

## Effect of imported Duroc boars on meat quality of finishing pigs in Estonia

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**Abstract.** The objective of this study was to evaluate the carcass and meat quality characteristics of Duroc-sired progeny marketed in May and June 2014. Carcasses of the following genotypes were evaluated: purebred Landrace (LxL), crossbred Large White x Landrace (LWxL) and LWxL crosses with Duroc (DxLW/L) and Duroc x Landrace (D/LxLW/L) terminal boars. Carcass characteristics recorded: hot carcass weight, carcass length, backfat thickness and loin eye area (LEA). The following physicochemical parameters determined in the *Longissimus thoracis* muscle were pH value, colour, electroconductivity, water-holding capacity, drip loss, cooking loss, and dry matter, protein, fat and ash content. Duroc-sired pigs were slaughtered at the older age, but at about the same live weight as those of other genotypes. The study revealed that genotypes incorporating Duroc breed had significantly shorter carcasses (D/LxLW/L –  $95.38 \pm 0.98$  cm and DxLW/L –  $96.88 \pm 0.95$  cm;  $P < 0.01$ ), but a larger LEA (D/LxLW/L –  $51.75 \pm 1.44$  cm<sup>2</sup> and DxLW/L –  $52.24 \pm 1.39$  cm<sup>2</sup>;  $P < 0.05$ ) compared to white-coloured genotypes (carcass length: LxL –  $101.12 \pm 0.95$  cm and LWxL –  $101.82 \pm 0.98$  cm; LEA: LxL –  $46.35 \pm 1.39$  cm<sup>2</sup> and LWxL –  $47.04 \pm 1.44$  cm<sup>2</sup>). Duroc sire had a significant effect on the muscle protein and intramuscular fat (IMF) content. DxLW/L genotype had the greatest IMF level ( $2.71 \pm 0.21\%$ ;  $P < 0.05$ ), while it was the lowest in the LxL and LWxL ( $1.23 \pm 0.21\%$  and  $1.71 \pm 0.22\%$ , respectively). Genotype combinations had no effect on carcass fat deposition. The differences that exist between the breeds of pigs make it possible to modify breed-specific traits such as growth performance, leanness and meat quality. It can therefore be concluded that Duroc boars provide Estonian pig breeders with a valuable source of genetic material for improving the carcass and meat quality of finisher pigs.

**Key words:** Duroc, Landrace, Large White, crossbreeding, carcass quality, meat quality, leanness, backfat.

**Abbreviations:** D – Duroc, L – Landrace, LW – Large White, FLA – fat layer area, IMF – intramuscular fat, LEA – loin eye area, WHC – water-holding capacity.

## INTRODUCTION

Growing consumer demand for healthier and enhanced meat products forces breeders to develop new practices to improve meat quality of pigs. It encourages the pig breeders to use different breeds to utilize them in commercial pig production. Production of crossbred finisher pigs is extensively used to improve farm efficiency (Bennet et al., 1983). Meat quality of pigs has become increasingly essential for the pig industry. Many factors affect meat quality of pigs, including nutrition, slaughter management, breed etc. According to Josell et al. (2003), most of the meat quality parameters are affected by breed. It is thus essential to consider that carcass and meat quality traits depend on the genotype when selecting animals for crossbreeding scheme (Jiang et al., 2012).

The number of different breeds of pigs imported to Estonia has increased over the past two decades. Beside foreign white-coloured Landrace (L) and Large White (LW) breeds, several coloured pig genotypes were introduced, which were used to improve meat quality of local finishers. The first Hampshire boars were imported from Sweden in 1999, whereas four years later they were replaced with the Pietrain breed imported from Austria. As the meat flavour and colour characteristics of the crossbred progeny genotypes above did not satisfy local consumers, the Estonian Pig Breeding Association decided to introduce another new breed from Canada. Hence the Duroc (D) boars were introduced to Estonia twenty years after the first sire breed was imported from Sweden. Several studies have shown that meat from the pigs of Duroc-sired genotypes has a higher intramuscular fat (IMF) level (McGloughlin et al., 1988; Edwards et al., 1992; Oliver et al., 1994), which affects the sensory quality of meat. Kriauzienė & Rekštys (2003) and Klimas et al. (2007) demonstrated that the crossbreeding scheme, in which a terminal Duroc boar was utilized, had superiority over other genotypes.

To choose the best crossbreeding strategy for pork production, it is important to understand, that pig carcass and meat quality characteristics depend on the breeds used. Therefore, a study was conducted to evaluate the carcass and meat quality characteristics of Duroc-sired progeny utilized in commercial pig production.

## MATERIAL AND METHODS

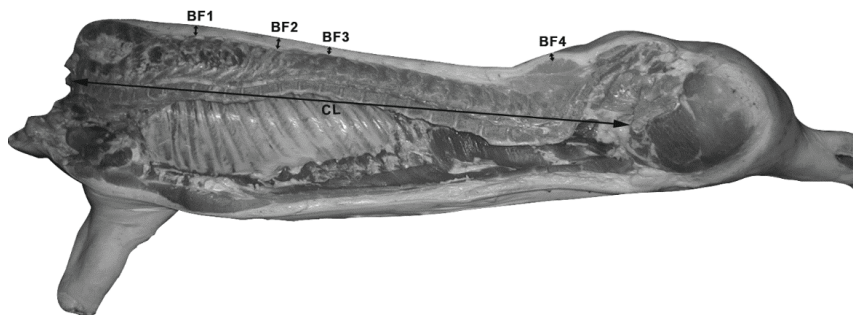
### **Animals and sample collection**

A total of 40 marketed pigs (20 gilts and 20 barrows) of four different genotypes (ten animals in each group) were evaluated from May to June 2014. The control scheme included purebred Estonian Landrace breed and its cross with Estonian Large White terminal boar. White coloured combinations were opposed to DxL and purebred Duroc-sired progeny, the maternal side of which contained LWxL genotypes. White coloured pigs were born and reared in a top nucleus, and both genotypes Duroc-sire in it in a well-managed commercial herd. The pigs were penned in groups and had ad libitum access to oat-corn-soybean meal based diet (Table 1).

**Table 1.** Chemical composition of pig diets

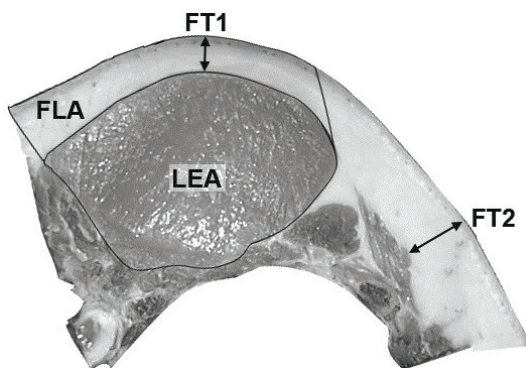
Component	Growers 25–60 kg	Finishers >60 kg
Dry matter, %	87.6	87.9
Metabolisable energy, MJ kg <sup>-1</sup>	12.6	12.4
Crude protein, %	16.0	15.0
Crude fat, %	3.4	3.0
Crude fibre, %	5.5	5.5
Crude ash, %	5.1	4.8
Lysine, g kg <sup>-1</sup>	9.8	9.8
Methionine, g kg <sup>-1</sup>	2.8	2.6
Ca, g kg <sup>-1</sup>	7.0	6.4
P, g kg <sup>-1</sup>	6.3	6.7
Na, g kg <sup>-1</sup>	1.5	1.5

Ten pigs of each genotype, aged 160–182 days, and of 98–133 kg live weight, were randomly selected. Live weight was recorded immediately prior to slaughter. Animals reared under similar conditions were slaughtered in local abattoirs. The carcasses were trimmed and bisected lengthwise along the vertebral column. Hot carcass halves were weighed after final trimming with the accuracy of 0.1 kg. Carcass measurements were taken 45 minutes after slaughter on the right side of the carcasses using a tape measure (Fig. 1) and the Intrascoper device (Alt, 2006). Intrascoper records were used to calculate the lean meat content of the carcasses according to the approved methodology (Alt, 2006).



**Figure 1.** Location of measurement sites on a carcass. Backfat thickness: BF1 – thickest spot in the shoulder; BF2 – above the 6<sup>th</sup> and 7<sup>th</sup> rib; BF3 – thinnest spot in dorsum; BF4 – highest spot above *Gluteus medius* muscle. Carcass length: CL – from the cranial edge of the first neck segment to the anterior edge of *Symphysis pubis*.

Carcasses were bisected between the 13<sup>th</sup> and 14<sup>th</sup> ribs perpendicular to the *Longissimus thoracis* muscle to take digital photos of the surface of the loin eye and the layer of fat on the above (Fig. 2) with Scan-STAR CPU device (Ingenieurbüro R. Matthäus, 2011<sup>a</sup>). Images were processed using Scan-STAR K software for PC to measure the loin eye area (LEA) and fat layer area (FLA) (Ingenieurbüro R. Matthäus, 2011<sup>a</sup>). These two areas were used to calculate the leanness index (1). Additionally, fat thickness was recorded at two separate spots (Fig. 2).



**Figure 2.** Parameters estimated with the Scan-STAR K imaging system. LEA – loin eye area, FLA – fat layer area, FT1 – fat thickness at the thinnest spot, FT2 – fat thickness above *Serratus dorsalis* muscle.

$$\text{Leanness index} = \frac{\text{Fat layer area (cm}^2\text{)}}{\text{Loin eye area (cm}^2\text{)}}, \quad (1)$$

Samples (200 g) were taken from the *Longissimus thoracis* muscle on the right side of the hot carcasses to estimate meat quality parameters. All samples were harvested at the same location on the loins and placed into plastic bags for transport to the laboratory. The physicochemical characteristics of meat were estimated 24 hours after slaughter by the meat laboratory at the Estonian University of Life Sciences.

### pH measurements

The initial and ultimate pH values of *Longissimus thoracis* muscle were measured 45 minutes and 24 hours after slaughter, respectively, by using a Testo 205 pH electrode (Testo AG, 2006). The electrode was calibrated with a standard buffer solution at 25 °C for the measurements. The PSE meat usually has an initial pH value less than 5.8 while DFD meat has an ultimate pH value above 6.0 (Warriss, 2000). Table 2 shows pH levels used in current study to determine stress-induced muscle damage.

**Table 2.** pH values of *Longissimus thoracis* muscle for PSE, normal and DFD meat (Warriss, 2000)

Category	pH <sub>45min</sub>	pH <sub>24hr</sub>
PSE	<5.8	<5.3
Normal	5.8–6.4	5.3–6.0
DFD	>6.4	>6.0

### Colour

The colour of muscle tissue samples was measured using an Opto-STAR optometer, which measures light intensity reflected from the muscle surface (Ingenieurbüro R. Matthäus, 2011<sup>b</sup>). Measurements were standardised by yellow and blue calibration blocks at room temperature.

### **Electroconductivity**

An LF-STAR CPU conductivity probe (Ingenieurbüro R. Matthäus. 2011<sup>c</sup>) was used to measure the electrical conductivity of muscle tissue. Two parallel steel electrodes were inserted into the muscle tissue and the electrical current between the electrodes was recorded. The results reflect the degree of muscle tissue damage, which is directly related to the water-holding capacity of muscle.

### **Water-holding capacity (WHC)**

The WHC of muscle was determined using the Grau and Hamm (1952; 1957) method, with minor modifications (Volovinskaja and Kel'man, 1961). Samples (0.3 g) were placed on an ash-free filter paper (No. 43, MN 640m) with the diameter of 150 mm, and exposed to 1 kg pressure between two glass plates. The surface area of flat squashed meat and wet stain areas were photographed with a Scan-STAR CPU device and measured with Scan-STAR K software (Ingenieurbüro R. Matthäus. 2011<sup>a</sup>). WHC was calculated according to the formula 2:

$$B = \frac{(A-8.4 \cdot V)}{A} \cdot 100, \quad (2)$$

where: B – proportion of the water emerged from the sample, %; A – total content of the water in the sample, mg; 8.4 – constant (1 cm<sup>2</sup> of filter paper area contains 8.4 mg water); V – area of the water emerged from the sample in the filter paper, cm<sup>2</sup>.

WHC (%) characterizes the ability of muscle to retain naturally occurring moisture even though external pressures are applied to it.

### **Drip and cooking loss**

Drip loss was measured according to the method described by Honikel (1998). Meat samples were placed on a non-absorbent mesh and dangled in a plastic bag. After storage of 24 hours at 4°C, the sample was weighed and drip loss calculated as percentage.

Cooking loss results from the loss of liquid and soluble substances from meat during thermal treatment. Muscle samples (100 g) were sealed into a plastic bag supplied with a thermometer. The bag was placed into hot water (95°C) and heated until the internal temperature of the sample increased up to 72°C. The sample was cooled down and weighed, and cooking loss was calculated as a percentage of the precooking weight.

### **Biochemical composition**

The dry matter content of muscle was determined according to the Estonian standard EVS-ISO 1442:1999 (EVS, 1997). The protein content was measured according to ISO 937:1978 (EVS, 1978) by using a Kjeltex device. The fat level of muscle was analysed with the Soxtec apparatus according to EVS-ISO 1444:1996 method (EVS, 1996). Ash content of the samples was determined by incineration in electric muffle furnace according to EVS-ISO 936:1998(E) methodology (EVS, 1998).

### Statistical analysis

General Linear Model procedure (3) of the SAS statistical package (SAS, 1999) was used to estimate the effect of the genotype on carcass and meat quality variables. All results are presented as least squares means  $\pm$  SEM.

$$Y_{ijk} = \mu + T_i + S_j + \varepsilon_{ijk}, \quad (3)$$

where:  $Y_{ijk}$  – dependent variable;  $\mu$  – model intercept;  $T_i$  – fixed effect of the pig genotype (LxL, LWxL, D/LxLW/L and DxLW/L;  $i = 1-4$ );  $S_j$  – fixed effect of the gender (gilt and barrow;  $j = 1, 2$ );  $\varepsilon_{ijk}$  – random residual effect.

Pearson correlation coefficients were calculated to assess the relationship between carcass and meat quality variables (not all results presented). Differences were considered statistically significant at the level of  $P < 0.05$ .

Data visualization was aided by Daniel's XL Toolbox Add-In for MS Excel, version 6.53, by Daniel Kraus, Würzburg, Germany.

## RESULTS AND DISCUSSION

### Field tests

Fast-growing animals make pig farming more profitable. The study showed that purebred Landrace and its cross with Large White breed achieved slaughter age 5.4–8.4 days earlier than both genotypes of the Duroc-sired finishers (D and DxL) (Table 3). The pigs crossed with the purebred Duroc sire reached slaughter weight significantly later (175.80 days,  $P < 0.05$ ) compared to purebred Landrace and LWxL crossbred pigs (167.40 and 167.70 days, respectively). Tănăvots et al. (2011<sup>a</sup>) demonstrated in their earlier study that white coloured pigs and their Duroc-sired crosses reached the desired slaughter weight at the same age. Yet, they found that the pigs reached slaughter weight later (at 182.92–191.76 days of age) than in the current study. While Tănăvots et al. (2011<sup>a</sup>) observed a significantly higher live weight at the same slaughter age in Duroc crosses compared to white-coloured genotypes, a prolonged fattening period did not result in the increase of the live slaughter weight of the finishers in the current study. On the contrary, both Duroc-sired genotypes were 1.16–3.82 kg lighter than those of the white-coloured pigs, but this difference was not statistically significant.

There were only small differences in carcass weight between genotype combinations, whereas the heaviest carcasses were found in white-coloured crossbred pigs and their cross with a purebred Duroc sire (80.45 kg, both), which also corresponds to the higher slaughter yield (69.22% and 70.55%, respectively). Čandek-Potokar et al. (2002) found also only small differences between genotype groups, although carcass weight was significantly higher in Duroc-sired crossbred animals.

Better growth performance was observed in white-coloured genotype combinations with daily gains over 690 g, while both crossbred genotypes with Duroc sire showed more modest results (651.33–652.24 g). Klimienė & Klimas (2013) demonstrated that growth performance may influence the lean meat content and backfat thickness of pigs with different genotypes, but not the size of the loin area. As the key to successful pig production is efficient feed conversion, the carcass daily gain can be considered an important quality parameter. Purebred Landrace pigs and crossbred animals with Large White and DxL terminal sires



showed slightly higher carcass daily gain (472.05, 474.47 and 475.23 g, respectively) than crossbreds with purebred Duroc sire (443.25 g). These findings contrast with those of Hurnik (2004) and Tănăvots et al. (2011<sup>a</sup>), both revealing better performance in Duroc-sired finishers. Nevertheless, the fattening performance of the local pigs has improved over recent years.

Carcass length expressed significantly ( $P < 0.01$ ) in white-coloured pigs, being 4.24–6.44 cm longer than in both of the Duroc-sired genotypes. While four years ago the average carcass length of white-coloured genotypes was 94.98 cm (Tănăvots et al., 2011<sup>a</sup>), the current study showed that the length of carcasses of these genotypes has increased, exceeding 100 cm (Table 3). On the contrary, Berg et al. (2003) did not find statistically reliable difference in carcass length between purebred Landrace and Duroc pigs.

**Table 3.** Least square means of fattening performance and carcass quality traits of finishers (n = 40, 10 of each genotype)

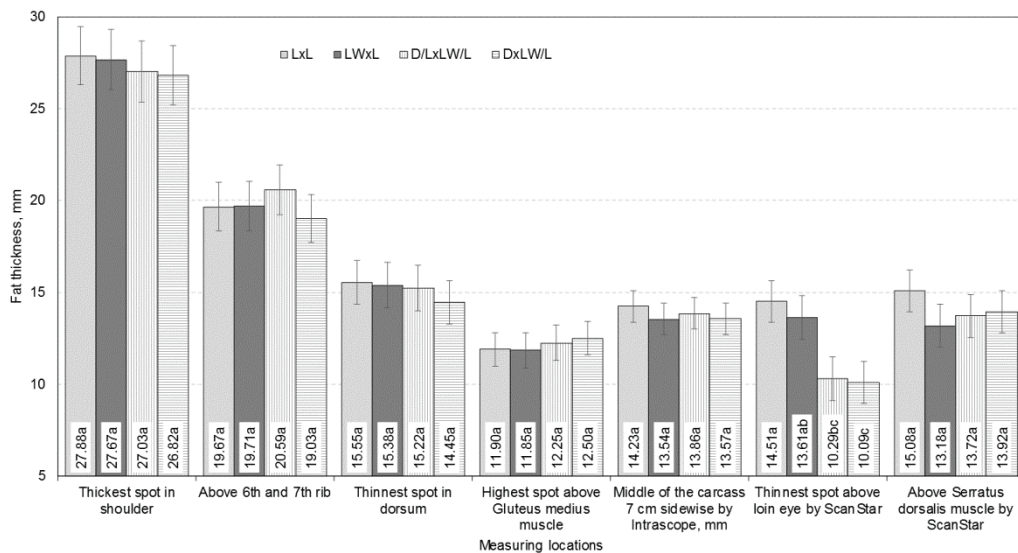
Traits	Genotype (♂x♀)							
	LxL		LWxL		D/LxLW/L		DxLW/L	
	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM
Age at slaughter, d	167.40 <sup>a</sup>	2.05	167.70 <sup>a</sup>	2.11	173.10 <sup>ab</sup>	2.11	175.80 <sup>b</sup>	2.05
Live weight, kg	115.48 <sup>a</sup>	3.05	116.31 <sup>a</sup>	3.15	112.49 <sup>a</sup>	3.15	114.32 <sup>a</sup>	3.05
Hot carcass weight, kg	78.96 <sup>a</sup>	2.11	80.45 <sup>a</sup>	2.18	77.06 <sup>a</sup>	2.18	80.45 <sup>a</sup>	2.11
Slaughter yield, %	68.34 <sup>a</sup>	1.09	69.22 <sup>a</sup>	1.12	68.58 <sup>a</sup>	1.12	70.55 <sup>a</sup>	1.09
Daily gain, g	691.87 <sup>a</sup>	16.16	697.26 <sup>a</sup>	16.67	652.24 <sup>a</sup>	16.67	651.33 <sup>a</sup>	16.16
Carcass daily gain, g	472.05 <sup>a</sup>	16.96	474.47 <sup>a</sup>	17.49	475.23 <sup>a</sup>	17.49	443.25 <sup>a</sup>	16.96
Carcass length, cm	101.12 <sup>a</sup>	0.95	101.82 <sup>a</sup>	0.98	95.38 <sup>b</sup>	0.98	96.88 <sup>b</sup>	0.95
Lean meat content, %	58.45 <sup>a</sup>	0.63	58.96 <sup>a</sup>	0.65	58.73 <sup>a</sup>	0.65	58.94 <sup>a</sup>	0.63
Loin eye area, cm <sup>2</sup>	46.35 <sup>a</sup>	1.39	47.04 <sup>a</sup>	1.44	51.75 <sup>b</sup>	1.44	52.24 <sup>b</sup>	1.39
Fat layer area, cm <sup>2</sup>	19.41 <sup>a</sup>	1.48	17.31 <sup>a</sup>	1.52	17.43 <sup>a</sup>	1.52	16.73 <sup>a</sup>	1.48
Leanness index	0.42 <sup>a</sup>	0.03	0.37 <sup>ab</sup>	0.03	0.33 <sup>b</sup>	0.03	0.32 <sup>b</sup>	0.03

<sup>abc</sup> – least square mean values in the same row with different superscript letters differ significantly ( $P < 0.05$ ); D – Duroc, L – Landrace, LW – Large White.

Even though the lean meat content (58.45–58.96%) did not differ significantly between genotype groups, the Duroc-sired crossbred pigs had significantly larger average LEA. Crossbred pigs sired by purebred Duroc boars had the largest loin eye (52.24 cm<sup>2</sup>), followed by pigs sired by crossbred Duroc and Landrace terminal boars (51.75 cm<sup>2</sup>). The LEA of purebred Landrace and crossbred LWxL pigs was 46.35 and 47.04 cm<sup>2</sup>, respectively (Table 3). The Duroc breed is generally used in crossbreeding programmes to improve meatiness traits, while the white-coloured genotypes exhibit stronger maternal effects. Hurnik (2004) concluded that loin eye size depends on the genetics of pig, as it was found that Duroc-sired genotypes had a larger loin eye than Landrace-sired animals. His study demonstrated a linear relationship between carcass weight and loin eye size. Similarly, in the current study a moderate correlation ( $r = 0.468$ ;  $P < 0.01$ ) was found between LEA and carcass weight of the pigs. A moderate correlation ( $r = 0.406$ ;  $P < 0.01$ ) was also found between the FLA and carcass weight, but there was no relationship ( $r = 0.074$ ;  $P > 0.05$ ) between the LEA and that of the FLA. The FLA above loin eye was slightly but not significantly smaller (0.58–2.68 cm<sup>2</sup>) in the pigs sired with purebred Duroc boars, being the largest (19.41 cm<sup>2</sup>) in purebred Landrace animals. These two traits showed that the FLA to LEA ratio was significantly ( $P < 0.05$ )

higher in Duroc-sired genotypes compared to purebred Landraces (Table 3). Similar results were obtained also by Tānavots et al. (2011<sup>a</sup>), although they detected a larger average LEA and a smaller FLA in all genotype combinations compared to current study, whereas the lower leanness index demonstrates the relatively faster increase in the backfat thickness over recent years.

Tānavots et al. (2011<sup>a</sup>) measured a slightly thicker backfat in the pigs sired with purebred Duroc terminal boars. Also, the Estonian farmers had prejudice that Duroc-sired finishers have thicker backfat. On the contrary, Berg et al. (2003) reported that purebred Duroc pigs had significantly ( $P < 0.05$ ) thinner backfat measured at the 10<sup>th</sup> rib (20.3 mm) than that of Landrace animals (23.7 mm). This study, however, did not confirm these results as none of the fat thicknesses measured at different locations did not differ significantly between genotype combinations (Fig. 3). Except, fat thickness at the thinnest spot above the *Longissimus thoracis* muscle (recorded by Scan-STAR) was significantly thinner in the pigs sired with purebred Duroc terminal boars (10.09 mm;  $P < 0.05$ ) compared with purebred Landrace (14.51 mm) and crossbred LWxL (13.51 mm) pigs. Similar results were also observed in DxL sired animals (10.29 mm), but a significant difference was found only with purebred Landrace pigs. Tānavots et al. (2011<sup>a</sup>) earlier study show a slight increase in backfat thicknesses in all genotype combinations.



**Figure 3.** Least square means ( $\pm$  SEM) of backfat thickness measured on the carcass of finishers at different locations (<sup>abc</sup> – least square mean values in the same row with different superscript letters differ significantly ( $P < 0.05$ ); D – Duroc, L – Landrace, LW – Large White).

Carcass backfat layer measured by tape measure was distributed rather unevenly across the body, being the thickest on the shoulder and the thinnest on the loin. Selection for leanness by using certain measuring locations may lead to excessive fat in other parts of the body (D’Souza et al., 2004; Suster et al., 2005), which indicates that deposition of



fat in the carcasses may vary. However, fat deposition in local genotypes was similarly distributed in all genotype combinations.

### Laboratory analysis

The muscles from Duroc-sired genotypes showed lower initial pH values than that from the white-coloured genotypes, whereas the pH of the muscles from D $\times$ L sired pigs differed significantly ( $P < 0.05$ ) (Table 4). One Duroc and two D $\times$ L sired pigs showed signs of PSE meat as the initial pH of muscle was below 5.8. In fact, the ultimate pH reached its normal level ( $\geq 5.3$ ) after 24 hours. The level of ultimate pH remained lower in the muscles from both Duroc-sired genotypes, but differed significantly ( $P < 0.05$ ) only from that of the crossbred white coloured animals. Eggert et al. (1998) and Brewer et al. (2002) concluded that the difference between the lean meat ultimate pH values of the finishers of different sire genotypes is insignificant. Some authors, however, have detected considerably higher initial (Jeleníková et al., 2008) and ultimate (Gjerlaug-Enger et al., 2010; Li et al., 2013) pH values in the muscle from purebred Duroc pigs compared to that of white-coloured animals. The ultimate pH affects traits such as colour and the ability of muscle to retain water. The current study showed that muscles with a lower ultimate pH was paler ( $r = 0.429$ ;  $P < 0.01$ ) and with slightly lower WHC ( $r = 0.155$ ;  $P > 0.05$ ).

**Table 4.** Least square means of the quality traits of *Longissimus thoracis* muscle of finishers ( $n = 40$ , 10 of each genotype)

Traits	Genotype (♂x♀)							
	LxL		LWxL		D/LxLW/L		DxLW/L	
	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM	$\bar{x}$	SEM
pH <sub>45min</sub>	6.05 <sup>a</sup>	0.06	6.14 <sup>a</sup>	0.07	5.84 <sup>b</sup>	0.07	6.00 <sup>ab</sup>	0.06
pH <sub>24hr</sub>	5.50 <sup>a</sup>	0.03	5.62 <sup>b</sup>	0.03	5.44 <sup>a</sup>	0.03	5.49 <sup>a</sup>	0.03
Colour <sub>45min</sub>	83.95 <sup>a</sup>	1.46	82.72 <sup>a</sup>	1.51	73.58 <sup>b</sup>	1.51	75.25 <sup>b</sup>	1.46
Colour <sub>24hr</sub>	74.94 <sup>ab</sup>	1.17	76.91 <sup>b</sup>	1.20	72.89 <sup>a</sup>	1.20	73.16 <sup>a</sup>	1.17
Electroconductivity <sub>45min</sub> , mS	3.72 <sup>a</sup>	0.40	3.61 <sup>a</sup>	0.41	4.77 <sup>a</sup>	0.41	3.74 <sup>a</sup>	0.40
Electroconductivity <sub>24hr</sub> , mS	7.99 <sup>a</sup>	1.03	7.25 <sup>a</sup>	1.06	8.11 <sup>a</sup>	1.06	6.26 <sup>a</sup>	1.03
Water-holding capacity, %	61.70 <sup>a</sup>	0.70	61.69 <sup>a</sup>	0.72	60.57 <sup>a</sup>	0.72	59.93 <sup>a</sup>	0.70
Drip loss, %	4.00 <sup>a</sup>	0.50	3.52 <sup>a</sup>	0.51	3.28 <sup>a</sup>	0.51	3.84 <sup>a</sup>	0.50
Cooking loss, %	45.00 <sup>a</sup>	0.64	43.99 <sup>a</sup>	0.66	44.32 <sup>a</sup>	0.66	44.52 <sup>a</sup>	0.64
Dry matter content, %	26.04 <sup>a</sup>	0.18	26.15 <sup>a</sup>	0.19	26.53 <sup>a</sup>	0.19	26.50 <sup>a</sup>	0.18
Protein content, %	23.60 <sup>a</sup>	0.16	23.23 <sup>ab</sup>	0.16	23.11 <sup>b</sup>	0.16	22.58 <sup>c</sup>	0.16
Intramuscular fat content, %	1.23 <sup>a</sup>	0.21	1.71 <sup>ab</sup>	0.22	2.19 <sup>bc</sup>	0.22	2.71 <sup>c</sup>	0.21
Ash content, %	1.21 <sup>a</sup>	0.02	1.20 <sup>a</sup>	0.02	1.22 <sup>a</sup>	0.02	1.21 <sup>a</sup>	0.02

<sup>a, b, c</sup> – least square mean values in the same row with different superscript letters differ significantly ( $P < 0.05$ ); D – Duroc, L – Landrace, LW – Large White.

Muscle tissue contains 26% dry matter and 25% protein (Warriss, 2000). Insignificantly higher dry matter level (0.35–0.49%) was found in both genotypes of Duroc-sired genotypes compared with white-coloured finisher groups (Table 4). In an earlier study, Tänavots et al. (2011<sup>b</sup>) observed that the *Longissimus thoracis* muscle of the Duroc-sired finishers contained 1.23% ( $P < 0.05$ ) more dry matter than that of white-coloured breed combinations.

While the protein content of muscle was strongly, but negatively related with the IMF content ( $r = -0.736$ ;  $P < 0.001$ ), the lean meat from the pigs of both Duroc-sired finisher groups that had a low protein level (DLxLW/L - 23.11%; DxLW/L - 22.58%), showed a remarkably high IMF level (D/LxLW/L - 2.19%; DxLW/L - 2.71%) in the *Longissimus thoracis* muscle. On the contrary, the highest protein level (23.60%) and the lowest IMF level (1.23%) were found in the muscle of purebred Landrace pigs, whereas the IMF content was 0.36% lower compared to an earlier study by Somelar et al. (2001). A similar tendency was observed also in Poland (Daszkiewicz et al., 2005), where 84% of the crossbred pigs under investigation had an IMF content of less than 2%. The difference may be caused by intensive selection for leanness and decrease in the backfat thickness in pigs. IMF level can vary considerably, from 1.1–7.0% (Fischer, 1994). DeVol et al. (1988) and Fischer et al. (2000) concluded that increased IMF content improves the eating quality of meat, whereas the optimal fat level of muscle is 2.5–3.5% (Bejerholm & Barton-Gade, 1986; Fernandez et al., 1999; Font-i-Furnols et al., 2012). However, according to Rincker et al. (2008), the IMF content only slightly affects the flavour, juiciness and tenderness of meat, or does not affect these qualities at all. Wood et al. (2004) suggested that the easiest way to optimise the IMF level is to use special breeds or crosses, such as Duroc, whose backfat is relatively thin. Berg et al. (2003) concluded, having studied various genotypes, that meat from Duroc pigs had higher WHC, IMF content and ultimate pH, and showed lower lightness value of the *Longissimus thoracis* muscle compared to the meat from Landrace and Yorkshire pigs.

## CONCLUSIONS

Producers have the possibility to use the boars with a higher lean meat content in breeding programme if they intend to improve that aspect in the finishers. The results of this study demonstrated that the genotype combination can affect carcass and meat quality traits. Carcass traits such as carcass length, LEA and leanness index were significantly affected by the Duroc sire line. Even in case of shorter carcasses, the weight of the carcass and slaughter yield was comparable with those of white-coloured genotypes. This is why we can presume that along with the significantly larger *Longissimus thoracis* muscle, other muscles of Duroc-sired pigs are also larger. Furthermore, Duroc sire had a consistent effect on meat quality traits such as protein and IMF content. Higher IMF content may positively affect the quality (taste and eatability) of pork that attracts consumers. Genotype combination had no effect on carcass fat deposition in different locations, which should refute breeders' fears about the negative effect of Duroc sires. Methodical investigation of the relationships between carcass and meat quality traits could help breed pigs for improved meat quality.

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## REFERENCES

- Alt, A. 2006. Preprocessing of pig carcasses and classification based on SEUROP system. Eesti Maaülikool. 24 pp (in Estonian).
- Berg, E.P., McFadin, E.L., Maddock, R.R., Goodwin, N., Baas, T.J. & Keisler, D.H. 2003. Serum concentrations of leptin in six genetic lines of swine and relationship with growth and carcass characteristics. *J. Anim. Sci.* **81**, 167–171.
- Bejerholm, C. & Barton-Gade, P.A. 1986. Effect of intramuscular fat level on eating quality in pig meat. Proc 32nd European Meeting of Meat Research Workers. Bristol, UK, 196–197.
- Bennet, G.L., Tess, W.M., Dickerson, G.E. & Johnson, R.K. 1983. Simulation of breed and crossbreeding effects on costs of pork production. *J. Anim. Sci.* **56**, 801–813.
- Brewer, M.S., Jensen, J., Sosnicki, A.A., Fields, B., Wilson, E. & McKeith, F.K. 2002. The effect of pig genetics on palatability, color and physical characteristics of fresh pork loin chops. *Meat Sci.* **61**, 249–256.
- Čandek-Potokar, M., Monin, G. & Zlender, B. 2002. Pork quality, processing, and sensory characteristics of dry-cured hams as influenced by Duroc crossing and sex. *J. Anim. Sci.* **80**, 988–996.
- Daszkiewicz, T., Bąk, T. & Denaburski, J. 2005. Quality of pork with a different intramuscular fat (IMF) content. *Polish J. Food Nutr. Sci.* **14/55**, 31–36.
- DeVol, D.L., McKeith, F.K., Bechtel, P.J., Novakofski, J., Shanks, R.D. & Carr, T.R. 1988. Variation in composition and palatability traits and relationships between muscle characteristics and palatability in a random sample of pork carcasses. *J. Anim. Sci.* **66**, 385–395.
- D'Souza, D.N., Pethick, D.W., Dunshea, F.R., Suster, D., Pluske, J.R. & Mullan, B.P. 2004. The pattern of fat and lean muscle deposition differs on the different pork primal cuts of female pigs during the finisher growth phase. *Livest. Prod. Sci.* **91**, 1–8.
- Edwards, S.A., Wood, J.D., Moncrieff, C.B. & Porter, S.J. 1992. Comparison of the Duroc and Large white as terminal sire breeds and their effect on pigmeat quality. *Anim. Prod.* **54**, 289–297.
- Eggert, J.M., Schinckel, A.P., Mills, S.E., Forrest, J.C., Gerrard D.E., Farrand, E.J., Bowker B. C. & Wynveen, E. J. 1998. Growth and Characterization of Individual Backfat Layers and Their Relationship to Pork Carcass Quality. Purdue University Swine Day Report. 14–20.
- EVS. 1978. Meat and meat products—Determination of nitrogen content (Reference method). ISO 937:1978. Estonian Centre for Standardisation. 3 pp.
- EVS. 1996. Meat and meat products—Determination of free fat content. ISO 1444:1996. Estonian Centre for Standardisation. 3 pp.
- EVS. 1997. Meat and meat products. Determination of moisture content. (Reference method). EVS-ISO 1442:1999. Estonian Centre for Standardisation. 4 pp.
- EVS. 1998. Meat and meat products—Determination of total ash. ISO 936:1998(E). Estonian Centre for Standardisation. 3 pp.
- Fernandez, X., Monin, G., Talmont, A., Mourot, J., Leuret, B. 1999. Influence of intramuscular fat content on the quality of pig meat—2. Consumer acceptability of *m. longissimus lumborum*. *Meat Sci.* **53**, 67–72.

- Fischer, K., 1994. The topography of the intramuscular fat content in cattle and swine. *Mitteilungsblatt der Bundesanstalt für Fleischforschung, Kulmbach.* **33**, 112–120. (in German).
- Fischer, K., Reichel, M., Lindner, J.P., Wicke, M. & Branscheid, W. 2000. Influence of sire breed on the eating quality of pork. *Archiv für Tierzucht.* **43**, 477–485 (in German).
- Font-i-Furnols, M., Tous, N., Esteve-Garcia, E. & Gispert, M. 2012. Do all the consumers accept marbling in the same way? The relationship between eating and visual acceptability of pork with different intramuscular fat content. *Meat Sci.* **91**(4), 448–453.
- Gjerlaug-Enger, E., Aass, L., Ødegård, J. & Vangen, O. 2010. Genetic parameters of meat quality traits in two pig breeds measured by rapid methods. *Animal.* **4**(11), 1832–1843.
- Grau, R. & Hamm, R. 1952. A simple method for the determination of water binding capacity in the flesh. *Fleischwirtschaft,* **4**, 295–297 (in German).
- Grau, R. & Hamm, R. 1957. About the water-binding capacity of the mammal muscle. II The determination of water binding capacity of the muscle. *Z. Lebensmittel–Untersuchung und Forschung.* **15**, 446–460 (in German).
- Honikel, K.O. 1998. Reference methods for the assessment of physical characteristics of meat. *Meat Sci.* 49:447–457.
- Hurnik, D. 2004. Loin eye size and what factors drive it? Atlantic Swine Research Partnership Inc. Annual Report. 18–20.
- Ingenieurbüro R. Matthäus. 2011<sup>a</sup>. Scan-STAR CPU device. User manual. 5 pp.
- Ingenieurbüro R. Matthäus. 2011<sup>b</sup>. Opto-STAR device. User manual. 20 pp.
- Ingenieurbüro R. Matthäus. 2011<sup>c</sup>. LF-STAR device. User manual. 17 pp.
- Jeleníková, J., Pipek, P., Miyahara, M. 2008. The effects of breed, sex, intramuscular fat and ultimate pH on pork tenderness. *Eur. Food Res. Technol.* **227**, 989–994.
- Jiang, Y.Z., Zhu, L., Tang, G.Q., Li, M.Z., Jiang, A.A., Cen, W.M., Xing, S. H., Chen, J. N., Wen, A.X., He, T., Wang, Q., Zhu, G.X., Xie, M. & Li, X.W. 2012. Carcass and meat quality traits of four commercial pig crossbreeds in China. *Genet. Mol. Res.* **17**;11(4), 4447–4455.
- Josell, A., von Seth, G. & Tornberg, E. 2003. Sensory quality and the incidence of PSE of pork in relation to crossbreed and RN phenotype. *Meat Sci.* **65**, 651–660.
- Klimas, R., Klimienė, A. & Rimkevičius, S. 2007. Efficiency of use of pigs, bred in Lithuania, in the hybridization combinations. *Veterinarija ir Zootechnika.* **38**(60), 22–27.
- Klimienė, A. & Klimas, R. 2013. The effect of growth rate to meatiness traits in purebred and crossbred pigs. *Veterinarija ir Zootechnika.* **63**(85), 37–43.
- Kriaucienė, J. & Rekštys, V. 2003. Compatibility of various pig breeds at common and complex crossbreeding. *Veterinarija ir Zootechnika.* **21**(43), 85–89.
- Li, Y.X., Cabling, M.M., Kang, H.S., Kim, T.S., Yeom, S.C., Sohn, Y.G., Kim, S.H., Nam, K.C. & Seo, K.S. 2013. Comparison and Correlation Analysis of Different Swine Breeds Meat Quality. *Asian-Australasian J. of Anim. Sci.* **26**(7), 905–910.
- McGloughlin, P., Allen, P., Tarrant, P.V. & Joseph, R.L. 1988. Growth and carcass quality of crossbred pigs sired by Duroc, Landrace and Large White boars. *Livest. Prod. Sci.* **18**, 275–288.
- Oliver, M.A., Gou, P., Gispert, M., Diestre, A., Arnau, J., Nougiera J.L. & Blasco, A. 1994. Comparison of five types of pig crosses. 2. Fresh meat quality and sensory characteristics of dry cured ham. *Livest. Prod. Sci.* **40**, 179–185.
- Rincker, P.J., Killefer, J., Ellis, M., Brewer, M.S. & McKeith, F.K. 2008. Intramuscular fat content has little influence on the eating quality of fresh pork loin chops. *J. Anim. Sci.* **86**, 730–737
- SAS. 1999. SAS OnlineDoc V8. SAS Institute Inc., Cary, NC, USA. <http://www.sfu.ca/sasdoc/sashtml/onldoc.htm> Last visited 04.01.2014.
- Somelar, E., Tänavots, A., Saveli, O. 2001. Meat Quality Research of Pure- and Crossbred Pigs in Estonia. 7<sup>th</sup> Baltic Animal Breeding Conference. Tartu. 138–143.

- Suster, D., Leury, B.J., Hewitt, R., Kerton, D.J. & Dunshea, F.R. 2005. Porcine somatotropin alters body composition and the distribution of fat and lean tissue in the finisher gilt. *Australian J. of Exp. Agric.* **45**, 683–690.
- Testo AG. 2006. Testo 205 pH/Temperature Measuring Instrument. Instruction Manual. Lenzkirch. 14 pp.
- Tänavots, A., Pöldvere, A., Soidla, R., Lepasalu, L. & Žurbenko, S. 2011. Factors affecting carcass and meat quality characteristics of pigs. I Effect of breed of sire and sex on carcass composition in pigs. *Agraarteadus*. **22**(1), 45–52 (in Estonian).
- Tänavots, A., Pöldvere, A., Soidla, R., Lepasalu, L. & Žurbenko, S. 2011<sup>b</sup>. Factors affecting carcass and meat quality characteristics of pigs. II Effect of breed of sire, sex and PH1 on meat quality traits. *Agraarteadus*. **22**(1), 53–61 (in Estonian).
- Warriss, P.D. 2000. Meat Science: An Introductory Text. CABI Publishing. 310 pp.
- Wood, J.D., Nute, G.R., Richardson, R.I., Whittington, F.M., Southwood, O., Plastow, G., Mansbridge, R., da Costa, N. & Chang, K.C. 2004. Effects of breed, diet and muscle on fat deposition and eating quality in pigs. *Meat Sci.* **67**, 651–667.
- Volovinskaja, V.P. & Kel'man B. Ja. 1962. Development of a method for determination of water binding capacity of meat. Trudy VNIIMMP. 128–138 (in Russian).