PAPER

THE EFFECT OF INTRAMUSCULAR FAT CONTENT ON THE MEAT QUALITY OF PLW X PL PIGS

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ABSTRACT

This study aimed to determine the effect of intramuscular fat content (IMF) on the quality of meat from PLW x PL pigs. Meat was evaluated in terms of intramuscular fat content (n=80), technological properties, visual and tactile aspects, and colour measurements. It was demonstrated that meat containing more IMF was characterised by higher tenderness and marbling, but lower water content and a lower proportion of the yellow b* colour. Furthermore, it had a lower C* saturation, a lower h° hue, and lower muscle pigment content.

Keywords: pigs, intramuscular fat, meat quality

1. INTRODUCTION

There are numerous works indicating a significant role of intramuscular fat content (IMF) in determining the traits of pork (FERNANDEZ *et al.*, 1999a, b; FORTIN *et al.*, 2005). Its content in meat depends on numerous factors such as species, breed and sex (HOCQUETTE *et al.*, 2010; WOOD *et al.*, 2004; BOCIAN *et al.*, 2009; 2012; JANKOWIAK *et al.*, 2010; TYRA and ŻAK, 2012; feeding (WOOD *et al.*, 2004; ALONSO *et al.*, 2010), method of maintenance and age of slaughtered animals (ANDRÉS *et al.*, 2001), body weight at slaughter (LATORRE *et al.*, 2004), carcass muscling and subcutaneous fat thickness (PIETRUSZKA *et al.*, 2015). Irrespective of the above factors, intramuscular fat content is intimately related to some quality traits of meat.
Intramuscular fat (IMF) in pork is one of the main factors that influence the sensory quality parameters of meat, especially suitability for processing and cooking (FERNANDEZ *et al.*, 1999a; DASZKIEWICZ *et al.*, 2005; CZARNIECKA-SKUBINA *et al.*, 2010). The number and size of intramuscular adipocytes is related to variability in IMF content (HOCQUETTE *et al.*, 2010). The muscle fibre microstructure and fibre types -affect the accretion rate of intramuscular fat (FIEDLER *et al.*, 2003; WOJTYSIAK, 2014). According to DE VRIES *et al.* (2000), consumers mostly prefer pork with an IMF content of 2.5-3%. CZARNIECKA-SKUBINA *et al.* (2007) stated that pork with a higher (>2.51%) IMF content, despite having better processing value, tenderness, juiciness, palatability, and marbling, is less accepted by consumers. A minimum IMF content of 1.5% was considered necessary to ensure appropriate juiciness, tenderness, and palatability (FORTIN *et al.*, 2005). Reducing IMF content may have a negative impact on sensory and processing features of meat (CZARNIECKA-SKUBINA *et al.*, 2007; BOCIAN *et al.*, 2009). According to ELLIS (2006) an IMF content ranging from 1.8% to 2.6% is an indicator of good quality pork.
The most popular and common pig breeds in Poland are the Polish Large White (PLW), the Polish Landrace (PL), and their crossbreds (BLICHARSKI and SNOPKIEWICZ, 2017). The study aimed to determine the effect of IMF on some meat quality traits of Polish Large White x Polish Landrace (PLW x PL) pigs.

2. MATERIALS AND METHODS

2.1. Animals and sampling

The tested meat was obtained from 80 fattening pigs, F_1 crossbreds (Polish Large White x Polish Landrace), 50% gilts and 50% hogs. The crossbred PLW x PL fattening pigs came from and were kept on the same farm under the same environmental conditions, in accordance with welfare requirements. The animals were fed *ad libitum* with the same complete mixtures, according to standard requirements (GRELA and SKOMIAŁ, 2014). The composition and nutritional value of the complete mix are given in Table 1.
When fattening was complete, the animals were individually weighed and transported to a slaughterhouse about 100 km away. The slaughter was carried out in accordance with the applicable procedures after a 2-hour rest. The average live weight of slaughtered pigs was 106±9.57 kg.

Table 1. The nutritional value of feed mixtures.

Composition of feed mixture	Fattening period	
	30 to 70 kg	70 to 110 kg
Ground wheat (%)	20	15
Ground barley (%)	25	10
Ground triticale (%)	40	60
Protein concentrate[a] (%)	15	15
Metabolizable energy (MJ/kg)	13.20	13.34
Crude protein (g/kg)	156	158

[a]Composition: metabolizable energy, 13.30 MJ/kg; crude protein, 37.60%; crude fibre, 2.50%; crude ash, 17,80%; crude fat, 1.20%; Ca, 4.40%; P, 1.20%; Na, 1.0%; Lysine, 4.50%; Methionine, 0.56%; Tryptophan, 0.50%; Threonine, 1.60%; Methionine + cystine, 1.40%. Vitamin-micromineral per kilogram of complete diet: vitamin A (E 672), 60000 IU; vitamin D3 (E 671), 16600 IU; vitamin E alfa tocopheryl acetate, 716 IU; vitamin K3 as sodium sulfate, menadione 16 mg; thiamine, 12 mg; riboflavin, 24 mg; pyridoxine, 20 mg; cobalamin, 200 mcg; biotin, 400 mcg; niacin, 113 mg; Ca-D-pantothenate, 70 mg; betaine, 1080 mg; Cu, 160 mg as copper sulfate; Fe, 640 mg as iron sulfate monohydrate; Mn, 320 mg as manganese oxide; Zn, 640 mg as zinc oxi; Se, 3.0 mg as sodium selenate; I, 16 mg as anhydrous calcium iodate.

On the day following the slaughter, the carcass fat and meat content were determined according to RÓŻYCKI and TYRA (2010). The thickness of backfat was determined on the cold right half-carcass at points over the shoulder (at the thickest point), on the back (behind the last thoracic vertebra and the first lumbar vertebra), and at three locations over the loin (cross-section of the gluteal muscle): over the rostral edge of the gluteal muscle, in the middle of the gluteal muscle, and over the caudal edge of the gluteal muscle. The arithmetic mean was calculated from the five measurements of backfat thickness. On a cross-section of the *longissimus lumborum* muscle taken from the last thoracic vertebra and the first lumbar vertebra, the surface contour was measured (loin eye), and then the determined cross-sectional area was measured using the LUCIA system (Image for Image Processing and Analysis, version 4.82.2004). The research did not require the consent of the Local Ethical Committee.

2.2. Meat analysis

The acidification of muscle tissue at 45 minutes post slaughter (pH_{45}) and at 48 hours post slaughter (pH_{48h}) was determined using an Elmetron CP-401 pH-meter with a blade electrode. The equipment was calibrated using Elmetron pH 7.0 and pH 4.0 buffers. The meat quality was evaluated at 48 h post slaughter based on the *longissimus lumborum* muscle, which were stored at a temperature of 4-6°C. Water-holding capacity (WHC) was determined using the method developed by GRAU and HAMM (1952) and modified by POHJA and NIINIVAARA (1957). A 300 mg sample of minced meat was placed on a Whatman 1 filter paper and put between two glass plates; then an even load of 2 kg was applied to it for 5 minutes. The area of juice infiltration was used to calculate the percentage of free water content in the meat, assuming that 1 cm^2 of infiltration corresponds to 10 mg of water. The surface of meat juice infiltration was measured using a LUCIA computer analysis system (System for Image Processing and Analysis, version 4.82.2004).
Thermal drip was determined at 48 h post slaughter using the method developed by WALCZAK (1959). A 20 g sample of minced meat (20 g) was placed in a hygroscopic gauze and heated in a water bath at a temperature of 85°C for 10 min. After taking the

sample out of the water bath, the gauze was removed, then the sample was cooled to a temperature of 4°C and weighed. Based on the difference in weight before and after the heat treatment, the percentage weight loss was calculated.
Shear force was measured using the INSTRON 3342 strength testing equipment with a Warner-Bratzler attachment (WBSF), in accordance with the methodology provided by SZALATA *et al*. (1999). A 120 g meat sample was heated in a water bath until the sample reached a temperature of 70°C on the inside. The heat treatment was performed in a 0.85% NaCl solution. Then, 10 mm × 10 mm bars were cut along muscle fibres, which were subsequently cut perpendicularly to the muscle fibres. The results were read as maximum shear force expressed in N.
The chemical composition of the meat, i.e. water, dry mass, total protein, and intramuscular fat content, was determined in accordance with POLISH STANDARD PN-A-82109:2010 with near-infrared transmission spectroscopy (NIT) using calibration on artificial neural networks (ANN) with the FOSS FoodScan equipment.
Visual and tactile evaluation was determined 48 h after slaughter on a slice of raw meat weighing 120 g. Visual and tactile assessment of the meat was carried out by a trained 10-person team. All evaluators had 4 years of experience in assessing pork meat. Visual properties of the raw meat were assessed: visual colour intensity according to a 6-grade scale (POLISH STANDARD PN-ISO 4121:1998) on which 1=very light, 6=dark purple; marbling based on Canadian and American models on a 10-grade scale (CHENG *et al*., 2015; NPPC, 1999) where 1=no intramuscular fat content, 10=very high marbling. Tactile evaluation of firmness was on a 7-grade scale (PN-ISO 4121:1998) where 1=very firm, 7=very soft.
Meat colour was also measured on a slice of raw meat at 48 h post slaughter using a Minolta CR 310 photocolorimeter (Konica Minolta, Japan) with a measuring port diameter of 50 mm. The equipment was standardized using a CR310 white calibration plate with the following coordinates: Y=92.80, x=0.3175 i y=0.3333. Colour parameters were determined in the CIE system, L*a*b* (L* - lightness, a* - participation of red, b* - participation of yellow) (CIE, 1986) using illuminant D 65 and a standard 2° observer. Chroma (C*) and hue angle (h°) were calculated according to the formula provided by BEATTIE *et al*. (1999) and BREWER *et at*. (2001):

$$C^* = \sqrt{(a^*)^2 + (b^*)^2}\ ,\ h^{\circ} = (\tan^{-1} b^* / a^*)$$

Muscle pigment was determined by colorimetry according to the method developed by HORNSEY (1956). A 40 ml mixture of acetone, water, and concentrated HCl in proportions 40:2:1 was poured over minced meat samples (10 g), which were then extracted for 1 hour. After filtering, the absorbency of the tested solutions was measured using a Marcel Media spectrophotometer at a wavelength of 640 nm. The optical density value (E) was multiplied by a factor of 680 in order to obtain the proper concentration of hematin expressed as micrograms of hematin per 1 g of meat.

2.3. Statistical analysis

The results were statistically analysed; the arithmetic mean and the standard deviation for carcass traits, and the standard error (SEM) for meat quality traits were calculated. Data were verified for homogeneity of variance with the Leven'e Test; in the absence of homogeneity of variance, statistical significance between groups was calculated using the nonparametric Kruskal-Wallis Test. A probability of $P < 0.05$ was considered statistically significant.

The obtained test results were compiled and analysed in three groups that were defined in terms of the intramuscular fat content (IMF) of the meat of the PLW x PL pigs according to the normal distribution of features (Gaussian curve): group I, <1% of IMF content; group II, 1-2.5% of IMF content; group III, >2.5% of IMF content. The meats were divided into IMF groups to verify the impact on meat quality of increased IMF in the meat of PLW x PL pigs.
Pearson's simple correlation coefficients between the IMF content and the meat slaughter traits and quality traits were calculated to numerically summarize the degree of association between any two variables. All calculations were conducted using Statistica PL.8.0 data analysis software (StatSoft Inc. STATISTICA, 2008).

3. RESULTS AND DISCUSSION

The data regarding the quantity and weight measurement of warm carcasses, average backfat thickness, and loin eye area are shown in Table 2. The obtained values of average backfat thickness indicate a higher fat content of pig carcass than reported in other studies (CZARNIECKA-SKUBINA *et al*., 2007; TYRA and ŻAK, 2012).

Table 2. Mean and standard deviation of carcass characteristics.

	Mean and standard deviation
Number (n)	80
Hot carcass weight (kg)	86.83±8.61
Average backfat thickness (mm)	23.23±5.27
Loin eye area (cm^2)	53.87±7.41

The characteristics of the technological properties of the tested pork are presented in Table 3 and analysed according to the intramuscular fat content. The 16 meat samples fell within the first group (lowest fat content), 48 meat samples within the II group and 16 meat samples within III group (highest fat content). In numerous tests, the highest percentage of meat samples had up to 2% of IMF (DASZKIEWICZ *et al.*, 2005; TYRA and ŻAK, 2012). The IMF content in the meat studied ranged from 0.79% to 3.20% and significantly differed between all the groups ($P<0.01$).
The acidity of muscle tissue is one of the parameters that determines meat quality and is used to determine the processing and cooking suitability of meat (KAJAK *et al*., 2007). Meat acidity is measured 45 minutes after slaughter and is a widely recognised criterion that reflects the intensity of post-slaughter changes that lead to meat quality defects such as PSE (HOFMANN, 1994). The ultimate pH is an indicator of meat quality and is associated with water-holding capacity, colour, and tenderness (KAJAK *et al*., 2007).
In this study, higher pH_{45} values were observed in group I than in group III ($P<0.05$); this can be explained by the fact that the group with the lowest IMF content contained carcasses with values from 6.21 to 6.84 pH, which had an impact on higher pH_{48} values. The meat pH value measured 48 h post slaughter was the highest in the meat with the lowest IMF content and differed significantly between group I and group II and III ($P<0.01$). The results of pH_{45} and pH_{48} presented in the paper are compatible with the results obtained by JAWORSKA *et al.* (2007), who showed that with an increase from 1.72% to 2.63% of IMF content in meat, the values of pH_{45} (6.40 to 6.36) and pH_{48} (5.52 to 5.50) decreased. CZARNIECKA-SKUBINA *et al.* (2007) demonstrated that pork with the

highest IMF content (>2.51%) was characterized by a significantly higher final pH (5.63), compared to meat with the lowest (<1.5%) and average (1.51-2.5%) IMF content (5.51 and 5.54) (P<0.05); moreover, it was characterized by a darker colour and lower protein content. DASZKIEWICZ *et al.* (2005) demonstrated that meat with lower IMF content (<1.0%) had lower pH_{45} (6.17) and similar values to obtained in this study at pH_{48} (5.44). In turn, KLONT (2005) indicated that a lower final pH causes the meat to have less water retention capacity and to be lighter in colour, while a higher final pH gives it a darker colour, less juice leakage during storage, and positively effects meat quality traits, i.e. succulence, tenderness and taste. The values obtained and presented in this study of pH_{45} as well as the final pH were typical for meat of good quality in accordance with the assumptions of HOFMANN (1994) and KLONT (2005).

Table 3. Characteristics of the technological properties of meat quality (mean value and standard error) in relation to IMF content.

	Group - IMF				
	I	**II**	**III**	**SEM**	***P***
	<1%	**1-2.5%**	**>2.5%**		
Number (n)	16	48	16		
Number (%)	20.00	60.00	20.00		
IMF (%)	0.79^{A}	1.59^{B}	3.20^{C}	0.10	0.001
pH_{45}	6.50^{a}	6.37	6.32^{b}	0.02	0.027
pH_{48h}	5.54^{A}	5.46^{B}	5.44^{B}	0.01	0.005
WHC (% of free water)	19.38^{a}	19.99	21.67^{b}	0.31	0.033
Thermal drip (%)	21.20	21.05	21.75	0.24	0.378
WBSF (N)	55.94^{A}	48.38^{A}	37.46^{B}	1.48	0.001
Chemical composition of meat					
Water content (%)	73.30^{A}	74.09^{B}	72.73^{C}	0.12	0.001
Total protein content (%)	23.09	23.40	23.11	0.07	0.343

$^{(A-C)}$Row means with different superscripts differ significantly at $P<0.01$.

$^{(a-b)}$ Row means with different superscripts differ significantly at $P<0.05$.

IMF - Intramuscular fat content; WHC - Water holding capacity; WBSF - Warner Bratzler shear force (N - Newton); pH_{45} - pH at 45 minutes post slaughter; pH_{48h} - pH at 48 hours post slaughter.

The meat with the lowest WBSF (shear force) contained the highest amount of IMF (group III) and was more tender than groups I and II ($P<0.01$). VAN LAACK *et al.* (2001) evaluated the impact of ultimate muscle tissue acidity (pH_u) and IMF content on tenderness and tenderization of pork. Similarly, RAMSEY *et al*. (1990) showed that increasing meat IMF content decreases its shear force.

The studies demonstrated that, along with increasing IMF content of the tested meat, the water content decreased and the dry mass content increased ($P<0.01$). DASZKIEWICZ *et al*. (2005) observed a similar relationship between the level of IMF and the chemical composition of pork. They showed that as the content of IMF and marbling increased, the content of dry matter increased and the content of total protein and ash decreased.

Table 4 contains the results of a visual and tactile evaluation, and an evaluation of colour and muscle pigment of meat. With the increase in IMF, marbling in meat increased (P <0.01).

Higher marbling of pork is associated with a higher IMF content (FERNANDEZ *et al*., 1999a; VAN DER WAL *et al*., 1992; VAN LAACK *et al*., 2001). CZARNIECKA-SKUBINA *et al*. (2007) showed that meat with the highest IMF content (≥2.51%) was characterized by a higher marbling (6.06 points) in relation to meat with the lowest (≤1.5%) IMF content (3.92 points). Also, PRZYBYLSKI *et al*. (2010) showed more marbling (4.28 points) in meat with 2.27% IMF content compared to 1.67 IMF meat (2.70 points) ($P < 0.05$).

Table 4. The results of visual and tactile evaluation of meat colour and muscle pigment content (mean value and standard error) in relation to IMF content.

	Group - IMF				
	I	**II**	**III**	**SEM**	***P***
	<1%	**1-2.5%**	**>2.5%**		
Visual and tactile evaluation					
Visual colour intensity (1-6 scale)	3.7	3.5	3.1	0.08	0.127
Marbling (1-10 scale)	1.0^{A}	2.3^{B}	3.9^{C}	0.13	0.001
Firmness (1-7 scale)	3.8^{a}	4.2	4.6^{b}	0.08	0.011
Colour measurements					
L^*_{48}	53.73	54.78	55.23	0.32	0.560
a^*_{48}	16.19	15.78	15.11	0.13	0.037
b^*_{48}	6.80^{A}	4.90^{Ba}	3.32^{Bb}	0.22	0.001
C^*_{48}	17.60^{A}	16.61^{A}	15.52^{B}	0.16	0.001
h^o_{48}	22.63^{A}	17.02^{Ba}	12.36^{Bb}	0.70	0.001
Muscle pigment (micrograms of hematin per 1 g of meat)	34.27^{Aa}	29.83^{b}	26.99^{B}	0.64	0.002

$^{(A-C)}$Row means with different superscripts differ significantly at $P<0.01$.
L* value represents lightness; a* proportion of red; b* proportion of yellow; C* saturation; h^o hue angle.

As evaluated tactilely, the highest hardness of meat was observed in samples in group I with a minimum content of IMF, compared to group III which was less hard ($P < 0.05$).
Meat colour constitutes an important quality indicator (POŁOM and BARYŁKO-PIKIELNA, 2004). Although lightness L* was highest for meat with the highest fat content, there were no statistically significant differences in terms of IMF content. The obtained results were typical of normal meat quality (WARRIS *et al*., 2006). There were no significant differences in the proportion of red a*, but there was a significant difference in the proportion of yellow b*, which was highest in the group with the lowest IMF ($P < 0.01$). Quality features of meat colour include colour saturation, colorimetric purity, and dominating light wavelength, referred to as hue. The highest colour saturation C* and h° hue were observed in meat with the lowest (<1%) IMF content ($P<0.01$). Similar values of meat colour parameters L*, a*, b*, and saturation C*, and higher values of h° hue than the ones obtained in this study were shown in previous studies (BOCIAN *et al*., 2015).
Muscle pigment content is one of the main factors that affect the evaluated meat colour. This study demonstrated significant differences in muscle pigment content. The highest content of muscle pigment was in meat from group I, which also had the lowest IMF content compared to group III, which had higher IMF content ($P<0.01$). These values are similar to the ones obtained previously by BOCIAN *et al*. (2015) for PLW x PL meat.
For more detailed interrelations between intramuscular fat content and the characteristics of the tested meat, the simple linear correlations between them were computed. The

coefficients of simple correlation between IMF and processing properties of meat, subjective visual and tactile evaluation, and its colour are shown in Table 5. The correlations between IMF and carcass weight, backfat thickness and loin eye area were also computed. The study confirmed a significant negative relationship between IMF and meat acidity pH_{45} (P<0.05) and pH_{48h}, WBSF, water content (P <0.01), visual colour intensity (P <0.05), proportion of red a* and yellow b* colour, its saturation C*, and h° hue, as well as muscle pigment content (P<0.01).

Table 5. Correlation coefficients between intramuscular fat content and other variables in meat.

	IMF
pH_{45}	-0.242*
pH_{48h}	-0.292**
WHC	0.140
Thermal drip	0.032
WBSF	-0.493**
Water content	-0.779**
Total protein content	-0.106
Visual colour intensity	-0.259*
Marbling	0.908**
Firmness	0.305**
L^*_{48} - value represents lightness	0.147
a^*_{48} - proportion of red	-0.302**
b^*_{48} - proportion of yellow	-0.584**
C^*_{48} - saturation	-0.473**
h^o_{48} - hue angle	-0.560**
Muscle pigment	-0.422**
Hot carcass weight	0.353**
Av. backfat thickness	0.195
Loin eye area	-0.006

(*)Statistical significance at P<0.05, (**) Statistical significance at P<0.01.

Intramuscular fat content was not related to carcass fat and meat content; only carcass weight was positively correlated with IMF (P<0.01), which may be explained by the impact of age on the higher animal body weight at slaughter. PIETRUSZKA *et al*. (2015) reported a significant positive correlation between IMF content and average backfat thickness (r=0.31, P<0.05), and a negative correlation with the loin eye area (r=-0.64, P<0.01); however, in contrast to this study, no significant relationship between IMF and pH_{45} was demonstrated. The high positive correlation between the IMF content and marbling (r=0.908) and the negative relationship with the shear force (r=-0.493) (P<0.01) obtained in this study are in line with the findings of LI *et al*. (2013), which also showed lower shear force of meat containing higher IMF content.

4. CONCLUSIONS

The meat obtained from the most popular Polish crossbred pigs contained more intramuscular fat and was characterized by greater shear force, lower pH_{45} and pH_{48h}, more marbling with lower water content, and a smaller proportion of yellow colour b*. In addition, it was characterized by a lower saturation of colour C*, its tone h°, and lower content of muscle pigment.

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