.05
HDL-cholesterol, mmol l^{-1}	50	1.09	1.11	1.08	0.14
	115	1.21	1.15	1.16	0.18
LDL-cholesterol, mmol l^{-1}	50	1.08[a]	1.51[b]	1.50[b]	0.21
	115	1.19[a]	1.57[b]	1.60[b]	0.23

a, b – values with different letters in the same row differ significantly at $P \leq 0.05$.

Table 4. Characteristics of meat derived from *longissimus dorsi* muscle.

Item	Feeding groups			SEM
	I	II	III	
pH_{24}	5.67	5.61	5.71	0.13
pH_{48}	5.58	5.59	5.67	0.12
EC_{24}, $mScm^{-1}$	10.5	11.4	10.8	1.82
EC_{48}, $mScm^{-1}$	11.5^{a}	13.2^{b}	13.7^{b}	1.76
Drip loss, %	3.42	3.62	2.89	0.48
Cooking loss, %	23.4	23.8	24.2	1.56
WHC, mg	17.8	18.6	17.2	1.67
M/T*	33.9	34.2	35.5	2.31
Shear force, N max	35.6	34.2	34.7	2.43
Shear energy, J	0.13	0.12	0.14	0.03
Analysis of meat texture (TPA)				
Hardness, N	102.5	98.3	95.8	3.28
Springiness, mm	0.38	0.39	0.38	0.04
Gumminess, N	33.8^{a}	39.7^{b}	36.6^{ab}	4.67
Chewiness, N x mm	12.97^{a}	15.64^{b}	14.12^{ab}	1.89

a, b – values with different letters in the same row differ significantly at $P \le 0.05$.
* – meat area/total area x 100

Table 5. The value of TBARS and colour parameters by CIE L*a*b*C*h in *longissimus dorsi* muscle.

Item	Feeding groups			SEM
	I	II	III	
TBARS, mg MDA kg^{-1} meat	0.65	0.76	0.77	0.11
Blooming muscle 30'				
L* – Lightness	51.63	49.58	50.94	1.27
a* – Redness	7.11^{a}	6.83^{b}	7.26^{a}	0.28
b* – Yellowness	4.22	4.18	4.23	0.09
C* – Chroma	8.26^{a}	8.00^{b}	8.40^{c}	0.36
H° – Hue	30.7	31.48	30.24	0.53
After heat treatment				
L* – Lightness	60.45^{a}	58.67^{b}	59.35^{ab}	1.34
a* – Redness	6.16^{a}	6.05^{a}	6.50^{b}	0.44
b* – Yellowness	4.57	4.25	4.59	0.21
C* – Chroma	7.67^{a}	7.39^{b}	7.95^{a}	0.77
h° – Hue	36.59	35.11	35.24	1.98

a, b – values with different letters in the same row differ significantly ($P \le 0.05$).

perimental treatment, whereas some carcass characteristics differed significantly. The weight of ham, lean percentage of ham and loin eye area were positively related to the addition of fish meal but not to premix supplementation. Furthermore, in the fatteners given both fish meal as a sole additive and fish meal with premix, the backfat thickness was by 6.3 and 9.5 mm, respectively, lower than in the control group. The differences were significant statistically ($P \le 0.05$). Addition of premix to the organic feed, enriched with

Table 6. Fatty acid composition in intramuscular lipids of *longissimus dorsi* muscle (% of total FA).

Fatty acid	Feeding groups			SEM
	I	II	III	
Lauric (C12:0)	0.08	0.07	0.07	0.02
Myristic (C14:0)	1.32	1.25	1.28	0.12
Palmitic (C16:0)	24.91	24.41	24.60	1.28
Palmitoleic (C16:1, n-7)	2.89	3.12	2.94	0.23
Stearic (C18:0)	14.63[b]	13.78[ab]	13.19[a]	0.65
Oleic (C18:1, n-9)	44.19	43.85	44.56	1.98
Linoleic (C18:2, n-6)	9.10[a]	10.11[b]	9.91[b]	0.44
Linolenic (C18:3, n-3)	0.45[a]	0.54[ab]	0.63[b]	0.08
Arachidic (C20:0)	0.18	0.16	0.22	0.06
Eicosenoic (C20:1, n-9)	0.64	0.79	0.76	0.09
Eicosadienoic (C20:2, n-6)	0.21[a]	0.28[b]	0.29[b]	0.03
Arachidonic (C20:4, n-6)	0.41[a]	0.53[b]	0.54[b]	0.06
Docosadienoic (C22:2, n-6)	0.29[a]	0.35[b]	0.37[b]	0.04
Other FA	0.70	0.76	0.68	0.11
Total FA	100.00	100.00	100.00	–
SFA	41.12	39.67	39.36	1.57
MUFA	51.67	52.02	52.40	1.16
PUFA	6.51	7.55	7.56	0.74

a, b – values in the same rows with different letters differ significantly at $P \le 0.05$.

fish meal, improved also the share of meat in carcass, increased kidney weight and decreased the weight of the liver ($P \le 0.05$).

Supplementing organic diet with fish meal resulted in the higher number of RBC in fatteners at slaughter whereas the effect of premix was negligible (Table 3). Hemoglobin content and WBC number were increased ($P \le 0.05$) in the slaughtered animals fed the diets supplemented with fish meal together with premix (Table 3).

Electrical conductivity (EC) of meat measured 24 h after slaughter was not significantly differentiated by experimental factors, though EC in groups II and III was slightly higher compared to group I (Table 4). EC taken after next 24 h (EC_{48}) depended on the pig diet composition. The addition of fish meal alone or fish meal fortified with premix increased this trait significantly ($P \le 0.05$). Fish meal also affected such important sensory traits of meat as its gumminess and chewiness. Values referring to these characteristics in the group II were remarkably higher than those found in group I.

Results for colour parameters (Table 5) in group III, fed both fish meal and premix, shows that value of C* Chroma established after 30 min blooming time was significantly higher compared to both group I and II. After heat treatment this relation was blurred, however one could reveal the modifying effect of premix supplementation. Fish meal increased significantly a*-Redness of heat treated meat and lowered the value of L*-Lightness, meanwhile premix tended to increase them.

The supplement of fish meal considerably ($P \le 0.05$) increased the contents of linoleic, linolenic, eicosadienoic, arachidonic and docosadienoic acids, decreasing ($P \le 0.05$) at the same time content of stearic acid (Table 6).

Discussion

The results characterizing performance and carcass traits of pig fatteners of control group animals, achieved in this trial were worse than those observed in conventional fattening (Sprysl and Stupka 2003, Millet et al. 2004), but they correspond closely with data given by Blair (2007) for the organic fattening. This study revealed considerable positive influence of both supplements used – fish meal, perceived as a protein source with high biological value, as well as mineral-vitamin premix, on body weight gains, feed intake and FCR. These additives allowed to achieve the productive effect, comparable with the medium level of production, noted in conventional pigs' rearing. Their impact was especially imposing in the first fattening period. Fish meal added as a sole supplement to the typical organic diet increased in that period by near 9% average daily gains, at lower, at the same time, by 6%, feed intake. The FCR in this treatment was improved by 13.5%. Premix additive, used together with fish meal fortified significantly fish influence, improving feed conversion ratio by as much as 26%. Similarly, positive influence of these additives on growing pig performance fed commercial feed achieved Kim et al. (2009). There are not any studies dealing with the influence of the investigated in this trial factors on fattening pigs performance.

The experimental factors did not have any influence on dressing percentage, but used together, increased ($P \leq 0.05$) by about 10% the carcass meat content. They increased also significantly kidney weight, decreasing at the same time the weight of the liver. Feeding the animals of group I (control) and II with the imbalanced diets (without premix additive) was probably a reason of the higher weight of the liver in comparison with group III animals, receiving the diets enriched with mineral-vitamin premix. There are not any available publications regarding this problem. Fish meal supplement, regardless of lack or presence of premix, increased significantly the weight and lean of ham and loin eye area. Both fish meal, given as the only supplement, as well as fed together with mineral-vitamin premix had considerable impact on carcass fatness, decreasing by 20 and 31%, respectively, backfat thickness.

All the hematological and biochemical blood indices in the all groups' animals were within reference values (Winnicka 2008). Among hematological indicators observed an influence of experimental factors on hemoglobin concentration and number of RBC and WBC in blood of fatteners at slaughter was observed. In comparison with them, remarkably lower susceptibility of these characteristics was found in pigs weighing 50 kg. It might suggest that the effects were not linked to the sensitivity of organism itself (younger are usually more sensitive) but to the time of exposure to the experimental factor.

Supplementing organic mixture with fish meal had an adverse and confusing effect on some biochemical blood indices. It should be emphasised that the mentioned effect was strong enough to manifest regardless pigs weight (age). Despite to the common knowledge covering fish meal, it increased in blood the level of total cholesterol and LDL as well. The mineral-vitamin premix did not modify the influence of fish meal.

Among the meat characteristics examined only few depended on fish meal addition and some of them were modified by premix, given in fish meal marriage. One of these characteristics was electrical conductivity (EC) measured 48 h post slaughter, which was significantly higher in meat of fatteners receiving fish meal. A positive reaction of the animals on that feed additive, concerning their meat gumminess and chewiness was noted as well. What seems to be worthy of mentioning is the effect of premix because it alleviated, to a certain extent, the influence of fish meal (not significantly, however).

The experimental factors used in this study had different influence on some colour parameters. Fish meal supplementation in the diet decreased significantly C*-Chroma and a*-Redness at blooming muscle 30'. It diminished also C*-Chroma in meat after heat treatment, whereas fish meal enriched with vitamin-mineral premix had opposite impact on the above mentioned meat characteristics.

The supplement of fish meal given as the only supplement as well as together with premix affected profile of biologically essential PUFA – both n-6 (linoleic, eicosadienoic and docosadienoic) as well as n-3 (linolenic). The opposite reaction of the investigated experimental factors was revealed with respect to stearic acid. The results obtained correspond with those achieved in the other studies (Claudi-Magnussen 1999, Hansen et al. 2006, Kim et al. 2009).

Conclusions

Considering daily gains and feed conversion ratio it seems reasonable to fortify typical organic mixture with fish meal as well as with mineral-vitamin premix. The investigated in this study fish meal effect on the most valuable parts of carcass, as well as upon fatty acid profile was also positive; meanwhile the effect of premix was not univocal. In few cases it was reasonable; in the most others its addition was negligible. A negative impact of fish meal incorporated into plant-based mixtures concerned only the levels of total blood cholesterol and LDL, which were substantially higher.

References

AOAC (**2000**) Official Methods of Analysis. International, 17th ed., AOAC Inter, Gaithersburg, MD, USA.

Blair R (**2007**) Nutrition and Feeding of Organic Pigs. 1st ed., Hardback, University of British Columbia, Canada Pub, pp 5-6.

CIE (**1986**) Colorimetry, Official Recommendations of the International Commission on Illumination, 2nd ed., Pub, CIE 15.2, Vienna, Austria.

Claudi-Magnussen C (**1999**) Organic pig production, comparison of organic and conventional retail meat products meat and eating quality. Report of 22nd September. Ref. nr. 17.258/01 Danish Meat Research Institute, Roskilde, pp 1-28.

Feldman B, Zinki J, Jain N (**2000**) Schalm's veterinary haematology. 5th ed., Philadelphia: Williams and Wilkins, USA, pp 21-100.

Friedewald WT, Levy RI, Fredrickson DS (**1972**) Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem 18: 499-502.

Grau R, Hamm R (**1953**) Eine einfache Methode zur Bestimmung der Wasserbindung in Muskel. Die Naturwissenschaften 40: 29-30.

Grela ER, Kowalczuk-Vasilev E (**2010**) Nutritional and dietary value of organic pork versus other meat products. In: Bojar W (ed) Lublin region – ecological region of the XXI century: ecological or genetically modified food? TNOiK, Toruń, pp 181-195.

Grela ER, Semeniuk V (**2008**) Chemical composition and nutritive value of feedingstuffs from organic and conventional farms. New Development in Science and Research on Organic Agriculture, Bioacademy – Proceedings, Lednice, Czech Republic, pp 138-141.

Hansen LL, Claudi-Magnussen C, Jensen SK, Andersen HJ (**2006**) Effect of organic pig production systems on performance and meat quality. Meat Sci 74: 605-615.

Hofmann K, Hamm R, Blüchel E (**1982**) Neues über die Bestimmung der Wasserbindung des Fleisches mit Hilfe der Filterpapierpreßmethode. Fleischwirtschaft 62: 87-94.

Honikel KO (**1998**) Reference methods for the assessment of physical characteristics of meat. Meat Sci 49: 447-457.

Jonsäll A, Johansson L, Lundström K, Andersson KH, Nilsen AN, Risvik E (**2002**) Effects of genotype and rearing system on sensory characteristics and preference for pork (M. *Longissimus dorsi*). Food Qual Prefer 13: 73-80.

Kim SW, Easter RA (**2001**) Nutritional value of fish meals in the diet for young pigs. J Anim Sci 79: 1829-1839.

Kim DH, Seong PN, Cho SH, Kim JH, Lee JM, Jo C, Lim DG (**2009**) Fatty acid composition and meat quality traits of organically reared Korean native black pigs. Livest Sci 120: 96-102.

Kirchgessner M, Roth FX (**1983**) Equation for prediction of the energy value in mixed feeds for pigs. J Anim Physiol Anim Nutr 50: 270-275.

Millet S, Hesta M, Seynaeve M, Ongenae E, De Smet S, Debraekeleer J, Janssens GP (**2004**) Performance, meat and carcass traits of fattening pigs with organic versus conventional housing and nutrition. Livest Prod Sci 87: 109-119.

Pinkiewicz E (**1971**) Laboratory diagnostics in animal diseases, 1st ed., PWRiL, Warsaw.

Sundrum A (**2005**) Carcass yield and meat quality in organic pig production. In: Hovi M, Walkenhorst M, Padel S (eds) Systems development: quality and safety of organic livestock products. Proceedings of 4th SAFO Workshop, 17-19 March 2005 Frick, CH, pp 77-86.

Šprysl M, Stupka R (**2003**) The effect of feeding technologies on the economics of fattening pigs. Agric Econ-Czech 49: 284-289.

Winnicka A (**2008**) Reference values of basic laboratory analysis in veterinary medicine, 4th ed., SGGW Publishers, Warsaw, pp 17-31, 48-49.

Witte VC, Krause GF, Bailey ME (**1970**) A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. J Food Sci 35: 582-585.