Animal (2015), **9:11**, pp 1897–1903 © The Animal Consortium 2015
doi:10.1017/S1751731115001433

animal

Factors affecting the tissues composition of pork belly

K. Duziński[1†], D. Knecht[1], D. Lisiak[2] and P. Janiszewski[2]

[1]*Institute of Animal Breeding, Wroclaw University of Environmental and Life Sciences, Chelmonskiego 38C, 51-630 Wroclaw, Poland;* [2]*Division of Meat and Fat Technology, Prof. Wacław Dąbrowski Institute of Agricultural and Food Biotechnology, Jubilerska 4, 04-190 Warsaw, Poland*

(Received 24 March 2015; Accepted 2 July 2015; First published online 28 July 2015)

*Bellies derived from the commercial population of pig carcasses are diverse in terms of tissue composition. Knowledge of the factors influencing it and the expected results, permits quick and easy evaluation of raw material. The study was designed to determine the factors affecting the tissues composition of pork bellies and to estimate their lean meat content. The research population (*n *= 140 pig carcasses) was divided into groups according to sex (gilts, barrows), half-carcass mass (<40, 40 to 43.9, 44 to 46.9, ⩾47 kg) and lean meat content class: S (⩾60%), E (55% to 60%), U (50% to 55%), R (<50%). Bellies were subjected to a detailed dissection. Half-carcass mass affected the levels of all the analysed parameters. The only exception was the mass of the fat with the skin in the 40 to 43.9 kg group, for which the value did not differ statistically between the two groups <40 and 44 to 46.9 kg. Decrease in lean meat content affected the growth of the fat and skin mass in a linear way. No differences were observed between class S and E in terms of belly muscle mass. A 0.37% higher share of belly in the half-carcass was found for barrows (*P *< 0.001), although bellies issued from barrows were characterized by a higher proportion of fat with skin compared with gilts (*P *= 0.02). Interactions were observed between sex and half-carcass mass, so the sex of heavy half-carcasses becomes an important determinant for conditioning the muscle content. Equations were calculated and allow a fast and highly accurate determination of the lean meat content in bellies, suggesting they may be used directly in the production line.*

Keywords: pigs, sex, carcass mass, lean meat content, pork belly

Implications

The belly is generally classified as a fatty primal cut but is also definitely thinner and softer than years ago. The determination of factors influencing belly content is needed to determine its technological value for defined market. Based on the study outcomes, it is possible to estimate tissue composition of pork bellies analysing sex, half-carcass mass and lean meat content. The presented solutions permit a quick and easy evaluation of raw material and its allocation to the adequate market.

Introduction

The tissues composition of pork primal cuts determines their further use. The quality parameters of finishing pig carcasses slaughtered all over the world have been constantly changing, especially in recent years. The main assumptions of improving pork production are to increase the lean meat content of the carcass and to reduce fat (Kouba and Bonneau, 2009). These goals are determined by the demands of the processing plants and consumers. Estimation of the overall lean meat content of the carcass is still the most common form of grading pig carcasses and adjustment of purchase price based on this parameter confirms its strong relationship to the economic value of the carcass (Marcoux *et al.*, 2007). The improvement of the pig population based on reducing backfat thickness has resulted in a decrease in the total fat content, mainly over the leg and back, including intermuscular and intramuscular fat (Vališ *et al.*, 2005). In addition, a negative correlation between the content of meat and fat in the carcass has definitely accelerated the process of the reduction of whole carcass, as well as the primal cuts fatness (Hermesch, 2008). A consequence of these changes is the increasing share of muscle tissue in primal cuts (Kosovac *et al.*, 2009). The belly perfectly reflects the nature of these transformations.

The belly is generally classified as a fatty primal cut and, in contrast to other primal cuts of the carcass, has a higher fat content in relation to the amount of muscles (Stupka *et al.*, 2004). However, over the last 40 years, the decline in fat level of bellies has exceeded 29% (Person *et al.*, 2005). Simultaneously, there has recently been an observable increase in the mass of ham of 19% and loin of 21%, but the mass of belly

† E-mail: kamil.duzinski@up.wroc.pl

https://doi.org/10.1017/S1751731115001433 Published online by Cambridge University Press

has remained almost constant (Stetzer and McKeith, 2003). Currently, pork bellies are definitely thinner and softer than years ago. However, the international pork trade forces producers to adapt their products for specific markets.

Export and import of pork is based primarily on market demand and consumer preferences. Asian meat markets show a high demand for pork primal cuts (Uttaro and Zawadski, 2010); however, it is not easy to enter this market and maintain continuity of supply. The economic value of a carcass depends on the requirements for cuts, which often are also sold in unprocessed form (Knecht *et al.*, 2012). Pork belly is one of the particularly desirable cuts in Eastern markets (Nam *et al.*, 2010; Oh and See, 2012). Hence, the importance of a detailed analysis of the composition and the share of the cut in pig carcasses is needed. Bellies derived from the carcasses of pigs from the commercial population are diverse in terms of tissue composition. It has been suggested that the belly composition is affected mainly by the sex, slaughter mass and lean meat content of the carcasses rather than crossing variant (Vališ *et al.*, 2005). Thus, an issue or prime importance is the determination of the influence of those factors on the belly content in the carcass for the current commercial finisher population, and the potential to estimate their technological value in order to sort raw material at the earliest stage of production.

In the light of the above considerations, the aim of this study was to determine the factors affecting the estimation of the tissues composition and lean meat content of pork bellies.

Material and methods

Design of the study

Finisher pigs chosen for experiments came from the Polish commercial population of pigs. The slaughter of animals was carried out in a meat plant in the province of Pomerania, after a few hours of rest from the time of delivery. The carcasses were bled, separated along the centre line and deprived of tongue, bristle, hooves, genital organs, perirenal fat, kidneys, diaphragm, eyes, middle ear, brain and spinal cord. For further studies only that raw material with a *postmortem* hot carcass weight between 60 and 120 kg was classified. The total research population consisted of 140 pig carcasses. Lean meat content in carcasses were predicted at the end of the slaughter line, using Capteur Gras/Maigre (CGM; Sydel, Lorient, France) device (EC, 2011).

The carcasses were divided into groups differentiated in terms of sex (gilts, barrows), half-carcass mass (<40, 40 to 43.9, 44 to 46.9, ⩾ 47 kg) and carcass classes based on their lean meat content: S (⩾60%), E (55% to 60%), U (50% to 55%), R (<50%), and marked directly on the slaughter line. After a 24 h cooling period, the right half-carcasses were chosen. Bellies derived from all carcasses were subjected to a detailed dissection. The belly was separated from the jowl by a cut between fourth and fifth rib following the line of the ribs. The ventral part of belly was separated from the belly by a cut starting 4 cm caudally of the last rib first in straight line to ventral and then following cranially along a line just dorsal from the row of teats (Walstra and Merkus, 1996). Dissections were performed according to EU reference methodology by specially trained personnel. As part of the detailed belly dissection, the following aspects were defined: belly, fat with skin (subcutaneous and intermuscular), bone and muscle masses. An approved electronic scale was used for the weighing of belly and tissue components derived from the dissection, with an accuracy to the nearest 1 g. The percentage of belly in each half-carcass and the percentage of dissected tissues in the belly were calculated. The level of lean meat content was calculated following the EC Regulation formula using dissection data (EC, 2006).

Statistical analysis

Numeric materials were analysed statistically using the STATISTICA (2013) program. The values set out in the tables determine the arithmetic mean ($\bar{x}$), RMSE and *P*-values. The application of the GLM was preferred because the collected data were checked for normality with the Kolmogorov–Smirnov test and with the Brown–Forsythe test for homogeneity of variance. The statistical model consisted of main effects (sex, half-carcass mass, lean meat content class) and interactions between them. To determine the statistical differences, the following level $P \leqslant 0.05$ of significance were considered. To indicate the significance of differences between means Tukey's *post-hoc* test was applied. The regression equations estimating the percentage value and quantity of meat in the belly were designated using stepwise regression. Models of equations were based on correlations with the dependent variable and the following variables. Only significant correlations ($P \leqslant 0.05$) were used to obtain the smallest possible estimation error: lean meat content and the half-carcass mass. Estimation accuracy was determined via the prediction error and the adjustment of variables. During calculations, all outliers identified in the data set as larger than 0.5 Cook's distance were removed and eliminated by a needle plot of Cook's analysis.

Results

Mass of belly and dissected components

The mass of the belly and its tissue compositions depending on the analysed factors are presented in Table 1. The differences between gilts and barrows were not significant, except for fat with skin mass. Definitely, a higher proportion of this parameter was found in barrows ($P = 0.02$). Half-carcass mass affected all the analysed parameters ($P \leqslant 0.05$). Proportional increases in the mass of belly, fat with skin, bone and muscle were recorded with increasing half-carcass mass. The only exception was the mass of the fat with the skin in the 40 to 43.9 kg group, for which the value did not differ statistically between the two groups <40 and 44 to 46.9 kg. A decrease in lean meat content affected the growth of the fat and skin mass in a linear way ($P < 0.001$). The highest bone mass was observed for carcasses in class E and its differences between R and U classes amounted to 56.87 and 42.64 g, respectively ($P \leqslant 0.05$). No differences

https://doi.org/10.1017/S1751731115001433 Published online by Cambridge University Press

Table 1 *Mass (g) of the pork belly and dissected components (fat with skin, bones and muscles) according to sex, half-carcass mass and carcass lean meat content*

	Sex		Half-carcass mass (kg)				Lean meat content[1]					*P*-value		
Factors	Gilts	Barrows	<40	40 to 43.9	44 to 46.9	⩾47	S	E	U	R	RMSE	S	HM	LMC
n	70	70	31	38	34	37	14	59	52	15				
Belly	3346	3438	2837^{d}	3215^{c}	3550^{b}	3901^{a}	3217	3447	3357	3464	196	0.19	<0.001	0.25
Fat with skin	1164	1289	1034^{a}	1173^{ab}	1247^{b}	1427^{c}	827^{a}	1144^{b}	1322^{c}	1599^{d}	83	0.02	<0.001	<0.001
Bones	228	215	186^{a}	203^{a}	245^{b}	249^{b}	229	245^{b}	202^{a}	188^{a}	25	0.26	0.01	0.005
Muscles	1944	1923	1607^{d}	1830^{c}	2046^{b}	2214^{a}	2149^{a}	2049^{a}	1821^{b}	1662^{b}	112	0.66	<0.001	<0.001

S = sex; HM = half-carcass mass; LMC = lean meat content.
^{a,b,c,d}Values within a row with different superscripts significantly differed at $P \leqslant 0.05$.
[1]Lean meat content for class S (⩾60%), E (55% to 60%), U (50% to 55%) and R (<50%).

Table 2 *Percentage of the pork belly in half-carcass and dissected components (fat with skin, bones and muscles) in belly according to sex, half-carcass mass and carcass lean meat content*

	Sex		Half-carcass mass (kg)				Lean meat content[1]					*P*-value		
Factors	Gilts	Barrows	<40	40 to 43.9	44 to 46.9	⩾47	S	E	U	R	RMSE	S	HM	LMC
n	70	70	31	38	34	37	14	59	52	15				
Belly	7.49	7.86	7.57	7.63	7.82	7.69	7.37	7.65	7.7	7.98	0.29	<0.001	0.23	0.24
Fat with skin	34.72	37.32	36.29	36.28	35.06	36.43	25.53^{a}	33.21^{b}	39.22^{c}	46.02^{d}	2.27	0.02	0.73	<0.001
Bones	6.86	6.29	6.62	6.34	6.94	6.42	7.19^{b}	7.13^{b}	6.07^{a}	5.47^{a}	0.74	0.05	0.62	0.004
Muscles	58.14	56.09	56.75	57.09	57.69	56.88	66.94^{a}	59.41^{b}	54.41^{c}	48.1^{d}	2.62	0.04	0.55	<0.001

S = sex; HM = half-carcass mass; LMC = lean meat content.
^{a,b,c,d}Values within a row with different superscripts significantly differed at $P \leqslant 0.05$.
[1]Lean meat content for class S (⩾60%), E (55% to 60%), U (50% to 55%) and R (<50%).

were observed between S and E classes in terms of belly muscle mass. However, it should be noted that the muscle mass decreased together with a decreasing lean meat content. S and E classes exhibited significantly higher lean meat content than the R ($P \leqslant 0.01$) and U ($P \leqslant 0.05$) classes.

Share of belly and dissected components

The percentage of belly in half-carcass and dissected components of belly, depending on the factors studied, are presented in Table 2. Sex had a significant effect on the characteristics of the percentage of the analysed parameters in the carcass. A higher share of belly in the half-carcass (+0.37 percentage point) was found for barrows ($P < 0.001$), and bellies issued from barrows were characterized by a higher proportion of fat with skin compared with gilts ($P = 0.02$). Gilts achieved a +2.05 percentage point higher level of muscle in the belly ($P = 0.04$), and a higher proportion of bone ($P = 0.05$). Half-carcass mass did not affect the percentage of belly in half-carcass or the composition of the tissues to a statistically significant level. The highest differences between the analysed parameters were found according to the lean meat content classes. This highlighted a linear decrease in the belly muscle and an increase in fat with skin, along with a decrease in carcass lean meat content class (S to R). The share of bones in the belly was at a similar level in classes S and E and higher than in class R ($P \leqslant 0.01$) and U ($P \leqslant 0.05$), without differences between R and U classes.

Statistical analyses also revealed interaction between the half-carcass mass and sex on the muscle mass of belly (Figure 1). Heavier (⩾47 kg) half-carcasses from gilts exhibited higher muscle mass of belly than those from barrows ($P \leqslant 0.01$), whereas differences between sexes on belly muscle mass were not significant for all groups of lighter half-carcasses (<40, 40 to 43.9 or 44 to 46.9 kg). The number of subgroup observations for calculating the interaction was similar and ranged from 15 to 20 observations.

The regression equation estimating the percentage of lean meat content in the belly

Lean meat content in belly (%) = 1.21083 lean meat content of carcass predicted by CGM (%) − 0.00003 half-carcass mass (g) − 7.81917

This equation has been developed on the basis of 139 observations, because in order to increase the precision of the estimation one observation was classified as an outlier. The lean meat content of a carcass from CGM adopted as the regression coefficient in the equation was significant ($P \leqslant 0.01$), whereas the half-carcass mass was a factor added to lift the accuracy of the equation. The results for equation were as follows: F value = 330.74, estimation SE = 2.32, $R^2 = 0.828$. The SE of lean meat content in carcass predicted by CGM coefficient was 0.047, the SE of half-carcass mass coefficient was 0.00004 and the SE of intercept was 3.04. Figure 2a shows the regression curve, which illustrates

https://doi.org/10.1017/S1751731115001433 Published online by Cambridge University Press

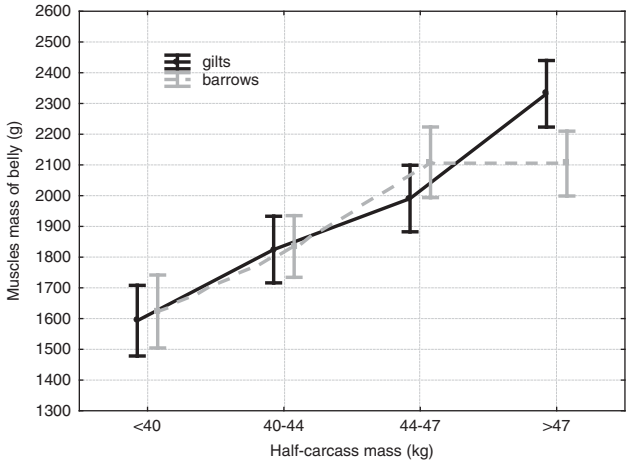


Figure 1 Muscle mass of pork belly according to half-carcass mass and sex.

a high correlation between the observed percentage share of the lean meat content in the belly from dissection and the predicted lean meat content of the belly based on the developed regression equations. The uniform distribution of the residuals shown in Figure 2b demonstrates the good fit of the equation for the study population.

The regression equation estimating the lean meat content (g) in the belly

Lean meat content in belly (g) = 32.38 lean meat content in carcass predicted by CGM (%) + 0.05 half-carcass mass (g) − 1865.38

The developed equations were based on data from 140 dissected carcasses. The results for the equation were as follows: F value = 177.74, estimated SE = 173.5, $R^2 = 0.72$. The proposed regression coefficients were statistically significant ($P \leqslant 0.01$), the SE of lean meat content in carcass predicted by CGM coefficient was 3.51, the SE of half-carcass mass coefficient was 0.003 and the SE of intercept was 226.9. The results in Figure 3a present the fit of the equation estimating the share of meat in the belly to the real value. Similar to the situation in Figure 2a for the first equation, a uniform dispersion of residuals was obtained (Figure 3b).

Discussion

The quality of carcass and primal cuts is an important issue in pig production from both the scientific and practical points of view and is based on different parameters and criteria (Kosovac *et al.*, 2009; Tomović *et al.*, 2014). Our results confirm the influence of the examined factors on the percentage composition of the belly tissues.

The influence of sex was observed on the percentage of belly in the carcass and tissues from dissection, whereas there was no effect on quantitative composition, except for fat and skin mass. This represents a partial negation of the results obtained by the study of Bahelka *et al.* (2011), who also proved the existence of quantitative differences

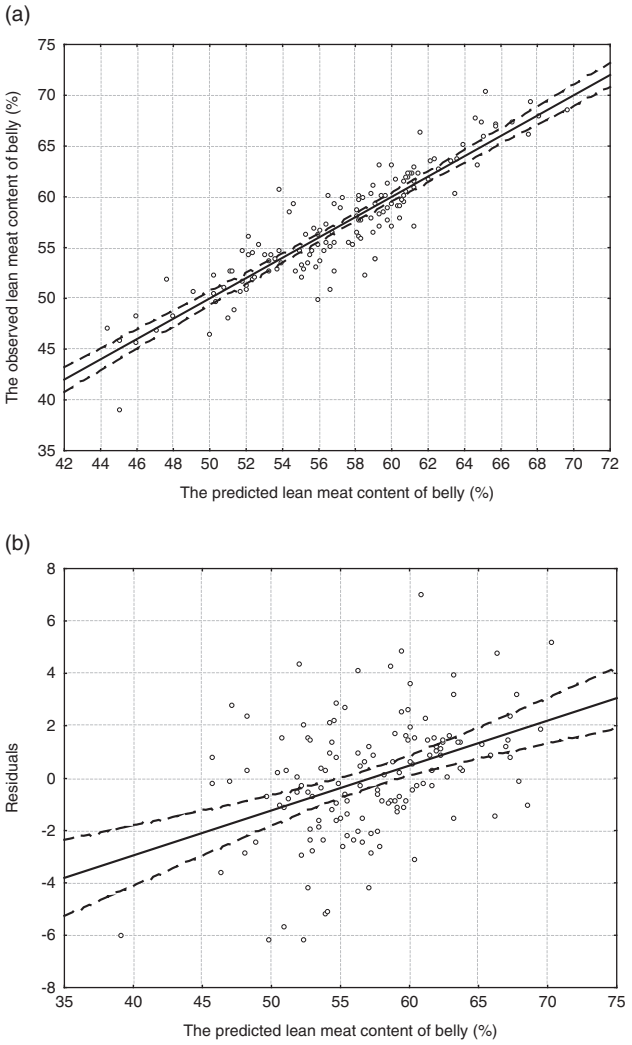


Figure 2 Scatter plots of regression line with confidence intervals (a) and residuals (b) representing differences between percentage lean meat content in pork belly based on dissection and prediction.

between bellies from gilts and barrows. However, on the other hand our results almost fully confirms the study conducted by Vališ *et al.* (2005), although the presented values of the variables were different. These discrepancies could be due to different methods employed for the selection of animals to form the study population. Such an interpretation is confirmed by the lower average mass of belly and dissected tissues obtained in our experiment compared with the results of the above authors. The nature of changes in the quality of belly depending on sex was also emphasized in work by Correa *et al.* (2008), who showed a softer fat for gilts. The quality of fat, however, was not investigated in our research.

Half-carcass mass did not affect the content of belly, or tissue proportion, which was similar to observations by Vališ *et al.* (2005). The same authors additionally reported a decrease in lean meat content in carcasses with increased slaughter mass over 109 kg. Almost identical findings can be derived on the basis of an analysis of the half-carcass mass. The growth of muscle tissue during fattening is associated

https://doi.org/10.1017/S1751731115001433 Published online by Cambridge University Press

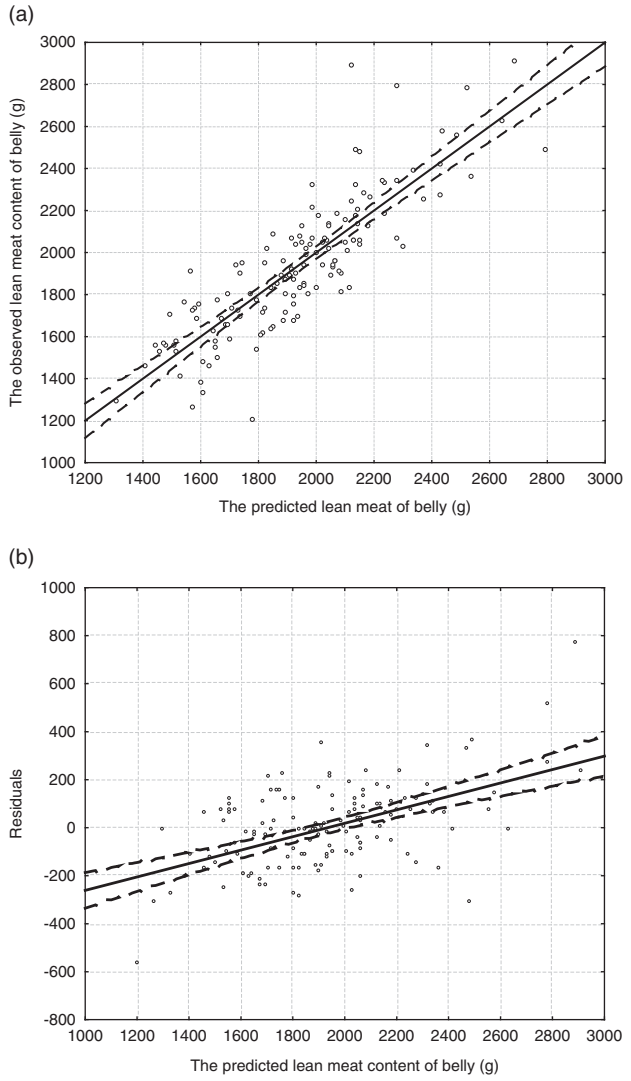


Figure 3 Scatter plots of regression line with confidence intervals (a) and residuals (b) representing differences between lean meat content (g) in pork belly based on dissection and prediction.

with the deposition of protein and fat in the body (Schinckel, 2001). Pigs are characterized by breed and interindividual variability in relation to this feature (Szulc *et al.*, 2012). Crossing the border of the steady growth of muscle and fat tissues causes the rapid growth of the second. This is directly linked to an appropriate level of nutrition (Skiba *et al.*, 2012). With an increasing slaughter mass of finishers the mass of primal cuts also increases, with the exception of belly (Borzuta *et al.*, 2010), which on the example of half-carcass mass, also confirms our findings.

The tissue composition of belly is associated with the evaluation of pig carcasses on the basis of the overall lean meat content. A higher lean meat content for the whole carcass is the result of the changing structure of the commercial pig population in Poland. Over the last few years an increase in slaughter mass and average lean meat content of the carcass has been achieved (Lisiak *et al.*, 2012). In agreement with the observations of other authors, we reported that the higher meat classes and lower average backfat thickness are associated with a decrease in the percentage of belly in the carcass (Stupka *et al.*, 2004; Pulkrábek *et al.*, 2006; Duziński *et al.*, 2015), but with an increasing muscle mass and percentage of meat in belly (Lonergan *et al.*, 2001). A belly muscle content >50% is considered a preferred feature in terms of production and consumption (Pulkrábek *et al.*, 1998). We easily obtained this value in the research population, except for the carcasses in the class R.

The tissue composition of belly, and especially its muscle content, depends on the interactive effects of sex and half-carcass mass. It turns out that the sex of pigs is an important determinant of the muscle content in bellies from heavy half-carcasses, but would not impact this trait in light half-carcasses. This is in accordance with the fact that barrows are characterized by a higher accumulation of fat in the belly than gilts during the longer lasting finishing period (Freeden, 1980; Correa *et al.*, 2008).

The regression equations developed in this study allow an estimation of the percentage value and quantity of meat in belly. The lean meat content in belly has a significant economic impact on processing and consumer acceptance of pork (Bahelka *et al.*, 2011); thus, it is advisable to determine this parameter precisely. The use in the equations of the lean meat content of the carcass is justified owing to its relationship, and this confirmed its relationship with the content of the meat in belly (Vališ *et al.*, 2005). Genetic selection and progress in pig nutrition have led to a more efficient conversion of feed into the growth of muscle tissue (Schinckel, 2001). The heritability of lean meat content in belly has been estimated in the range 0.21 to 0.34 (Tholen *et al.*, 2001; Hermesch, 2008).

The introduction of half-carcass mass to the equations helped to increase the precision of the estimation, and therefore was also justified statistically. In addition, in our earlier study one of the parameter for estimating the mass of belly was also carcass weight (Lisiak *et al.*, 2015). However, Freeden (1980) suggested that neither mass of carcass nor belly were good indicators of the quality of this cut. The apparent discrepancy between results of Freeden (1980) and present ones could be due to the previously mentioned changing structure of slaughtered finishing pigs over the years. The present raw material is characterized by a higher relationship to half-carcass mass and primal cuts.

A quick estimation of bellies allows an instant determination of the technological value and the separation of raw material. The development of equations is of particular importance in the context of the changing tissue composition of belly. The assessment of composition is difficult because of the large diversity between the interleaving of intermuscular fat and meat (Stupka *et al.*, 2004). Thinner bellies are characterized by a lighter front surface, which distorts the measurement surface contributing to large measurement errors (Hermesch, 2008). However, the studies conducted on modern devices estimate not only the whole carcass lean meat content, but also primal cuts and achieve the precision of accuracy similar to manual dissection (Picouet *et al.*, 2010;

https://doi.org/10.1017/S1751731115001433 Published online by Cambridge University Press

Daumas *et al.*, 2013). Among all primal cuts, magnetic resonance imaging techniques allows a very good prediction of muscle and subcutaneous fat tissue quantities, even though prediction of intermuscular fat quantity is slightly less accurate (Monziols *et al.*, 2006). However, for economical and practical reasons, it is important to develop equations based on measurements that can easily be done in practice to predict belly composition, as presented in this study.

Conclusions

Summing up the results of our research, it should be noted that sex mainly affected the amount of fat with skin obtained from the belly of pig carcasses. In addition, sex had an impact on the percentage level of all the analysed parameters. The study evidenced a proportional increase in belly mass and all of its tissues, with an increase in half-carcass mass, indicating that increasing carcass weight does not modify the proportion of tissue components in belly. Lean meat content class affected the belly tissue composition for the mass of muscles, fat with skin and bones and similar differences were noted for the percentage analysis of these components. The demonstration of the interaction between the half-carcass mass and sex emphasizes the merits of taking this factor into account, particularly with heavier carcasses. The equations developed based on the half-carcass mass and lean meat content allow for the fast and highly accurate determination of the lean meat content in belly, without the use of advanced equipment. This suggested solution may be used directly in the production line. Knowledge of the factors influencing the tissues composition of pork bellies and the expected results, if they occur, permits a quick and easy evaluation of raw material and its allocation to the adequate market.

Acknowledgements

This work was financed from statutory activity. The authors wish to thank K. Bernhardt for revising the English version of the manuscript.

References

Bahelka I, Oravcová M, Hanusová E and Demo P 2011. The effect of sex and terminal sire line on carcass characteristics of pork belly. Archiv Tierzucht 54, 264–270.

Borzuta K, Lisiak D, Borys A, Strzelecki J, Magda F, Grześkowiak E and Lisiak B 2010. Study on the effect of lean meat content on commercial value of porcine carcass. Nauka Przyroda Technologie 4, 1–14.

Correa JA, Gariepy C, Marcoux M and Faucitano L 2008. Effects of growth rate, sex and slaughter weight on fat characteristics of pork bellies. Meat Science 80, 550–554.

Daumas G, Donko T and Monziols M 2013. Identification of possible and relevant post mortem reference methods for carcass composition. In Proceedings of 2nd Annual Conference of COST action farm animal imaging, Kaposvar, Hungary (ed. C Maltin, C Craigie and L Bünger), pp. 14–17. Quality Meat Scotland, Ingliston, UK.

Duziński K, Knecht D, Lisiak D and Środoń S 2015. The estimation of pork carcass primal cuts value based on backfat thickness. Journal of Central European Agriculture 16, 112–121.

EC 2006. EC Regulation, Commission Regulation No 1197/2006 of 7 August 2006 amending Regulation (EEC) No 2967/85 laying down detailed rules for the application of the Community scale for grading pig carcasses. Official Journal of the European Union L217, 6–7.

EC 2011. EC Decision, Commission implementing Decision No C(2011) 5745 of 16 August 2011 amending Decision 2005/240/WE authorising methods for grading pig carcasses in Poland. Official Journal of the European Union L209, 43–48.

Freeden HT 1980. Yields and dimensions of pork bellies in relation to carcass measurements. Journal of Animal Science 51, 59–68.

Hermesch S 2008. Genetic relationships between composition of pork bellies and performance, carcase and meat quality traits. Animal 2, 1178–1185.

Knecht D, Jankowska A and Zaleśny G 2012. The impact of gastrointestinal parasites infection on slaughter efficiency in pigs. Veterinary Parasitology 184, 291–297.

Kosovac O, Vidović V, Živković B, Radović Č and Smiljaković T 2009. Quality of pig carcasses on slaughter line according to previous and current EU regulation. Biotechnology in Animal Husbandry 25, 791–801.

Kouba M and Bonneau M 2009. Compared development of intermuscular fat and subcutaneous fat in carcass and primal cuts of growing pigs from 30 to 140 kg body weight. Meat Science 81, 270–274.

Lisiak D, Borzuta K, Janiszewski P, Magda F, Grześkowiak E, Strzelecki J, Powałowski K and Lisiak B 2012. Verification of regression equations for estimating pork carcass meatiness using CGM, IM-03, Fat-O-Meat'er II and Ultra-Fom 300 devices. Annals of Animal Science 12, 585–596.

Lisiak D, Duziński K, Janiszewski P, Borzuta K and Knecht D 2015. A new simple method for estimating the pork carcass mass of primal cuts and lean meat content of the carcass. Animal Production Science 55, 1044–1050.

Lonergan SM, Huff-Lonergan E, Rowe LJ, Kuhlers DL and Jungst SB 2001. Selection for lean growth efficiency in Duroc pigs influences pork quality. Journal of Animal Science 79, 2075–2085.

Marcoux M, Pomar C, Faucitano L and Brodeur C 2007. The relationship between different pork carcass lean yield definitions and the market carcass value. Meat Science 75, 94–102.

Monziols M, Collewet G, Bonneau M, Mariette F, Davenel A and Kouba M 2006. Quantification of muscle, subcutaneous fat and intermuscular fat in pig carcasses and cuts by magnetic resonance imaging. Meat Science 72, 146–154.

Nam KC, Jo C and Lee M 2010. Meat products and consumption culture in the East. Meat Science 86, 95–102.

Oh SH and See MT 2012. Pork preference for consumers in China, Japan and South Korea. Asian-Australasian Journal of Animal Sciences 25, 143–150.

Person RC, McKenna DR, Griffin DB, McKeith FK, Scanga JA, Belk KE, Smith GC and Savell JW 2005. Benchmarking value in the pork supply chain: processing characteristics and consumer evaluations of pork bellies of different thickness when manufactured into bacon. Meat Science 70, 121–131.

Picouet PA, Teran F, Gispert M and Font-i-Furnols M 2010. Lean content prediction in pig carcasses, loin and ham by computed tomography (CT) using a density model. Meat Science 86, 616–622.

Pulkrábek J, Pavlík J, Smital J, Fiedler J and Houška L 1998. Quantification of changes of the carcass at various slaughter weight. Scientia Agriculturae Bohemica 29, 119–127.

Pulkrábek J, Pavlík J, Vališ L and Vítek M 2006. Pig carcass quality in relation to carcass lean meat proportion. Czech Journal of Animal Science 51, 18–23.

Schinckel AP 2001. Nutrient requirements of modern pig genotypes. In Recent developments in pig nutrition 3 (ed. J Wiseman and PC Garnsworthy), pp. 399–438. Nottingham University Press, Nottingham, UK.

Skiba G, Raj S, Poławska E, Pastuszewska B, Elminowska-Wenda G, Bogucka J and Knecht D 2012. Profile of fatty acids, muscle structure and shear force of musculus longissimus dorsi (MLD) in growing pigs as affected by energy and protein or protein restriction followed by realimentation. Meat Science 91, 339–346.

Stetzer AJ and McKeith FK 2003. Benchmarking value in the pork supply chain: quantitative strategies and opportunities to improve quality Phase I. American Meat Science Association, Savoy, IL. pp. 1–6.

Stupka R, Šprysl M and Čítek J 2004. Evaluation of the formation of the belly lean meat part in relation to the achieved carcass lean meat share. Scientia Agriculturae Bohemica 35, 104–110.

Szulc K, Skrzypczak E, Buczyński JT, Stanisławski D, Jankowska-Mąkosa A and Knecht D 2012. Evaluation of fattening and slaughter performance and

https://doi.org/10.1017/S1751731115001433 Published online by Cambridge University Press

determination of meat quality in Złotnicka Spotted pigs and their crosses with the Duroc breed. Czech Journal of Animal Science 57, 95–107.

Tholen E, Brandt H, Henne H, Stork FJ and Schellander K 2001. Genetic foundation of AutoFOM-traits. Archiv Tierzucht 44, 167–179.

Tomović VM, Žlender BA, Jokanović MJ, Tomović MS, Šojić BV, Škaljac SB, Tasić TA, Ikonić PM, Šošo MM and Hromiš NM 2014. Technological quality and composition of the *M. semimembranosus* and *M. longissimus dorsi* from Large White and Landrace pigs. Agricultural and Food Science 23, 9–18.

Uttaro B and Zawadski S 2010. Prediction of pork belly fatness from the intact primal cut. Food Control 21, 1394–1401.

Vališ L, Pulkrábek J, Pavlík J, Vítek M and Wolf J 2005. Conformation and meatiness of pork belly. Czech Journal of Animal Science 50, 116–121.

Walstra P and Merkus GSM 1996. Procedure for assessment of the lean meat percentage as a consequence of the new EU reference dissection method in pig carcass classification. Report ID-DLO 96.014, DLO-Research Institute for Animal Science and Health, Zeist, The Netherlands.

https://doi.org/10.1017/S1751731115001433 Published online by Cambridge University Press