



Meat Quality of Crossbred Porkers without the Gene *RYR1^T* Depending on Slaughter Weight

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ABSTRACT: The first aim of the study was to compare selected meat quality parameters in porkers without the gene *RYR1^T* (ryanodine receptor gene). These were porkers slaughtered at 100 to 115 kg and 116 to 130 kg live weight. The second aim of the study was to determine the occurrence frequency of standard-quality meat (red, firm, nonexudative [RFN]) and the occurrence frequency of defective meat (pale, soft, exudative [PSE] and acid, soft, exudative [ASE]). The analysis was conducted on the *longissimus lumborum* muscle in 114 crossbred porkers. The porkers were a cross of Camborough 22 sows and boars from lines 337PIC (Pig Improvement Company), Norsvin Landrace and Pietrain. All of the animals were provided with identical environmental and nutritional conditions. The average weight of the slaughtered animals in the light and heavy groups was 110 kg and 122 kg, respectively. Both groups had the same average post-slaughter meatiness (56.5%). A statistical analysis of selected meat-quality parameters did not show any significant differences between the weight groups. On the other hand, the classification based on carcass quality showed an occurrence frequency of defective meat in heavier crossbred porkers (116 to 130 kg) that was three times higher than in those crossbred animals which weighed 100 to 115 kg when slaughtered. In porkers without the gene *RYR1^T*, the defective meat types PSE and ASE occurred with a frequency of 17.54%. (**Key Words:** Acid Meat, Crossbreds, PSE, *RYR1^T* Gene, Slaughter Weight)

INTRODUCTION

One of the unsettling problems faced by the Polish and European meat industries is the high share of pig carcasses with symptoms of wateriness (Pospiech et al., 1998; Fischer 2007). For this reason, it is necessary to look for ways of decreasing the watery meat in pig carcasses. The genetic improvement of animals and the optimisation of

environmental factors must be taken into account when working to improve meat quality (Eblis et al., 1999; Monin et al., 1999; Rosenvold and Andersen, 2003; Migdał et al., 2004; Koćwin-Podsiadła et al., 2006; Łyczyński et al., 2006; Borzuta et al., 2010; van Arendonk, 2011). The reports in scientific publications, however, are citing more and more frequent cases of lowered meat quality in animals without the *RYR1^T* (ryanodine receptor gene) gene (Fàbrega et al., 2002; Kortz et al., 2004; Florowski et al., 2007). At the same time, many authors are reporting that an increase in the live weight of porkers may be one of the factors which improve the quality of meat as well as limit the defects related to wateriness (Martin et al., 1980; Lee and Choi, 1999; Beattie et al., 1999; Koćwin-Podsiadła et al., 2002; Przybylski et al., 2005; Zybert et al., 2005; Correa et al., 2006; Strzelecki et al., 2007). This view, though, has not been confirmed by all research studies done in this area (Pospiech et al., 1983; Cisneros et al., 1996; Leach et al.,

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1996; Latorre et al., 2004; Barowicz et al., 2006).

The first aim of our study was to compare selected quality parameters for the meat of porkers without *RYRI*^T and slaughtered at 100 to 115 kg and 116 to 130 kg live weight. The second aim was to determine the occurrence frequency of standard-quality meat (red, firm, nonexudative [RFN]) and defective meat (pale, soft, exudative [PSE] and acid, soft, exudative [ASE]).

MATERIAL AND METHODS

The study was conducted on 114 porkers which were crossbred sows and boars of Camborough 22, lines 337PIC (Pig Improvement Company, Hendersonville, TN, USA) (C22×PIC), N = 34; Norsvin Landrace (C22×NL), N = 35 and Pietrain (C22×Pi), and N = 45. In each group, there were similar numbers of barrows and gilts sired by three boars. All the animals were provided with identical environmental and nutritional conditions.

After fattening, the animals were subjected to starvation for 20 hours. Next the animals were transported in special vehicles to a large industrial slaughter house located 40 km away. The slaughtering was conducted in accordance with standard veterinary and technological regulations and took place after 2 hours of lairage. Porkers were stunned using electrical current. Manual Lotterschmidt Weinberger tongs were used. The porkers were bled in a horizontal position.

The porkers were weighed before being slaughtered. After slaughter, the ULTRA-FOM 300 apparatus was used to estimate meatiness in the *longissimus lumborum* (*ml*) muscle of the warm carcasses. The meat quality of the hanging carcasses was assessed in the *ml*, at the level of the last thoracic vertebra. The estimation of meat quality was based on the measurements of its pH (pH_{45'} and pH_{24h}), electrical conductivity (EC_{90'} and EC_{24h}), lightness (L*), and thermal drip and water holding capacity. Meat pH, electrical conductivity, and lightness were determined using the HandyLab 2 (Schott Geräte, Mainz, Germany) apparatus

with a glass and calomel electrode, LF-STAR (Matthäus, Nobitz, Germany) apparatus, and Minolta 508i spectrophotometer, respectively. Thermal drip was calculated as the difference in the meat sample weight before and after heating in a water bath at 85°C for 10 min.

Water holding capacity measured as free water content (%) was determined with Grau and Hamm's method (1952) modified by Pohija and Niinivaara (1957).

Meat quality was determined in accordance with the method described by Borzuta and Pospiech (1999), with particular focus on the following parameters:

RFN pH_{45'} >5.8; EC_{90'} <8 mS/cm; EC_{24h} <8 mS/cm
 PSE pH_{45'} ≤5.8 ; EC_{90'} ≥8 mS/cm ; EC_{24h} ≥8 mS/cm
 ASE pH_{45'} >5.8; EC_{90'} <8 mS/cm; EC_{24h} ≥8 mS/cm.

Polymorphism in locus *RYRI* was established using the PCR-RLFP (polymerase chain reaction-restriction fragment length polymorphism) method (Fujii et al., 1991). The biological material comprised porcine blood. Isolation of DNA from blood leukocytes was based on methodology provided by Kawasaki (1990) and modified by Coppieters et al. (1992). An Engine MJ Research (PTC-200 Peltier Thermal Cycler, Ramsey, MN, USA) thermocycler was used to perform the PCR amplification.

For the purpose of the analyses, the crossbred porkers were divided into two weight groups: 100 to 115 kg (light porkers) and 116 to 130 kg (heavy porkers).

Statistical methods

The obtained results were statistically verified using the SAS v. 9.2 (2011) statistical package. Basic statistical parameters were determined with the MEANS-SAS v. 9.2. (2011) procedure.

In the first analysis (Tables 1, 2, and 3), the significance of the experimental factors (breed, sex, slaughter weight, warm carcass weight, post-slaughter meatiness) was determined with a multifactorial/multivariate analysis of

Table 1. Evaluation of the influence of experimental factors on the examined features

Item	Fixed effects			Regression effects β	
	Breed	Sex	Slaughter weight	Hot carcass weight	Meatiness
Slaughter weight (kg)	**	NS	-	**	NS
Hot carcass weight (kg)	**	NS	**	-	NS
Meatiness (%)	NS	**	NS	NS	-
pH _{45'}	NS	NS	NS	NS	NS
pH _{24h}	*	*	NS	**	NS
EC _{90'} (mS/cm)	NS	NS	NS	NS	NS
EC _{24h} (mS/cm)	NS	NS	NS	NS	NS
Lightness (L*)	**	NS	NS	NS	NS
Cooking loss (%)	NS	NS	NS	NS	NS
WHC, free water content (%)	**	NS	NS	NS	NS

NS, not significantly; EC, electrical conductivity; WHC, water holding capacity.

** Statistical significance at (p≤0.01); * Statistical significance at (p≤0.05).

Table 2. Selected meat quality parameters depending on animal breed

Traits	Breed					
	C22×PIC		C22×NL		C22×Pi	
	Mean	SD	Mean	SD	Mean	SD
Slaughter weight (kg)	118.69 ^A	8.13	115.97 ^B	7.15	113.69 ^C	5.60
Hot carcass weight (kg)	92.13 ^A	6.44	90.10 ^B	6.13	88.11 ^C	4.82
Meatiness (%)	56.98	3.66	56.97	2.52	55.79	3.02
pH _{45'}	6.09	0.26	6.19	0.31	6.04	0.26
pH ₂₄	5.54 ^a	0.04	5.57 ^b	0.08	5.53 ^a	0.08
EC _{90'} (mS/cm)	5.24	2.50	4.68	2.41	4.77	2.32
EC _{24h} (mS/cm)	5.63	2.62	5.47	2.66	5.19	2.22
Lightness (L*)	56.99 ^A	3.23	54.85 ^B	1.96	57.40 ^A	2.79
Cooking loss (%)	27.20	1.65	27.09	2.38	27.64	1.86
WHC, free water content (%)	36.88 ^A	2.29	34.89 ^B	1.95	36.49 ^A	2.13

C22, Camborough; PIC, Line 337; NL, Norsvin Landrace; Pi, Pietrain; SD, standard deviation; EC, electrical conductivity; WHC, water holding capacity.

^{A-C} Statistical significance at (p≤0.01); ^{a-c} Statistical significance at (p≤0.05).

covariance using the GLM-SAS v. 9.2. (2011) procedure, according to the following linear model:

$$y_{ijkl} = \mu + g_i + s_j + sw_k + \beta_1 cw_{ijkl} + \beta_2 mt_{ijkl} + e_{ijkl}$$

y_{ijkl} , value of the analysed trait;

μ , total mean;

g_i , animal breed fixed effect (i = 1,2,3);

s_j , sex of the animal (j = 1,2);

sw_k , slaughter weight in the group (k = 1,2);

β_1, β_2 , partial regression coefficients;

cw_{ijkl} , weight of warm carcass;

mt_{ijkl} , post-slaughter carcass meatiness;

e_{ijkl} , random error;

In the second analysis (Table 4), breed groups were divided into two weight groups; the 100 kg to 115 kg slaughter weight group and the 116 kg to 130 kg group.

To thoroughly compare the means for a given item, a

Table 3. Selected meat quality parameters depending on slaughter weight of animals

Traits	Slaughter weight (kg)			
	100 to 115		116 to 130	
	Mean	SD	Mean	SD
Slaughter weight (kg)	110.05 ^A	3.38	122.18 ^B	4.21
Hot carcass weight (kg)	85.43 ^A	3.27	94.77 ^B	4.06
Meatiness (%)	56.53	2.87	56.49	3.41
pH _{45'}	6.12	0.25	6.09	0.31
pH ₂₄	5.54	0.06	5.55	0.09
EC _{90'} (mS/cm)	4.63	2.04	5.17	2.72
EC _{24h} (mS/cm)	5.22	2.28	5.61	2.66
Lightness (L*)	56.51	2.72	56.51	3.13
Cooking loss (%)	27.61	1.88	27.06	2.05
WHC, free water content (%)	36.19	2.25	36.05	2.30

SD, standard deviation; EC, electrical conductivity; WHC, water holding capacity.

^{A-C} Statistical significance at (p≤0.01).

number of multiple comparisons were conducted using Duncan's new multiple range test and the T-test. Correlations between given factors (meat quality classes, genotype, pre-slaughter body weight) were determined using the contingency analysis procedure with Fisher's exact test and V_{Cramer} coefficient (proc FREQ- SAS v. 9.2., 2011).

RESULTS AND DISCUSSION

None of the examined porkers had the stress resistance gene ($RYRI^T$). The evaluation of the significance of experimental factors on the analysed meat qualitative features was presented in Table 1. The evaluation showed that breed affects several of the qualitative parameters of meat but sex only affects carcass meatiness and the final pH value of meat. Among the three analysed animal breeds, the C22×NL crossbred animals proved to have the highest pH₂₄, lowest L* value, and lowest free-water content (p≤0.05; Table 2). The average weight of the slaughtered animals in the group of lighter porkers was 110 kg, while in the group of heavier porkers it was 122 kg. The same post-slaughter average meatiness of 56.5% was found in both groups. The analysis of the qualitative meat features, according to the weight group of the slaughtered animals, did not show any statistically significant differences (p>0.05; Table 3). The obtained low pH_{45'} values indicated the fast course of glycogenolysis. These values were much lower than in the studies of other researchers (Czyżak-Runowska et al., 2005; Grześkowiak et al., 2009; Łyczyński et al., 2009; Edwards et al., 2010). In the slaughtered carcasses of porkers with higher body weights, we observed a tendency for lower free-water content, which was not statistically confirmed (p = 0.6051; Table 3). A higher free-water content was noticeable in the heavier carcasses of the C22×PIC crossbred animals (37.01%) compared to the heavier

Table 4. Selected meat quality parameters depending on breed and slaughter weight (kg) of animals

Trait	C22×PIC 100 to 115		C22×PIC 116 to 130		C22×NL 100 to 115		C22×NL 116 to 130		C22×Pi 100 to 115		C22×Pi 116 to 130	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	Slaughter weight (kg)	108.00	4.35	122.96	4.48	110.06	3.93	121.88	3.95	110.69	2.48	121.08
Hot carcass weight (kg)	84.30	3.85	95.26	4.18	85.40	3.69	94.81	4.10	85.81	2.86	93.79	3.89
Meatiness (%)	56.92	3.25	57.00	3.87	57.08	1.95	56.85	3.04	56.11	3.15	55.02	2.61
pH _{45'}	6.14	0.13	6.07	0.30	6.20	0.28	6.19	0.34	6.07	0.26	5.98	0.26
pH ₂₄	5.53	0.03	5.54	0.04	5.56	0.04	5.58	0.11	5.53	0.07	5.53	0.11
EC _{90'} (mS/cm)	5.18	1.29	5.26	2.87	4.47	2.31	4.90	2.55	4.54	2.09	5.33	2.81
EC _{24h} (mS/cm)	4.63	1.41	6.04	2.90	5.67	2.89	5.28	2.48	5.18	2.15	5.24	2.48
Lightness (L*)	56.32 ^{ab}	2.73	57.24 ^b	3.41	54.98 ^a	1.94	54.71 ^a	2.03	57.37 ^b	2.78	57.49 ^b	2.93
Cooking loss (%)	26.89	1.40	27.32	1.75	27.48	2.22	26.69	2.53	27.88	1.79	27.05	2.00
WHC, free water content (%)	36.54 ^{AB}	2.47	37.01 ^A	2.27	35.03 ^{ABb}	1.84	34.74 ^{Bb}	2.11	36.71 ^{ABa}	2.23	35.93 ^{AB}	1.82

C22, Camborough; PIC, Line 337; NL, Norsvin Landrace; Pi, Pietrain; SD, standard deviation; EC, electrical conductivity; WHC, water holding capacity. ^{A-C} Statistical significance at ($p \leq 0.01$); ^{a-c} Statistical significance at ($p \leq 0.05$).

carcasses of the C22×NL crossbred animals (34.74%); ($p \leq 0.05$; Table 4). As reported by Przybylski et al. (2012), a big drip loss significantly decreases the sensory value of meat.

The analysis of meat colour in our study showed that only the breed influenced meat lightness (L*), and this was seen in those porkers with a slaughter weight of 100 to 115 kg ($p \leq 0.05$; Table 4). Slaughter weight did not affect L* values. Most authors report darker colour in heavier porkers compared to lighter porkers (Barowicz et al., 2006; Virgili et al., 2012).

The average values of all quality differentiators were within what is considered the normal meat category. Nonetheless, in our study, the qualitative analysis of the *longissimus lumborum* muscle of particular carcasses revealed the presence of defective meat. The defects in most cases were related to PSE meat but in some cases, acidic

meat was observed. For that reason, further analyses included both defects (PSE and ASE). These two defects were then placed into one group – the defective meat group. Meat defects were observed in 20 carcasses, which means 17.54% of the investigated material.

Based on the distribution analysis of meat defects, a correlation was observed between the frequency of meat defects and the weight group of slaughtered animals within the entire analysed population ($p \leq 0.05$; $V_{\text{Cramera}} = 0.25$; Figure 1). The qualitative classification showed a meat defect frequency that was three times higher in the material obtained from carcasses of heavier porkers as opposed to the lighter ones, (respectively 8.47% and 27.27%). It can be assumed that slaughtered porkers of higher body weight are less resistant to the stress related to slaughtering, and in particular, to stunning. During stunning, the electric current parameters should be individually adjusted to the body

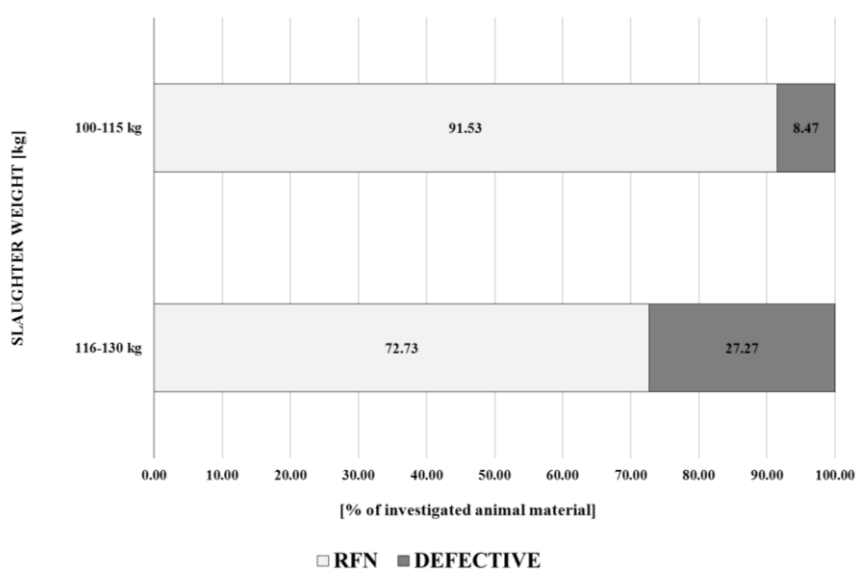


Figure 1. Frequency of occurrence of RFN meat and defective meat (PSE and ASE) depending on slaughter weight of animals. RFN, red, firm, non-exudative; PSE, pale, soft, exudative; ASE, acid, soft, exudative.

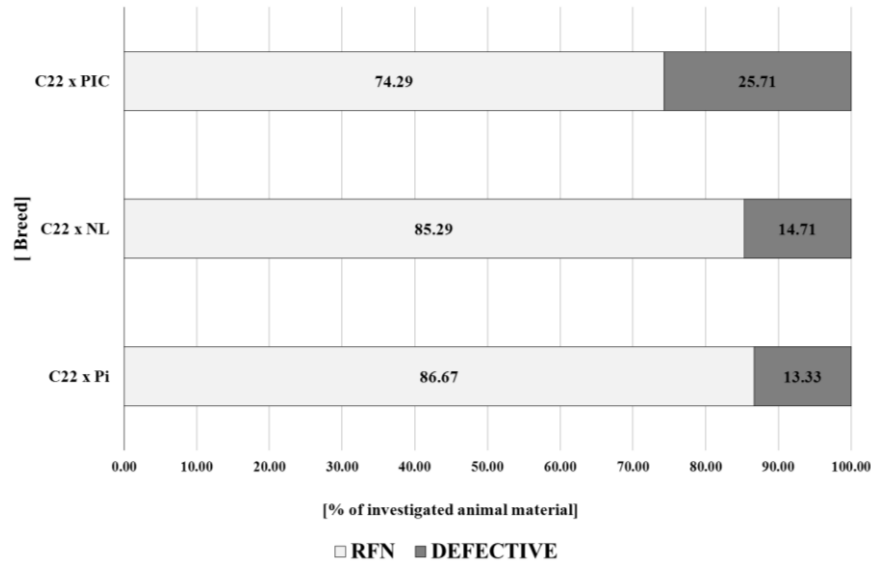


Figure 2. Frequency of occurrence of RFN meat and defective meat (PSE and ASE) depending on the breed. RFN, red, firm, non-exudative; PSE, pale, soft, exudative ; ASE, acid, soft, exudative.

weight of a given animal. The literature shows that an undeniably better meat quality is achieved when using the CO₂ stunning system than when electrical stunning is used, irrespective of the type of electrode applied, stun duration or level of current used (Velarde et al., 2000; Heather et al., 2003). Moreover, the design of slaughter handling systems and the slaughtering procedures can have an effect on the meat quality (Faucitano et al., 1998).

No significant influence of breeds ($p > 0.05$; Figure 2) and breed and slaughter-weight ($p > 0.05$; Figure 3) on the occurrence of meat defects was observed.

Pospiech et al. (1983) reached similar conclusions in their studies. They evaluated the quality of meat derived from pigs slaughtered at different body weights: 90, 100,

110, 120, and 130 kg. The mentioned authors discovered most meat defects in the groups of the lightest porkers slaughtered at the body weight of 90 kg as well as in the group of heavier ones slaughtered at 120 kg. According to these authors, the differences in metabolism may have been related to changes in the nutrition levels of the animals. Similarly, Cisneros et al. (1996) observed that meat quality decreased with the increase in slaughter weight, which was manifested in an increased thermal drip. In crossbred porkers derived from the mating of boars (Pietrain×Large White) and sows (Landrace×Large White), the increase in slaughter weight from 116 to 133 kg did not positively influence meat quality (Latorre et al., 2004). In the research conducted by Barowicz et al. (2006), the increase in the

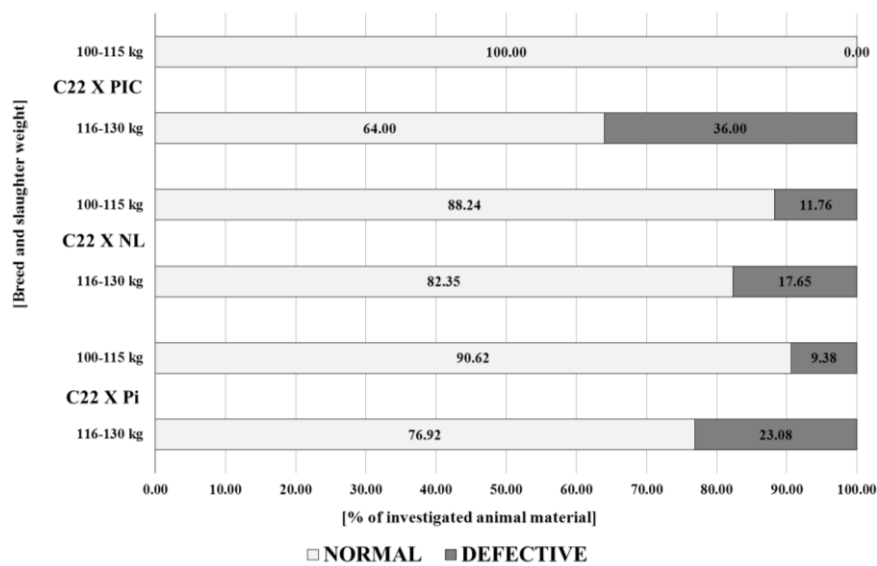


Figure 3. Frequency of occurrence of RFN meat and defective meat (PSE and ASE) depending on breed and slaughter weight of animals. RFN, red, firm, non-exudative; PSE, pale, soft, exudative ; ASE, acid, soft, exudative.

slaughter weight from 101 kg to 129 kg caused a significant darkening in the meat and the meat had a less pleasant scent. Numerous researchers report that heavier animals are characterised by better quality meat with fewer defects. These results were confirmed by the studies of Łyczyński et al. (2006a). They observed lower levels (17.1%) of defects in PSE and ASE meat. These levels were noted in heavier carcasses whose muscle tissue was characterised by a higher content of intramuscular fat compared to lighter carcasses of lower intramuscular fat content (25.7%). Similarly, the studies of Beattie et al. (1999) showed that meat quality can be improved when the carcass weight is from 70 to 100 kg. Also Correa et al. (2006) showed that porkers can be slaughtered at higher body weights of 107 to 125 kg without deterioration of carcass and meat quality. Also Strzelecki et al. (2007), in contrast to our study, showed that the slaughter weight of porkers at 133 kg, significantly improved the physicochemical and sensory parameters of meat and raw smoked tenderloin compared to porkers slaughtered at 114 kg.

CONCLUSION

Based on our research and the research of other authors, we can conclude that the elimination of the *RYRI^T* gene in carcasses does not guarantee meat of good quality. It should be pointed out, that animals of high genetic potential must receive proper nutrition and care at all the production stages including breeding, fattening, handling before slaughter, slaughter, post-slaughter handling of carcasses, and meat distribution. In summary, the level of PSE and ASE meat with defects in the carcasses without the *RYRI^T* gene, amounted to 17.54%. The conducted quality classification of *longissimus lumborum* muscle in different carcasses indicated that meat with defects occurs three times more often in the crossbred animals of higher body weight (116 to 130 kg) than in crossbred animals slaughtered at lower body weights (100 to 115 kg). Statistical analysis of meat quality parameters in different weight groups of the crossbred animals did not reveal any significant deterioration in quality. These results indicate the necessity of conducting individual quality evaluations of different carcasses.

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