Genetic but not lean grade impact on growth, carcass traits and pork quality under organic husbandry

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ABSTRACT

Organic pig production may be conducted with different genetic types and the carcass outcome can differ in fatness content, however, the contribution of each effect to meat quality characteristics is not well established. The objective of this study was to evaluate two genetic types (Duroc x (Gascon x Duroc), Duroc-sired vs. Pietrain x (Landrace x Large White), Pietrain-sired) slaughtered at a different weights to achieve similar target carcass fatness (90 kg or 105 kg of body-weight, respectively), and the effect of two carcass lean grades (<60% or ≥60% lean) on growth rates, carcass and pork quality under organic husbandry. The daily gain and carcass yield were lower in Duroc than in Pietrain-sired pigs. The post-mortem and ultimate pH, moisture, lightness (L*), yellowness (b*), cooking loss and intramuscular fat content of loin meat were not influenced by genetic type, while redness (a*) and tenderness (shear force) were lower in Duroc than their Pietrain counterparts. Partition tree analysis showed that the highest shear force (≥ 4.63 kg) and the highest fat depth at *Gluteus medius* muscle (≥16 mm) were associated with Duroc-sired pigs. The lowest redness (a*<2.23) was associated with leaner (≥60%) pork. The crossbred finishing pig including 75% Duroc genes showed lower growth performance, carcass weight and dressing out than the Pietrain sired crossbreds. Lean grade was not associated with earlier differences in growth, carcass performance or meat quality, except for a tendency for greater compression at 80%force in leaner raw pork.

Highlights

- The crossbred finishing pig including 75% Duroc genes and a local breed (Gascon) in maternal sire showed lower growth performance, carcass weight and dressing out than the Pietrain sired crossbreds.
- Slaughtered at similar carcass fatness degree, the pork loin from Duroc genetic type had lower redness (a*) and it was tougher than their Pietrain counterparts.
- Lean grade was not associated with earlier differences in growth, carcass performance or meat quality, except for a tendency for greater compression at 80%force in leaner raw pork.
- Under the current organic husbandry system, the Pietrain-sired pigs may be recommended.

Keywords: carcass fatness; daily gain; meat colour; shear force; intramuscular fat.

1. Introduction

Crossbreeding with Duroc breed as sire line allows the improvement of meat quality traits (Ramírez and Cava, 2007), including tenderness (Dilger *et al.*, 2010) and darkening of colour (Blanchard *et al.,* 1999; Lindahl *et al.,* 2006), particularly with improved maternal crossbreds (Landrace x Large-White). Likewise, Duroc breed is used to produce dry-cured pork products, since accumulates greater intramuscular fat and fat quality traits than other sire breeds as Pietrain, which is normally very lean (Affentranger *et al.,* 1996; Latorre *et al.,* 2009). The genetic influence on pork quality is based on the differences among breeds as well as the differences among animals within the same breed (Murray *et al.* 2001) and feeding strategies (Edwards, 2005, Sundrum *et al.,* 2011). However, the suitability of local and selected swine breeds (either in maternal or sire lines) under organic production system has been debated, as the local breeds are generally characterised by inferior growth rates and feed efficiency (Leenhouwers and Merks, 2013). The performance and products of local pig breeds may be practically untapped and market potential of their products unexploited (Sans *et al.,* 2004; Kušec *et al.,* 2018). As consequence it could be relevant for marketing of meat products from European local pig genetic resources (Gascon, Berkshire, Euskal Txerria, Porco Celta, etc), often reared in traditional small-scale production system linked to a specific environment (Bozzi and Crovetti, 2013).

According to Eurostat (2017), 58% of pig carcases in European Union were graded as S (Lean Meat Content (LMC) ≥60%), whereas in the studies by Millet *et al.* (2004) and Farke and Sundrum (2005), LMC of carcasses in organic pig production was about 55% on average (E grade). While being primarily focused on the production of lean meat and because of antagonistic relationships between several quantitative and qualitative traits such as flavour, tenderness and juiciness, the payment system does not honour and even discourages the production of pork with a high eating quality (Bonneau and Lebret, 2010; Sundrum *et al.,* 2011).

Organic pig diets cannot include in-feed crystalline amino acids and, unless high dietary crude protein is supplied, the amino acid requirements of pigs fail to be met in some periods; thereby they normally show greater carcass fatness (Millet *et al.,* 2005; Lebret, 2008). On the one hand, the intramuscular fat (IMF) content may be a desirable trait as it is the prominent criterion for eating quality of pork, well known for enhancing softness, tenderness and overall liking of pork (Wood *et al.,* 2004; Font-i-Furnols *et al.,* 2012). Otherwise, the meat colour is the most important intrinsic quality factor at the moment of the purchase since the consumer uses it as indicator of freshness (Ripoll *et al.,* 2012), and both of them can be affected by animal genetics and lean grade.

Therefore, the aim of the present study was to evaluate the effects of genetic type and lean grade on animal growth, carcass and meat characteristics of organic pork loin, slaughtered at a similar target carcass fatness.

2. Material and methods

2.1. *Animals, experimental design and sampling.*

The study involved a total of 48 pigs born between 15th December 2016 and 10th January 2017 in 2 batches (3 weeks apart), from two genetic types (n=26 animals were Pietrain x (Landrace x Large White) (Pi x (LD x LW) and n=22 animals were Duroc x (Gascon x Duroc) (Du x (Gc x Du)). The pigs were selected from 12 sow litters, 6 per genetic type. Half of the animals were females; the other half were castrated males. The Pi-sired pigs derived from Pi line of Selecció Batallé (Riudarenes, Girona, Spain) and the Du genetic types derived from Du line of German Genetic (Stuttgart-Plieningen, Germany). In total, 32 pig carcasses (around 3 pigs/litter) and loin meat from 24 pigs (2 pigs/litter) were sampled. All pigs had the same commercial diet *ad libitum* (Table 1). Treatments pigs were kept in accordance with the European Community standards for organic livestock and livestock products (EC-regulation 889/2008 supplementing the EC-regulation 834/2007). Briefly, the pigs from both genotypes were housed together in three concrete floor pens with a space allowance ≥2.3 m^2/pig (straw-bedded indoor area 7.6 x 3.1 m^2; outdoor area 5.9 x 3.2 m^2). Each pen had a dry single-space self-feeder (indoor area) and a square nipple drinker (outdoor area).

2.2. *On-farm and abattoir measurements.*

The individual body-weight (BW) was determined at the start of the growing phase (initial age 68±15 days) and prior to slaughter (after 20 hours of fasting) to calculate the average dairy gain (ADG) and killing out proportion. The BW at slaughter was set at approximately 105 kg (Pi-sired) or 90 kg (Du-sired) to reach similar lean content (around 60% lean in both genetic types). Slaughtering was performed in a nearby commercial abattoir (68 km away) (Escorxador Frigorífic d'Avinyó S.A., Barcelona, Spain). Pigs were brought in the morning (between 9:00 and 11:00) with a small truck provided with a relatively flat loading ramp. At the abattoir, animals were allowed 3-4 hours rest period with full access to water but not to feed. Pigs were stunned by CO_2 (concentration 87%) using a dip lift system, exsanguinated, scalded, skinned, eviscerated according to standard commercial procedures and split down the midline. Hot carcass weight was individually recorded before the carcasses were refrigerated in line processing at 2º C. The carcasses were graded with an automated image analysis system (VCS 2000, E+V Technology GmbH, Oranienburg, Germany) and classified in two classes (<60% and ≥60% LMC). Backfat thickness was measured at 3rd-4th last rib and over the *Gluteus medius* muscle (at its thinnest point). At 45 min *post-mortem*, the loins were excised from the carcass following the standard procedures of the abattoir and they were trimmed by an expert staff to eliminate part of the external fat for commercial requirements. Immediately afterwards, individual 10-cm caudal *Longissimus lumborum* was sampled (approximately 500 g), packaged in polyethylene bags and stored at 4ºC in darkness overnight.

One-day post-mortem, the samples of *L. lumborum* muscle were sliced in five slices (2 cm thickness each, ~100 g). The first slice was used to determinate pH, colour and proximate composition (moisture, IMF). The remaining four slices (cut starting from the cranial end, individually assigned to analyses) were used to determine drip losses (thawing and cooking), Warner-Bratzler shear force and compression tests at two aging days (1 and 8 days). Meat samples were stored at 4ºC during either 24 h (2 samples) or 8 days (2 samples) in the vacuum-packed plastic bag and stored at -20ºC until textural measurements.

2.3. *Meat quality analyses.*

The pH at 45 min at 24 h after slaughter was measured at a mid-lumbar position in the loin muscle, with a pH-meter equipped with a spear-tipped probe (Testo 205, Testo AG, Lenzkirch, Germany). The electrode was calibrated with a standard buffer solution at 25 °C for the measurements. Colour measurements were taken in duplicate after 30 min blooming, at 4-6 °C, by determining the CiELab colour coordinates (L*, lightness; a*, redness; and b*, yellowness) with spectrophotometer (CM-2600d Konica Minolta Sensing Inc., Osaka, Japan) with a measurement area diameter of 8 mm, including a specular component and a 0% UV, standard illuminant D65 that simulates daylight (colour temperature of 6504 K), 10° observer angle, and zero and white calibration. Because the steak was sliced perpendicularly to the fibre direction, colour measurement was made on the same direction of the fibres. The integrating sphere has a diameter of 52 mm, and the measurement area was covered with a dust cover CM-A149.

The samples were thawed in vacuum-packaged bags for 24 h at 4°C, removed from the packages, blotted dry for 20 min, and weighed. Thawing losses were calculated by dividing the difference in weight between the fresh and thawed samples by the initial fresh weight. A compression test was carried out in loin slice samples (a minimum of eight replicates), 1 cm^2 in cross-section, were cut with muscle fibres parallel to the longitudinal axis of the sample and were analysed using a modified compression device described by Lepetit (1989). That device avoids transversal elongation of the sample. Stress at 20 % and 80% of maximum compression was assessed using an Instron 5543 (Instron Limited, Barcelona, Spain) machine with a probe speed of 50 mm/min, expressed in kg/cm^2.

Warner-Bratzler shear force (WBSF) test was performed on cooked meat. The loin samples were cooked by placing the vacuum bags in a water bath (75ºC) with automatic temperature control to internal temperature of 70ºC, controlled by thermocouples connected to a data logger. After cooking, samples were cooled at room temperature overnight and the percentage of cooking loss was recorded. The difference between pre- and post-cooking weights was divided by the pre-cooked weight to calculate cooking losses percentage. Samples were then cut parallel to the long axis of the muscle fibers into rectangular cross-section slices of 10 × 10 mm x 30 mm (height x width x length). Pieces (8/slice) were sheared perpendicular to the fiber orientation, with a Warner-Bratzler device attached to Instron model 5543 (Instron Ltd., Buckinghamshire, UK), and equipped with a 500 N load cell and a crosshead speed of 150 mm/min.

Moisture content was quantified according to the ISO recommended standards 1442:1997 (ISO 1997). Fat content was quantified using the Ankom procedure (AOCS Am 5–04) (AOCS 2004) with an Ankom extractor (XT10, Ankom Technology, Madrid, Spain). Loin slices were trimmed of intermuscular and subcutaneous fat prior to IMF analysis. Analyses were run in duplicate.

2.4. *Statistical analysis.*

The data were analysed with the JMP Pro 13 statistical software (SAS Institute, Cary, NC, USA) with a standard model including genetic type, lean content and sex as fixed effects. Single interactions between fixed effects were removed from the final model because they were non-significant ($P>0.05$). Values are presented as least square means ± standard error of the mean (SEM). The level of significance was set at 0.05, but tendencies were commented if the level of significance was below 0.10. Differences between least square means were assessed with the Tukey test. Partial correlations between texture parameters were also evaluated.

Classification trees (partition option from multivariate methods) from JMP Pro software were used to predict both genetic type and carcass grading as a function of potential predictor variables (pH, colour, moisture, IMF, fat thickness, water-holding capacity and shear force at 1 day and 8 days aged raw and cooked) using recursive partitioning. The variables were selected according to G2 (likelihood-ratio chi-square) test of association and logworth (-log(p-value)) value. The logworth values are the logs of adjusted p-values for the chi-square test of independence. These are adjusted to account for the number of ways that splits can occur. The partition algorithm imputes (that is, randomly assigns) values for the missing values, and this allows the variables that are poorly populated to be noticed, if they indeed help explain banding.

3. Results

3.1. Pig growth rates.

The initial age was not different between genetic types nor between lean grades. The initial and final BW was affected by genotype, being higher in Pi x (LD x LW) than in Du x (Gc x Du) pigs (P<0.01). The initial BW was affected by lean grade (P<0.05), but final BW did not differ (P>0.05), as shown in Table 2. As expected, the average daily gain was affected by genetics, the Pi x (LD x LW) pigs growing faster than their Du x (Gc x Du) counterparts (P<0.01). The age at slaughter did not differ between the genetic types and lean content grades (P>0.05). The pigs classed as leaner (≥60% lean) were heavier at the start of the growing period than those fattier (<60% lean) (*P*<0.05) and tended to grow slower during the fattening period than fattier pigs (P=0.06). Although the initial BW was similar across sexes (15.5±0.67 vs. 14.8±1.06 kg, in barrows and gilts, respectively; P>0.05), the ADG and thereby the slaughter BW was higher in barrows than in gilts (702±19 vs. 568±34 g and 100.5±1.16 vs. 93.8±2.06 kg, respectively; P<0.01).

3.2. Carcass characteristics.

The effect of genetic type on carcass weight, carcass yield and fatness measurements are shown in Table 3. The carcass weight and dressing out were affected by genetic type, being higher in Pi x (LD x LW) than in Du x (Gc x Du) pigs (P<0.001). The backfat thickness and *subcutaneous* fat covering the *Gluteus medius* muscle were similar between genotypes (P>0.05). Lean content did not affect carcass weight and dressing out (P>0.05). There was significant effect of sex on carcass weight, being higher in barrows than in gilts (75.1±1.3 *vs.* 65.7±2.2 kg; *P*<0.01).

3.3. *Meat quality traits.*

The results concerning chemical composition and colour parameters of raw pork according to genetic type and lean content are detailed in Table 4. The loin pH at 45 min and 24 h post-mortem was not affected by genetics and lean grade (P>0.05). None of the CIELab colour attributes differed significantly between carcass lean groups (P>0.05). However, the redness (*a**) was greater in Pi x (LD x LW) than in Du x (Gc x Du) pigs (P<0.05), whereas lightness (*L**) and yellowness (*b**) did not differ between genetic types (P>0.05). Loins from Du x (Gc x Du) pigs did not differ from Pi x (LD x LW) pigs in IMF and moisture content (either in raw or cooked pork aged 1 day) (P>0.05). Likewise, these variables (IMF and moisture) were not statistically affected by lean grade (P>0.05). There was significant difference between sexes in redness index (a*), since loins from barrows had higher a* than those form gilts (3.22±0.26 *vs.* 1.86±0.41; *P*<0.05).

Cooking loss and the textural parameters of pork (aged 1 and 8 days), according to genetic type and lean content, are shown in Table 5. Cooking loss did not differ between genetic types or lean grades (P > 0.05). Resistance to cutting (WBSF) in pork aged 1 day was significantly lower in Pi x (LD x LW) than Du x (Gc x Du) (P=0.05), whereas no differences were observed between genetic types in pork loin aged 8 days (P>0.05).

The differences between genetic types in meat tenderness through compression measurements (20% and 80% stress) in raw pork aged 1 and 8 days were not significant (P>0.05), and only a tendency for greater force at stress 80% was observed in leaner (≥60% lean) compared to fatter (<60% lean) pork aged 1 day (P=0.06).

There was a significant effect of sex on compression force at 80% stress (pork aged 1 day), since loin from gilts showed higher force than that from barrows (6.34±0.47 *v.* 4.92±0.34 kg/cm^2; P=0.05).In pork aged 1 day, the WBSF was weakly correlated with compression force at 20% and 80% stress (r=0.08-0.26; P>0.05), while in pork aged 8 days the WBSF showed a positive correlation with compression force at 20% stress (r=0.55; P<0.05) but not with compression force at 80% stress (r=0.06; P>0.05).

3.4. Partition trees based on genetic type or carcass lean grade.

The best partition tree of technological characteristics of organic pork based on genetic type resulted in two splits (Figure 1). The final coefficient of determination (R2) was 0.47. The Column Contributions report (based on G^2) showed that shear force of cooked meat (aged 1 day) and fat depth at *G. medius* muscle were the main predictors of genetic type in the partition tree model. More Pietrain-sired pigs (77.8%) showed lower shear force at day 1 post-mortem (threshold set by autoregressive splitting at <4.63 kg), whereas more Duroc-sired pigs (92.3%) showed greater shear force (WBSF ≥ 4.63 kg). In this tougher meat, high fat depth at *G. medius* muscle (≥15 mm) was exclusively associated with Duroc-sired pigs (100%).

Another partition tree was developed for identifying technological characteristics of organic pork based on lean content (Fig. 2). The final R2 was 0.63. The column contributions report (based on G^2) showed that redness index (a*) of raw meat and fat depth at *G. medius* were the only predictors in the partition tree model. Pigs classified as leaner (≥60% lean) were associated exclusively (100%) with lower redness index (a*<2.23). More fatty pigs (<60% lean) (77.8%) showed higher redness index (a*≥ 2.23) at day 1 post-mortem. In this darker meat, high fat depth at *G. medius* muscle (≥16 mm) was associated exclusively (100%) with fattier pigs (< 60% lean).

4. Discussion

This work evaluated the role of genetic type and lean grade on growth, carcass and meat quality characteristics of organic pork. These effects were assessed both independently and together (by testing its interaction). In the present study, the use of 75% Duroc-genes crossbreds was not optimal in terms of growth and carcass performance, when compared to the Pietrain crossbred, which is a genetic type widely used in Europe. In general, Pietrain-sired pigs show slightly lower growth performance but higher dressing out percentage than Duroc-sired pigs, leading also to heavier carcasses (García-Macías *et al.,* 1996; Edwards *et al.,* 2003; Latorre *et al.,* 2003; Ramírez and Cava, 2007). However, in another work, the use of a local genotype (Basque, very closed to Gascon) reduced the growth performance compared to Large-White purebred pigs (Alfonso *et al.,* 2005). Thus, the inclusion of local genotypes (as Gascon) in breeding schemes seems to impair the daily growth outcome of crossbreds, which may be a highlight of unimproved selection on this trait. However, the pig growth of sired Duroc pigs (around 600 g/day) was in the range of earlier reports under organic husbandry (Hansen *et al.,* 2006; Sundrum *et al.,* 2011 and Wüstholz *et al.,* 2017).

Although the sire breeds in this study were chosen according to their differences in fat content (Duroc represented a fatty pig and Pietrain a lean type), the overall lean content in the present study was tailored across genetic types by adjusting the body-weight at slaughter (nearly 10-15 kg less in Duroc-sired than in Pietrain-sired pigs). When using this approach, no differences between sire genotypes were detected in carcass fatness (backfat thickness and at depth at *G. medius* muscle), as reported by Latorre *et al.* (2009), in agreement with the present study.

In addition, no statistical differences were detected between genetic types in pH at 45 min and 24 h post-mortem, similarly to García-Macías *et al.* (1996) and Alonso *et al.* (2009), and their values were in line with the expected pH reduction during meat aging.

Researchers have reported conflicting results regarding the objective colour attributes of meat according to crossbreds. This study revealed no significant differences in lightness (L*) and yellowness (b*) values between samples of *L. lumborum* from Duroc- and Pietrain-sired pigs, which agrees with results of Edwards *et al.* (2003). Pork loins with L* values between 49 and 60 would on average have consistently good visual appeal (Warriss *et al.* 1995). In addition, the lower a* values in Duroc than in Pietrain progeny agreed with Brewer *et al.* (2002), Edwards *et al.* (2003), Edwards *et al.* (2008) and Latorre *et al.* (2009). The red colour of muscle is caused by the presence of haem pigments, hence CIE a* values of meat are positively correlated with the haem pigment and iron content (Estévez *et al.,* 2006). Thus, under the same feeding and housing conditions, the only colour attribute that differed across genetic types was redness. These a* value differences between genetic types (0.84 units) may be of practical significance as consumers can discriminate a* value differences of as little as 0.65 units depending on the light source under which samples are viewed (Zhu and Brewer, 1999). Slaughter weights for commercial pigs yielding fresh pork are rarely above 110 kg and this surely explains part of the lack of differences in IMF between crossbreds, since many autochthonous pig breeds, as Gascon, are normally raised until heavier weights (Sans *et al.,* 2004; Franci *et al.,* 2005) and thereby they are fattier than commercial pigs.

The expected higher IMF content in Duroc-sired pork may contribute to higher tenderness compared to Pietrain-sired pork (Huff-Lonergan *et al.,* 2002, Suzuki *et al.,* 2005). However, this was not proven in this experiment, as even the former had greater shear force at 1 day of aging than the latter.

Cooking loss from loin was not affected by genotype, which agrees with Brewer *et al.* (2002), Edwards *et al.* (2003) and Latorre *et al.* (2009) though it was higher at 8 days than at 1 day of aging. In addition, the pork loin from Duroc x (Gascon x Duroc) genetic type was tougher (greater shear force) than their Pietrain-sired counterparts, which differed from Edwards *et al.* (2003), who did not observed any difference between sires, and Blanchard *et al.* (1999), who observed an improvement in tenderness and lower shear force in cooked pork with higher level of Duroc genes inclusion. In this study, the differences in shear force between genetic types cannot be attributed to concomitant differences in IMF but to other physical and chemical components of muscle. For example, it has been found that hydroxyproline content (an indicator of collagen content) (Colgrave *et al.,* 2008) was greater in Duroc than in Pietrain crossbreds (Tor *et al.,* 2012).

In this study, ageing of pork loin slices for 8 days post-slaughter reduced shear force, compared to that aged for only 1 day, in agreement with the results found by Channon *et al.* (2004) and Álvarez-Rodríguez *et al.* (2018). Indeed, the shear force at 8 days of aging was within the range considered as tender pork by Van Oeckel *et al.* (1999) (3.9 kg) and Moeller *et al.* (2010) (3.4 kg). Compression force showed no differences between genetic types. This may reflect a lack of differences in tenderness as assessed by consumers, as the force values obtained for puncture test gave a greater degree of correlation with the sensory tenderness, hardness and elasticity than the shear test forces (Cierach and Majewska, 1997). However, it must be pointed out that more samples from Duroc-sired pigs had greater shear force than 4.63 kg (threshold value obtained from partition trees) and, within the tougher meat, pork from Duroc-sired pigs had greater subcutaneous fat depth at *Gluteus medius* (threshold found at ≥16 mm) than pork from Pietrain-sired pigs. It was noteworthy that ham fat depth had more discriminative power than backfat thickness in tree partitioning.

The used compression device allowed us to differentiate both components of meat stress, including stress due to muscle myofibrils (stress at a rate of compression of 20%) and the other due to total collagen (stress at a rate of compression of 80% (Lepetit, 1989). Aging affects the components responsible for meat toughness myofibrils and connective tissue (collagen) in different ways (Sacks *et al.,* 1988). Meat toughness decreases through aging due to a protease (μ-calpain) and its inhibitor (calpastatin), both of which regulate myofibrillar degradation and are the main source of variation in the final tenderness values (Koohmaraie and Geesink, 2006). Connective tissue breaks partially during aging (Nishimura *et al.,* 1998); therefore, aging does not modify the meat stress at 80 % but modify the meat stress at 20 %. On the other hand, both total collagen content and myofibrils plus the thermal solubility of collagen interfere on the WBSF. Because there were no differences in stress at 20% or 80%, but there were on WBSF, we can argue that differences between genetic types come from the solubility of collagen. That could explain that some authors reported the pork loin from Duroc genetic type was tougher than Pietrain counterparts, while Blanchard *et al.* (1999) reported the opposite and Edwards *et al.* (2003) who did not observe any difference between sires. We may suggest that the total collagen content was greater in Duroc than in Pietrain crossbreds (Tor *et al.,* 2012) but also, and more important, is less soluble.

In many studies, the influence of carcass fatness is not separated from that of genetic type, henceforth both effects are confounded. The approach used herein was to tailor the slaughter weight to compare similar carcass fatness levels across genetic types, but a range of carcass grades was obtained by this grouping. The leanest pigs (≥60% lean grade), regardless of genetics, grew slower than the rest of animals. This would highlight an association between daily growth and fat tissue growth, or, in other words, a not linear relationship between daily growth and muscle growth. Such response may be affected by the husbandry system, which involves greater animal exercise due to higher space allowance and potential drawbacks in essential amino acid requirements. Accordingly, Millet *et al.* (2005) concluded that higher growth rate under organic husbandry caused an extra fat deposition and that the individual daily feed intake would one of the determining factors for the daily gain.

Increased carcass fatness (or lower lean grade) did not affect the dressing out proportion, the colour attributes and the technological characteristics of pork (as pH or drip loss) (Álvarez-Rodríguez *et al.,* 2018), which was in line with the current results. However, tree partitioning revealed that higher carcass fatness (<60% lean) was related to higher redness of meat, especially when ham fat depth ≥16 mm. The redness (a*) values of meat are positively correlated with, not only the haem pigment and iron content (Estévez *et al.,* 2006), but with its IMF content (Karamucki *et al.,* 2013), which may explain this relationship under the present organic husbandry system.

5. Conclusions

The crossbred finishing pig including 75% Duroc genes and a local breed (Gascon) in maternal sire showed lower growth performance, carcass weight and dressing out than the Pietrain sired crossbreds. In addition, when they were slaughtered at similar carcass fatness degree, the pork loin from Duroc genetic type had lower redness (a*) and it was tougher than their Pietrain counterparts. Lean grade was not associated with earlier differences in growth, carcass performance or meat quality, except for a tendency for greater compression at 80%force in leaner raw pork. Therefore, under the current organic husbandry system, the Pietrain-sired pigs may be recommended.

Conflicts of Interest

The authors declare no conflicts of interest.

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Table 1 Feedstuffs and chemical composition of compound feed (g/100 g fresh matter, as-fed basis unless otherwise stated).

Ingredients	*(g/100 g fresh matter)*
Barley	34.8
Maize	20.0
Wheat	13.4
Maize germ meal	4.0
Soybean pressed cake	12.3
Pea	10.0
Vegetable protein concentrate	2.0
Oil soybean	0.5
Calcium carbonate	0.9
Dicalcium phosphate	1.3
Sodium chloride	0.4
Vitamins and minerals	0.4
Calculated composition	
Metabolizable energy (MJ/kg)	9.5
Total lysine (%)	0.7
Analysed composition	
Gross energy (MJ/kg)	16.3
Crude protein	14.0
Crude fibre (%)	4.0
Ether extract (%)	3.7
Ash (%)	4.8

Table 2 Growth performance of organic pigs as affected by genetic type and lean grade[1].

	Genetic type		Lean grade		SEM[1]	P-value[2]	
	Pi x (LD x LW)	Du x (Gc x Du)	<60%lean	≥60%lean		Genetic type	Lean grade
Initial age, days	69.0	71.2	68.1	72.1	2.90	0.61	0.47
Initial body weight, kg	16.9	14.3	14.1	17.1	0.65	0.007	0.02
Final body weight, kg	104.4	90.7	100.1	95.1	2.05	0.001	0.18
Age at slaughter, day	202	204	201	205	3.00	0.60	0.47
Average daily gain, g	663	593	654	602	15.5	0.003	0.06

[1] Values are presented as least square means ± standard error of the mean (SEM). The level of significance was set at 0.05, but tendencies were commented if the level of significance was below 0.10.

[2] Interaction genetic type x lean grade non-significant in any variable ($P>0.05$).

Table 3 Carcass traits of organic pigs as affected by genetic type and lean grade[1].

	Genetic type		Lean grade		SEM[1]	P-value[2]	
	Pi x (LD x LW)	Du x (Gc x Du)	<60%lean	≥60%lean		Genetic type	Lean grade
N carcasses	*13*	*19*	*18*	*14*			
Carcass weight (kg)	78.1	62.6	71.7	69.0	1.55	<0.001	0.33
Dressing out (%)	75.1	70.3	72.3	73.1	*0.78*	<0.001	0.56
Lean content (%)	59.4	59.2	56.4	62.2	*0.95*	0.95	0.002
Fat thickness (mm)							
Backfat depth[3]	25.4	25.4	26.7	24.2	1.65	0.98	0.37
M. Gluteus medius	16.5	16.6	18.3	14.8	1.45	0.94	0.14

[1] Values are presented as least square means ± standard error of the mean (SEM). The level of significance was set at 0.05, but tendencies were commented if the level of significance was below 0.10.

[2] Interaction genetic type x lean grade non-significant in any variable (P>0.05).

[3] Backfat depth 3rd-4th rib (mm, including the skin).

Table 4 Meat characteristics of fresh pork as affected by genetic type and lean grade[1].

	Genetic type		Lean grade		SEM	P-value[1]	
	Pi x (LD x LW)	Du x (Gc x Du)	<60% lean	≥60% lean		Genetic type	Lean grade
pH 45 min	6.20	6.38	6.27	6.30	0.13	0.32	0.89
pH 24 h	5.64	5.68	5.67	5.66	0.05	0.50	0.89
Lightness (L*)	51.87	52.56	53.88	50.85	1.13	0.65	0.20
Redness (a*)	2.96	2.12	2.57	2.51	0.29	*0.04*	0.90
Yellowness (b*)	6.51	6.85	6.64	6.71	0.50	0.61	0.94
Thawing loss (%) aging 1 day	6.80	4.80	4.50	7.00	1.40	0.33	0.27
Thawing loss (%) aging 8 days	8.40	6.00	6.40	8.00	1.15	0.14	0.45
Moisture (%)	66.60	65.90	65.90	66.60	1.10	0.66	0.68
IMF (%)	2.05	2.26	2.23	2.08	0.30	0.63	0.75

[1] Interaction genetic type x lean grade non-significant in any variable (P>0.05).

Table 5 Meat cooking losses and texture (compression and shear force tests) of pork aged 1 and 8 days as affected by genetic type and lean grade[1].

	Genetic type		Lean grade		SEM	P-value[1]	
	Pi x (LD x LW)	Du x (Gc x Du)	<60% lean	≥60% lean		Genetic type	Lean grade
Pork loin aged 1 day							
Cooking loss (%)	21.7	23.9	21.9	23.7	2.15	0.47	0.63
Stress 20% on raw pork (kg/cm^2)	1.1	1.3	1.2	1.1	0.17	0.47	0.57
Stress 80% on raw pork (kg/cm^2)	5.2	6.1	6.2	5.0	0.38	0.15	0.06
Shear force on cooked pork (kg)	4.3	5.4	4.4	5.3	0.39	*0.05*	0.22
Pork loin aged 8 days							
Cooking loss (%)	27.5	25.5	26.2	26.8	1.27	0.26	0.76
Stress 20% on raw pork (kg/cm^2)	0.8	0.7	0.8	0.7	0.09	0.62	0.55
Stress 80% on raw pork (kg/cm^2)	5.7	5.9	6.0	5.6	0.60	0.86	0.74
Shear force on cooked pork (kg)	3.8	3.3	3.6	3.5	0.31	0.28	0.79

[1] Interaction genetic type x lean grade non-significant in any variable (P>0.05).

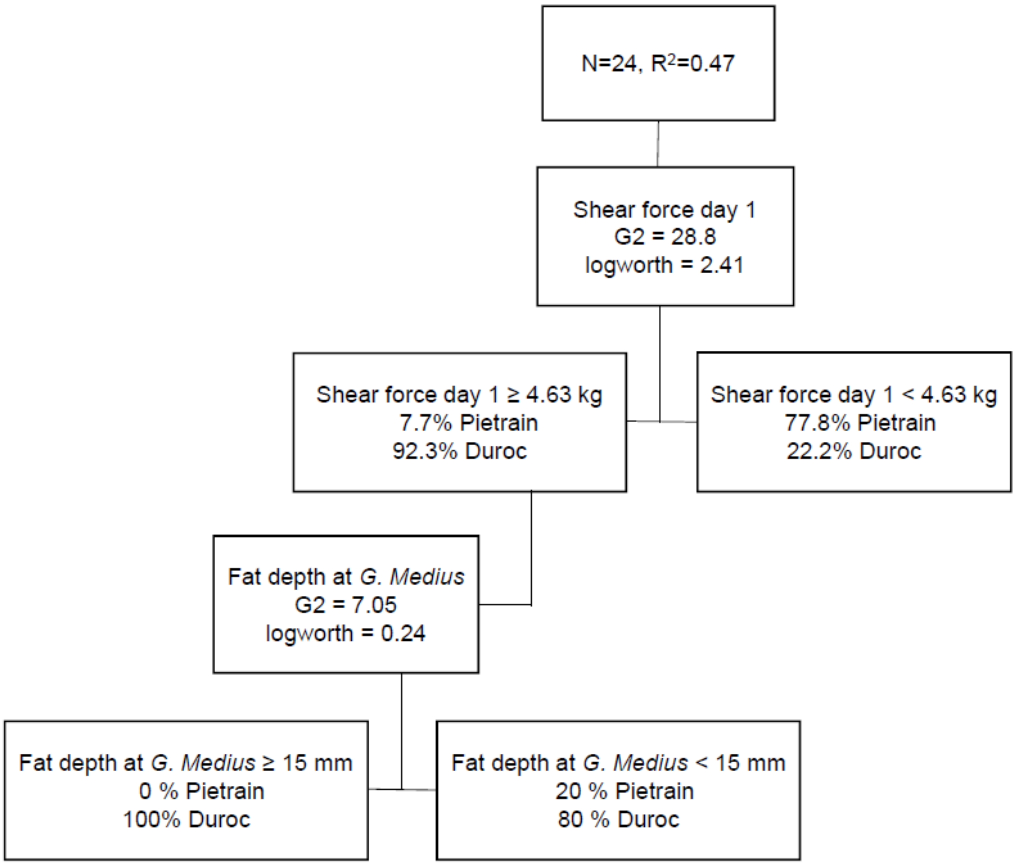

Fig. 1. Partition tree of technological characteristics of organic pork based on genetic type.

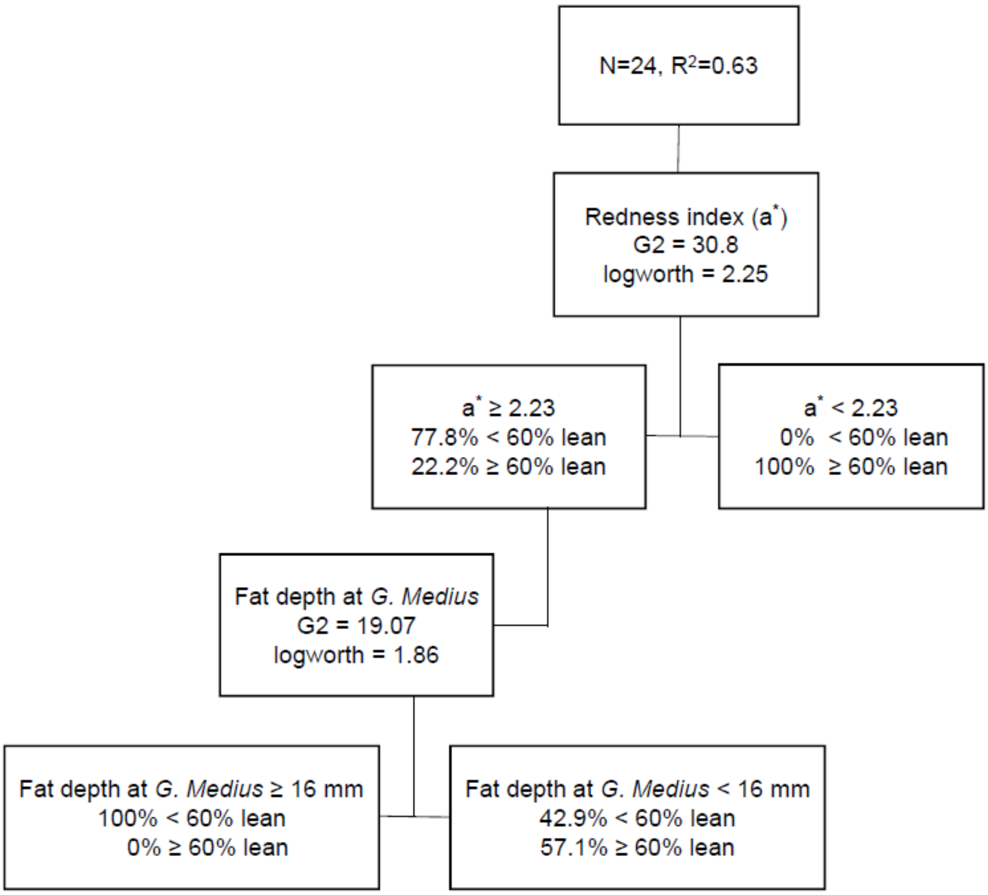

Fig. 2. Partition tree of technological characteristics of organic pork based on lean grade.