POLISH JOURNAL OF FOOD AND NUTRITION SCIENCES

http://journal.pan.olsztyn.pl
e-mail: pjfns@pan.olsztyn.pl

Pol. J. Food Nutr. Sci.
2009, Vol. 59, No. 4, pp. 329-333

QUALITY AND TECHNOLOGICAL PROPERTIES OF MEAT FROM LANDRACE-YORKSHIRE × DUROC AND LANDRACE-YORKSHIRE × DUROC-PIETRAIN FATTENERS

Halina Sieczkowska, Maria Koćwin-Podsiadła, Elżbieta Krzęcio, Katarzyna Antosik, Andrzej Zybert

Chair of Pig Breeding and Meat Science, University of Podlasie, Siedlce, Poland

Key words: fatteners, crossbreds, hot carcass weight, *RYR1* gene, meat quality

The present study was aimed at evaluating – for the domestic meat industry – the crosses of Danish pig breeds, originating from mating Landrace--Yorkshire (LY) sows with Duroc or Duroc-Pietrain (DP) boars, as regards their burdening with *RYR1* gene, as well as meat quality and technological value (including hot carcass weight). The studies were conducted on 64 porkers from two genetic groups: LY×D and LY×DP. Within each genetic group two weight classes were separated – 80 kg and 90 kg hot carcass weight. The model values for physicochemical properties and the technological value of meat obtained from LY×D fatteners, irrespective of the weight class (80 kg or 90 kg), as well as the 100% resistance of those animals to stress, fully justify their use for the commercial production of fatteners. In the national programme for commercial production the LY×DP crosses may also be used, though a preference should be made for slaughter at the higher hot carcass weight (90 kg) as a clear improvement was observed of the most important for the processing industry meat quality traits, expressed by the significantly lower drip loss during storage and higher technological yield (TY).

INTRODUCTION

The incompetent use of porkers in commercial crossing of both maternal (principally PL) and paternal lines (Pietrain, Hampshire) of high carcass meatiness may lead to a deterioration of the quality of meat products [Koćwin-Podsiadła, 1994; Różycki, 1998]. The national meat industry requires the raw material to meet high quality parameters with a simultaneous high share of meat in the carcass and prefers to slaughter fatteners at higher body weights. Despite the fact that the meat from lighter carcasses demonstrates a higher post-slaughter meatiness, it has a limited processing value [Grześkowiak, 1999; Zybert *et al*., 2001].

The breeds imported from Denmark, currently used in Poland for the improvement of slaughter pigs, are characterised both by a high muscle deposition and good quality of raw and processed meats, which is of special importance for the meat industry [Koćwin-Podsiadła *et al*., 2003, 2004b; Sieczkowska *et al*., 2007].

The present studies were aimed at evaluating, for the national meat industry, the crosses of Danish pig breeds, originating from mating Landrace-Yorkshire sows with Duroc (typical for the commercial production in Denmark) or Duroc-Pietrain boars (recommended for the national commercial production in Poland), as regards their burdening with RYR1 gene as well as meat quality and technological value (including hot carcass weight).

MATERIAL AND METHODS

The studies were conducted on 64 porkers from two genetic groups (32 animals each): Landrace-Yorkshire × Duroc – (LY×D) and Landrace-Yorkshire × Duroc-Pietrain – (LY×DP). Within each genetic group two classes of hot carcass weight (HCW) were separated: I – 80.0±2.5 kg and II – 90.0±2.5 kg. Both genetic groups and carcass weight classes contained the same numbers of gilts and castrates. Fatteners LY×D came from 10 litters (from associations of 10 LY gilts with 2 Duroc boars), and fatteners LY×DP came from 8 litters (from associations of 8 LY gilts with 3 DP boars). The animals came from the Jagodne Breeding Center, Poland. The parental animals of the fatteners tested were imported from Denmark (except Pietrain breed). The environmental and nutritional conditions were the same for all animals (Cargill complete concentrates according to age) throughout the rearing period and so were the slaughter and post-slaughter procedures. The fatteners were slaughtered during the autumn season (September-October), 2-4 h after transport (300 km), using an electric stunner (INARCO Dutch line) and bled lying down, in accordance with the procedure accepted at the Meat Plant SOKOŁÓW S.A., Sokołów Podlaski, Poland.

The analysed fatteners were characterised by a mean lean meat content (estimated at the Polish Pig Progeny Testing Station with the dissection method) at a level of 57.01±3.10%.

The material estimated was analysed for burdening with RYR1 gene according to the PCR/RFLP method [Kurył & Korwin-Kossakowska, 1993].

The evaluation of the quality of meat was performed after slaughter on the *Longissimus lumborum* (LL), on the basis of the following parameters: glycolytic potential (GP) and its components, *i.e*. content of glycogen and lactic acid, degree of muscle acidity (pH), electrical conductivity (EC), rate of ATP

Author's address for correspondence: Prof. Dr. Halina Sieczkowska, Chair of Pig Breeding and Meat Science, University of Podlasie, Prusa 14 Str., 08-110 Siedlce, Poland; tel. (48 25) 643 12 58; e-mail: hsieczkowska@ap.siedlce.pl

decomposition expressed by R_1 = IMP/ATP, meat lightness (L*), water holding capacity determined with the filter paper method (WHC), drip loss (DL), technological yield in curing and cooking processing (72°C), expressed by a TY indicator.

The glycolytic potential and its components were determined on samples of the LL muscle taken 45 min *post mortem*. The GP was calculated according to the formula elaborated by Monin & Sellier [1985], the content of glycogen according to the method by Dalrymple & Hamm [1973] and that of lactic acid according to Bergmeyer [1974]. The pH measurement was performed directly on the LL muscle 35 min and 24 h *post mortem* using a pistol pH-meter MASTER (Draminski, Olsztyn, Poland) calibrated with temperature compensation.

Moreover, 45 min after slaughter the pH was determined in a water homogenate of the muscle tissue, using a CP-311 pH-meter (Elmetron, Poland) with a glass-combined electrode type OSH-10-OO. The EC was measured with an LF-Star conductometer (Ingenieurbüro Matthäus, Noblitz, Germany) 2 h after slaughter. The lightness of the muscle tissue (L*) was determined using a Minolta apparatus (model CR 310, Minolta, Osaka, Japan) 24 h after slaughter. The value of an R_1 indicator was determined 45 min *post mortem* according to the method by Honikel & Fischer [1977]. The WHC was determined 24 h *post mortem* according to the method by Grau & Hamm [1952] as modified by Pohja & Ninivaara [1957]. In turn, 48 h *post mortem* determinations were made for the drip loss according to Prange *et al*. [1977] and the meat yield in the curing and thermal processing (72°C), expressed by TY (technological yield) indicator, according to Naveau *et al*. [1985] as modified by Koćwin-Podsiadła *et al*. [1998]. The samples of LL muscle were taken 24 h after slaughter. Meat cubes 1 x 1 x 1 cm were immersed in a solution containing 12% of NaCl, 0.07% of $NaNO_2$ and 0.06% of glucose. After 24 h of curing at 4°C, the samples were thermally processed in a water bath (to an internal temperature of 72°C).

Moreover, the samples obtained from the LL muscles were analysed for proximate composition: water and dry matter according to the PN-ISO 1442:2000 standard, total protein according to the method by Kjeldahl [PN-75/A04018] and intramuscular fat according to the method by Soxhlet [PN-ISO 1444:2000].

The material analysed was also tested for the frequency of *RYR1*^{T} gene using the PCR/RFLP method [Kurył & Korwin-Kossakowska, 1993].

On the basis of the extreme values obtained for pH_{45}, pH_{24} and R_1 four meat quality classes were separated *post mortem*: RFN – reddish-pink, firm, non exudative, PSE – pale, soft, exudative, AM – acid meat, and DFD – dark, firm, dry [Koćwin-Podsiadła, 1993; Koćwin-Podsiadła *et al*., 1998, 2004a].

The results obtained were elaborated statistically using a two factor analysis of variance in an orthogonal arrangement and taking into consideration two factors: genetic group and the class of hot carcass weight. The calculations were made according to the following linear model:

$$y_{ij}=\mu+a_i+b_j+ab_{ij}+e_{ij}$$

where: μ – overall mean, a_i – effect of genetic group, i = 1.2; b_j – effect of the class of hot carcass weight, j = 1.2; ab_{ij} – interaction: genetic group x hot carcass weight, and e_{ij} – random error.

The significance of differences between means was verified using Tukey's test [Statistica 6.0 StatSoft, Tulsa, OK, USA].

Moreover, using a one-way analysis of variance in orthogonal scheme, the influence of hot carcass weight (HCW) class on meat quality traits was analysed among each genetic group [Statistica 6.0 – StatSoft, Tulsa, OK, USA], (Table 2).

Table 2 collates only meat quality traits for which statistically significant differences between HCW classes were noted.

RESULTS AND DISCUSSION

Within the group of three-breed crosses not a single animal with *RYR1*^{T} gene was identified. However, in the group of fatteners with the blood of the Pietrain breed – LY×DP, 23 animals (about 72%) constituted homozygotes resistant to stress (CC) and 9 (28%) were heterozygotes (CT) as regards the RYR1 gene.

A two factor analysis of variance in an orthogonal arrangement demonstrated a highly significant or significant (at $p\leq0.01$ and $p\leq0.05$) effect of the genetic group on the majority of the meat quality parameters analysed (except for the value of the glycolytic potential, total protein content, meat lightness, WHC and technological yield – TY), (Table 1).

The effect of the hot carcass weight class was confirmed only for the content of intramuscular fat (at $p\leq0.05$). More beneficial values of the above-mentioned parameter were affirmed in theheavier fatteners group (Table 1).

An interaction was observed between the two factors examined (genetic group × hot carcass weight class) for the value of the glycolytic potential (at $p\leq0.05$) and the acidity level of the LL muscle 24 h *post mortem* (at $p\leq0.01$), (Table 1, Figures 1 and 2).

The three-breed LY×D crosses (irrespectively of the hot carcass weight class) were characterised by a higher content of dry matter and intramuscular fat (25.38% and 2.08%, respectively) as compared to the LY×DP fatteners (22.76% and 1.44%, respectively), (Table 1). Increasing the carcass weight by 10 kg (from 80 to 90 kg) in the group of LY×D crossbreds resulted in a statistically significant (by 0.66%) increase in the content of intramuscular fat (from 1.59 for the 80 kg to 2.25 for 90 kg), (Table 2).

The content of intramuscular fat similar to that reported by Wood *et al.* [1994] as optimal, was obtained only for the LY×D fatteners, fattened till the higher carcass weight and indicating favourable sensory properties of meat, such as tenderness, juiciness and taste, so highly valued by consumers.

Candek-Potokar *et al*. [1998], Koćwin-Podsiadła *et al*. [2004b] and Krzęcio *et al*. [2004] examining populations of LY×D crossbreeds, obtained an intramuscular fat content similar to that recorded in the present work for an analogous genetic group.

Fatteners obtained by four breeds LY×DP, compared with the three-breed crosses LY×D, were (irrespectively of the class of hot carcass weight) characterised by a quicker glycolytic metabolism 45 min *post mortem*, expressed by a lower con-

TABLE 1. The influence of genetic group and class of hot carcass weight on the meat quality traits.

Specification	The influence of the analysed factors			Genetic group		Hot carcass weight		Total n=64
	Genetic group	Hot carcass weight	Interaction: genetic group x hcw	LY×D n=32	LY×DP n=32	I-80±2.50 kg n=32	II-90±2.50kg n=32	
Glycolytic potential (μmol/g)	2.63 NS	0.55 NS	7.22*	134.45±21.10	131.72±26.06	135.10±23.81	131.06±23.43	133.11±23.52
Glycogen content (μmol/g)	5.12*	NS0,04	3.69 NS	47.44^{b}±8.99	41.10^{a}±14.01	45.04±11.86	43.57±12.43	44.32±12.06
Lactate content (μmol/g)	13.92**	0.23 NS	2.67 NS	39.57^{A}±9.07	50.17^{B}±13.37	45.02±13.17	44.55±11.98	44.79±12.50
Water content (%)	6.35*	1.16 NS	1.54 NS	74.62^{a}±0.80	75.21^{b}±0.32	75.19±0.34	74.88±0.70	75.01±0.60
Dry matter content (%)	133.30**	1.25 NS	0.90 NS	25.38^{B}±0.80	22.76^{A}±0.32	23.42±1.15	24.10±1.52	23.86±1.43
Protein content (%)	0.97 NS	0.44 NS	0.20 NS	22.64±0.82	22.54±0.29	22.54±0.26	22.60±0.66	22.57±0.53
Intramuscular fat content (%)	7.82**	4.13*	2.12 NS	2.08^{B}±0.84	1.44^{A}±0.27	1.42^{a}±0.26	1.82^{b}±0.72	1.66±0.61
pH_{35} LL	12.18**	0.26 NS	1.57 NS	6.62^{B}±0.14	6.48^{A}±0.18	6.56±0.18	6.53±0.16	6.54±0.17
pH_{45} LL (homogenate)	8.58**	0.07 NS	2.12 NS	6.60^{B}±0.10	6.18^{A}±0.26	6.36±0.35	6.41±0.22	6.38±0.29
pH_{24} LL	2.14 NS	0.83 NS	7.10**	5.67±0.10	5.64±0.11	5.65±0.10	5.66±0.11	5.65±0.11
R_1	76.43**	0.38 NS	1,89 NS	0.85^{A}±0.05	0.98^{B}±0.06	0.90±0.09	0.93±0.08	0.91±0.09
EC_2 (mS/cm)	9.05**	1.73 NS	0.69 NS	2.56^{A}±0.58	3.09^{B}±0.83	3.00±0.65	2.65±0.77	2.82±0.76
Meat lightness (L*) of LL	1.45 NS	0.60 NS	0.86 NS	54.32±3.14	54.18±2.82	54.38±2.61	54.09±3.32	54.24±2.96
Drip loss 48 h (%)	15.37**	1.42 NS	3.10 NS	5.16^{A}±2.18	7.73^{B}±3.29	6.88±3.27	6.00±2.80	6.44±3.05
WHC (cm^2)	2.46 NS	2.94 NS	0.24 NS	5.41±1.21	5.74±0.86	5.79±1.20	5.37±0.78	5.58±1.05
TY (%)	1.27 NS	1.49 NS	2.15 NS	104.28±3.97	104.12±4.31	103.66±3.93	104.74±4.28	104.20±4.11

Explanations: The table presents value F_{emp} and level of significance **p≤0.01;* p≤0.05; NS – differences insignificant. The data shown in the table are arithmetic means ± standard deviation; A, B – significant difference for the analysed traits at p≤0.01; a, b – significant difference for the analysed traits at p≤0.05; EC – electrical conductivity, WHC – water holding capacity, TY – Technological Yield.

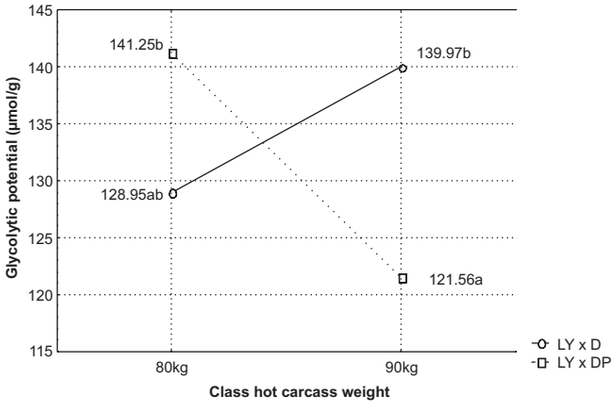

FIGURE 1. Interactive effect of genetic group and the class of hot carcass weight on the glycolytic potential.
Explanations: a, b – difference significant at p≤0.05.

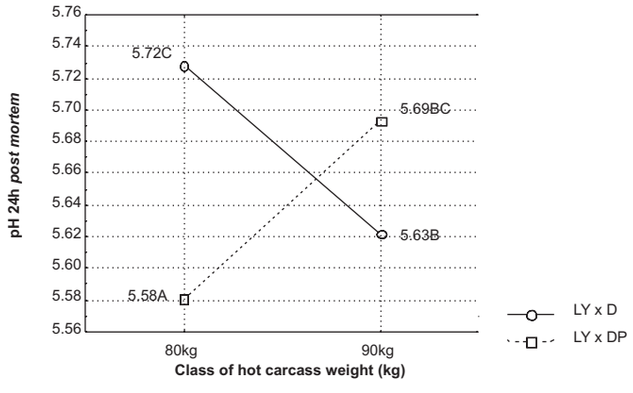

FIGURE 2. Interactive effect of genetic group and the class of hot carcass weight on pH_{24} *post mortem* of the LL muscle.
Explanations: A, B, C – difference significant at p≤0.01.

tent of lactic acid (50.17 μmol/g *vs.* 39.57 μmol/g) and a lower content of glycogen (41.10 μmol/g *vs.* 47.44 μmol/g) determined 45 min *post mortem*, and in a consequence by a lower value of pH_{35} and pH_{45} in the LL muscle (6.48 and 6.18, respectively), (Table 1). Moreover, in the meat of those animals, compared with the LY×D crossbreds, a more intensive energy metabolism was observed, expressed by the R_1 indicator (0.98) (Table 1). The values obtained in the LL muscle of the group of LY×D fatteners for pH_{35} and pH_{45} (6.62 and 6.60, respectively) and for R_1, *i.e.* the indicator of energy metabolism (0.85), are typical for normal meat (Table 1). Those crossbreds were additionally characterised by a lower electric conductivity measured 2 h *post mortem* (by 0.53 mS/cm) compared to the LY×DP crosses (Table 1). The comparatively rapid degree of muscle tissue acidity and intensive breakdown of ATP (expressed by the R_1 indicator) in LY×DP crossbreds during the first 45 min after slaughter was reflected by the frequency of PSE meat, which in this genetic group accounted for 19% (Table 3). The presence of meat with the PSE syndrome only in the group of crosses having a 25% share of Pi-

TABLE 2. Meat quality traits as affected by increasing hot carcass weight from 80.0 kg to 90.0 kg in respective genetic groups.

Specification	Genetic group	Hot carcass weight		F_{emp} Level of significance
		I 80.0±2.50kg n=16	II 90.0±2.50kg n=16	
Intramuscular fat content (%)	LY×D	1.59^{a}±0.47	2.25^{b}±0.88	2.08*
	LY×DP	1.39±0.17	1.50±0.33	1.43 NS
Drip loss 48 h (%)	LY×D	4.62±1.52	5.69±2.62	1.99 NS
	LY×DP	9.14^{B}±2.97	6.31^{A}±3.03	7.04**
WHC (cm^2)	LY×D	5.68±1.56	5.14±0.65	1.61 NS
	LY×DP	6.10^{b}±0.67	5.38^{a}±0.90	6.03 *
TY (%)	LY×D	105.20±3.82	103.36±4.02	1.76 NS
	LY×DP	102.13^{a}±3.50	106.12^{b}±4.20	8.53*

Explanations: The table presents value F_{emp} and level of significance **p≤0.01;* p≤0.05; NS – differences insignificant. The data shown in the table are arithmetic means ± standard deviation; A, B – significant difference for the analysed traits at p≤0.01; a, b – significant difference for the analysed traits at p≤0.05; WHC – water holding capacity, TY – Technological Yield.

TABLE 3. Frequency of faulty meat.

Class of meat quality	Frequency of faulty meat (%)	
	LY×D	LY×DP
RFN	100	81.25
PSE	0	18.75
AM	0	0
DFD	0	0

etrain blood on the paternal side is related to the presence in their genotype (in a heterozygosis form) of the stress susceptibility gene RYR1. Worthy of notice is that in the group of LY×D crossbreds, which were free of the RYR1 gene, there were found no carcasses with PSE type meat (Table 3).

As regards the degree of acidity of the LL muscle 24 h after slaughter, the results obtained for LY×D and LY×DP crosses, irrespectively of the carcass weight warm, were similar and typical for normal meat (5.67 and 5.64, respectively), (Table 1). Josell *et al*. [2003], examining LY×D fatteners observed a lower rate and degree of acidity, expressed by a lower pH_{45} and pH_{24} of the LL muscle as compared to the results obtained in the present work on an analogous genetic group.

In turn, Candek-Potokar *et al*. [2002], also examining a group of LY×D crossbreds, reported a more rapid decrease of pH during the first 45 min *post mortem* than both cited earlier and observed in the present studies. However, the acidity of the muscle tissue 24 h after slaughter was similar to that reported herein.

Krzęcio *et al*. [2004], in en experiment conducted on six genetic groups, including LY×D and LY×DP, reported analogous tendencies and similar results to those observed in the present study as regards the acidity of the LL muscle 45 min and 24 h *post mortem*, electric conductivity 2 h after slaughter and electric metabolism expressed by the R_1 indicator. In the LY×DP fattenerst the frequency of PSE meat calculated by the authors cited accounted for 12.5% and was lower than that observed in the present work by 6.5%.

The drip loss from the muscle tissue observed during storage must be analysed in detail as an excessive drip loss limits the possibility of selling the product as culinary meat.

The use of the Duroc boars for commercial crossing (LY×D) had, in the present studies, a positive effect on the considerable reduction of natural drip from the LL muscle 48 h after slaughter. Fatteners LY×D were (irrespectively of the hot carcass weight) characterised by a lower drip loss from the LL muscle during storage (from 24 to 48 h after slaughter), *i.e.* on average by 2.6% in relation fatteners LY×DP (Table 1). Drip loss noted 48 h *post mortem* in the group of LY ×D porkers at a level of 5.16% (Table 1) fits within extreme values stipulated by Bertram *et al.* [2000] for normal – non exudative meat.

Despite the differences observed between the genetic groups analysed in the volume of drip loss occurring during storage, there were no statistically significant differences recorded in the technological value expressed by the TY indicator. The values obtained for this indicator turned out to be high, *i.e.* 104.28% for LY×D and 104.12% for LY×DP (Table 1).

In studies conducted by Cheah *et al*. [1998] and Josell *et al*. [2003] on LY×D crossbreds, the drip loss measured 48 h *post mortem* was by 1% lower than that obtained in the present investigations on an analogous group of pigs.

Increasing the hot carcass weight by 10 kg (from 80 kg to 90 kg) in LY×D crossbreds did not result in any statistically significant differences in the volume of drip loss during storage (from 24 to 48 h), nor in the water holding capacity (WHC) or technological value (TY), (Table. 2). In turn, increasing the carcass weight by 10 kg in the group of LY×DP fatteners led to a considerable reduction in the drip loss from the LL muscle determined 48 h *post mortem* (by about 3%), improved the water holding capacity (by 0.72 cm^2) and increased by about 4% the technological value (TY), (Table 2).

These tendencies noted in the LY×DP fatteners were confirmed by the lowest value of the glycolytic potential recorded 45 min *post mortem* and, to a smaller degree, by the lower acidity of the LL muscle 24 h *post mortem* (Figures 1 and 2). Moreover, in the LY×DP genetic group the increase of carcass weight by 10 kg resulted in a statistically confirmed increase of pH recorded 24 h *post mortem* (from 5.58 to 5.69), (Figure 2).

CONCLUSIONS

Summarizing, the model values obtained for the physicochemical properties and the technological value of meat from LY×D fatteners having a 50% share of the Duroc breed on the paternal side (irrespectively of the HCW class of 80 kg or 90 kg), together with the 100% resistance of these animals to stress, fully justify the use of this type of crossing for the commercial production of fatteners. In the domestic programme for commercial production there may also be used crossbreds with a 25% share of the resistant to stress Pietrain breed on the paternal side – LY×DP. In the case of the latter cross, one should prefer slaughter at a higher hot carcass weight (90 kg), as at that weight one may observe a clear improvement of meat quality properties important for the meat industry and expressed by a significantly lower drip loss during storage and higher technological value of meat (TY). This would make it possible to obtain from those animals carcasses comparable to carcasses of three-breed crosses LY×D, both as regards lean meat content (57%) and meat quality.

REFERENCES

1. Bergmeyer H.U., Methods of Enzymatic Analysis. 1974, Academic Press, New York, p. 1127.
2. Bertram H.C., Petersen J.S., Andersen H.J., Relationship between RN- genotype and drip loss in meat from Danish pigs. Meat Sci., 2000, 56, 49–55.
3. Candek-Potokar M., Monin G., Zlender B., Pork quality, processing and sensory characteristics of dry-cured hams as influenced by Duroc crossing and sex. J. Anim. Sci., 2002, 80, 988–996.
4. Candek-Potokar M., Zlender B., Lefaucher L., Bonneau M., Effects of age and, or weight at slaughter on *Longissimus dorsi* muscle, biochemical traits and sensory quality in pigs. Meat Sci., 1998, 48, 287–300.
5. Cheah K.S., Cheah A.M., JustA., Identification and characterization of pigs prone to producing RSE (Reddish-Pink, Soft and Exudative) meat in normal pigs. Meat. Sci., 1998, 48, 249–255.
6. Dalrymple RH., Hamm R., A method for the extraction of glycogen and metabolites from a single muscle. J. Food Tech., 1973, 8, 439–444.
7. Grau R., Hamm R., Eine einfache Methode zur Bestimmung der Wasserbindung in Fleisch. Fleischwirtschaft., 1952, 4, 295–297.
8. Honikel K.O., Fischer H., A rapid method for the detection of PSE and DFD porcine muscles. J. Food Sci., 1977, 42, 1633–1636.
9. Grześkowiak E., Technological and consumers usefulness of meat from crossbreeding of Polish-White with participation of boars of Hampshire and Duroc breeds. 1999, Habilitation Thesis, Rozprawa habilitacyjna AR Szczecin. (in Polish).
10. Josell A., Von Seth G., Tornberg E., Sensory quality and the incidence of PSE of pork in relation to crossbreed and RN phenotype. Meat. Sci., 2003, 65, 651–660
11. Koćwin-Podsiadła M., Method of evaluation of faulty pork meat. Monografie nr. 26, 1993, WSRP Siedlce (in Polish).
12. Koćwin-Podsiadła M., Pigs susceptibility to stress. Hodowla i użytkowanie świń., praca zbiorowa pod redakcją B Grudniewskiej, ART. Olsztyn. 1994, wyd. II, 140 -165 (in Polish).
13. Koćwin-Podsiadła M., Krzęcio E., Antosik K., The Polish pork meat market, the meatiness and meat quality improvement in comparison to data and standards of leading UC countries. Żywność, Nauka, Technologia, Suppl., 2003, 4(37), 214–220 (in Polish)
14. Koćwin-Podsiadła M., Krzęcio E., Kurył J., Pospiech E., Grześ B., Zybert A., Sieczkowska H., Antosik K., Łyczyński. A., The influence of polymorphism of selected genes on meatiness and physicochemical and functional properties of muscle tissue. Postępy genetyki molekularnej bydła i trzody chlewnej Praca zbiorowa pod redakcją prof. M. Świtońskiego. 2004a, AR Poznań., pp 259–329 (in Polish).
15. Koćwin-Podsiadła M., Sieczkowska H., Zybert A., Krzęcio E., Antosik A., Łyczyński A., Miszczuk B., Physico-chemical and technological parameters of meat from fatteners obtained on the basis of F_0 generation imported Denmark. Anim. Sci. Pap. Rep., 2004b, 22, 153–159.
16. Koćwin-Podsiadła M., Przybylski W., Kaczorek S., Krzęcio E., Quality and technological yield of PSE (pale, soft, exudative) – Acid – and Normal pork. Pol. J. Food. Nutr. Sci., 1998, 48, 217–222.
17. Krzęcio E., Antosik A., Koćwin-Podsiadła M., Zybert A., Sieczkowska H., Kurył J., Łyczyński A., Quality and technological value of meat from porkers of six genetic groups as related to *RYR1*^{T} gene. Anim. Sci. Pap. Rep., 2004, 22, 19–30.
18. Kurył J., Korwin-Kossakowska A., Genotyping of Hal^n locus by PCR method explains some cases of incomplete penetrance of *Hal*^{n} gene. Anim. Sci. Pap. Rep., 1993, 11, 271–277.
19. Monin G., Sellier P., Pork of low technological quality with a normal rate of muscle pH fall in the immediate *post mortem* period: the case of the Hampshire breed. Meat. Sci., 1985, 13, 49–63.
20. Naveau J., Pommeret P., Lechaux P., Proposition d´une methode de mesure du rendement technologique: la„method Napole". Techni. Porc., 1985, 8, 7–13.
21. Pohja N.S., Ninivaara F.P., Die Estimmung der Wasserbindung des Fleisches mittels der Konstandruckmethods. Fleischwirtschaft., 1957, 9, 193–195.
22. Polish Standard PN-75/A-04018. Determination of nitrogen according to Kjeldahl and prediction for protein content (in Polish).
23. Polish Standard PN-ISO 1442:2000. Determination of water content (in Polish).
24. Polish Standard PN- ISO 1444:2000. Determination of free fat content (in Polish).
25. Prange H., Jugrrt I., Schrner E., Untersuchungen zur Muskel fleischqualitaet beim Schwein, arch. Exper. Vet. Med. Leipzig., 1977, 31, 235–248.
26. Różycki M., The improvement of breeding value of pigs regarding the fattening and slaughter performance. 1998, *in:* Mat. Konf. „Genetyczne i środowiskowe aspekty intensyfikacji produkcji trzody chlewnej, Balice, 1998, pp. 3–20 (in Polish).
27. Sieczkowska H., Koćwin-Podsiadła M., Krzęcio E., Zybert A., Antosik K., Quality and technological usefulness of meat from fatteners of Landrace and Landrace x Yorkshire Danish maternal lines. Roczn. Nauk. PTZ, 2007, 3, 4, 355–363.
28. Wood J.D., Wiseman J., Cole D.J.A., Control and manipulation of meat quality. 1994, *in*:: Principles of Pig Science. Nottingham University Press, pp. 433–456.
29. Zybert A., Koćwin-Podsiadła M., Krzęcio E., The influence of hot carcass weight on quantitative traits and lean meat content estimated according to method used in Polish pig testing stations. Pol. J. Food. Nutr. Sci., 2001, 51, 3(S), 252–255.

Received October 2008. Revision received June and accepted August 2009.