Effect of housing system, slaughter weight and slaughter strategy on carcass and meat quality, sex organ development and androstenone and skatole levels in Duroc finished entire male pigs

E. Fàbregaa,⁎, M. Gispert b, J. Tibaub, M. Hortós b, M.A. Oliver b, M. Font i Furnolsb

a IRTA, Veïnat de Sies, s/n, 17121 Monells (Girona), Spain
b IRTA, Finca Camps i Armet, 17121 Monells (Girona), Spain

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A B S T R A C T
This study aimed at evaluating the effect of housing system (HS), slaughter weight (SW) and strategy (SS) on carcass and meat quality, sexual organ development and boar taint in entire males. Twelve pens of 10 pigs were used (two trials). Half of male pens were allowed visual contact with females (MF) and half with males (MM). Half MM or MF were slaughtered at 105 or 130 kg in trial 1, or penwise or by split marketing in trial 2 at 120 kg. Housing system showed no significant effect on carcass or meat quality. MF presented significantly longer testicles and heavier bulbourethral glands compared to MM. The distribution of androstenone and skatole levels was affected by SW but not by HS or SS, samples with androstenone > 1 μg/g of the different groups falling within the range of 16 to 22%. All correlations between androstenone and sex organs were significantly and medium. Housing system and slaughter strategy did not reduce the risk of boar tainted carcasses.

1. Introduction

Piglet surgical castration is widely practised in most European countries to prevent boar taint, increase carcass fat content for high value products like cured ham and prevent aggressive behaviour after puberty. According to the “Attitudes, practices and state of the art regarding piglet castration in Europe” (PIGCAS) project approximately 79.3% (Fredriksen et al., 2009) of the EU male pig population is castrated each year. However, social claims against painful practices (see Prunier et al., 2006 for a review) have increased the pressure on pig producers to find alternatives to surgical castration.


1.1. Surgical castration

Androstenone and skatole are produced in the large intestine of pigs, but also in the accessory sex organs. Androstenone is produced in the ductus accesorius of the testes, while skatole is produced in the caecum (Bonneau, 1982) and genetics (Sellier, Le Roy, Fouilloux, Gruand, & Quesnel, 2000) or social environment may play a role in puberty attainment of puberty (Patterson, Willis, Kirkwood, & Foxcroft, 2002). Skatole is produced in the large intestine of pigs, but also in the accessory sex organs. Androstenone is produced in the ductus accesorius of the testes, while skatole is produced in the caecum (Bonneau, 1982) and genetics (Sellier, Le Roy, Fouilloux, Gruand, & Quesnel, 2000) or social environment may play a role in puberty attainment of puberty (Patterson, Willis, Kirkwood, & Foxcroft, 2002). However, contradictory to this, preliminary results of a study by Salmon and Edwards (2006) showed that boars with gilt contact were less physiologically mature at slaughter and showed reduced levels of sexual behaviours.

Boar taint is an unpleasant odour and flavour mostly attributable to the presence of androstenedione and skatole in the meat (Bonneau et al., 1992). Androstenone levels primarily depend on the stage of puberty (Bonneau, 1982) and genetics (Sellier, Le Roy, Fouilloux, Gruand, & Bonneau, 2000). Skatole is produced in the large intestine of pigs, but puberty status may also affect skatole levels by the interaction with either its metabolism (Babol, Squires, & Lundström, 1999; Doran, Whittington, Wood, & McGivan, 2002) or production (Babol et al., 1999; Zamaratskaia, Babol, Andersson, & Lundström, 2004). It has also been

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Corresponding author. Tel.: +34 972630236; fax: +34 972630533.
E-mail address: emma.fabrega@irta.cat (E. Fàbrega).

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suggested that social factors can exert a noticeable effect on the occurrence of boar taint (Giersing, Lundström, & Andersson, 2000).

The objective of this study was to investigate the effect of different housing systems (with and without visual contact between males and females) on pubertal development and carcass and meat quality traits (including carcass taint compounds) of pigs slaughtered either at 105 or 130 kg live weight or by split marketing vs. penwise slaughter.

2. Material and methods

2.1. Animals and housing

Two trials with a similar experimental design were carried out. The first trial implied a winter growing period of the pigs with an early spring slaughter whereas for the second trial growing period was in spring and slaughter in summer. For both trials, one hundred and forty piglets (90 entire males and 50 females) were moved from a commercial farm to the weaning unit at IRTA-Monells at a mean age of 21 days. The piglets were from the commercial cross (Large White x Landrace) x Duroc and a maximum of 4 piglets per litter were chosen. At a mean age of 63 days, 120 pigs per trial were enrolled on the study ensuring the highest homogeneous body weight possible for all the treatment groups. Forty females and 80 males were selected and identified using an 8-digit electronic chip that permitted the recording of individual feed intake. Pigs were allocated in groups of 10 pigs in 12 fattening pens. All pens were single sex with sight, sound and touch contact but not direct mixing with the same gender or opposite gender, in adjacent pens depending on the treatment. The pens were distributed in three rooms of the same building, with the same farming conditions. As shown in Fig. 1, in room A and C, two pens of females and two pens of males were allocated, whereas in room B there were 4 pens of males.

Ventilation and temperature at the experimental barn were mechanically controlled. Each pen measured 4 × 2.3 m (0.9 m²/pig), had a partly slatted floor (comprising 60% solid concrete and 40% slatted) and had one drinking bowl. Each pen was equipped with an IVOC®-station (INSENTEC, Marknese, The Netherlands). The feeding station consisted of a single-space food hopper with a trough which weighed continuously and had an electronic identification system that was activated by ear responders as pigs entered the station. Each time a pig visited the feeder, the pig identification number and weight of the food at the beginning and at the end of the visit were recorded automatically. To enable competition for food, the entrance of the hopper was always open. All pigs were fed the same commercial diet (14.09 MJ DE/kg, 17.9% crude protein, 7% crude fat, 1.95% lysine, 6.55% ash).

2.2. Slaughter procedure

The slaughter procedure was similar in both trials, but the following slaughter weights and strategies differed. In trial 1, two target slaughter weights were chosen: 105 and 130 kg, respectively. For trial 2, pigs were slaughtered either by split marketing (SM) when their individual weight was approximately 120 kg or penwise (PW) when the mean weight of the pen was 120 kg. Two pens of females (FE), two pens of males in visual contact with females (MF) and two pens of males in visual contact with males (MM) were included in each slaughter weight in trial 1 (105 or 130 kg) or slaughter strategy in trial 2 (SM or PW) (see Fig. 1). For trial 1, the pigs were slaughtered in 4 days, two for each slaughter weight and including 1 pen of each housing system every day of sacrifice (mean age of sacrifice 152 days for the 105 kg group and 170 days for the 130 kg group). For trial 2, pigs were slaughtered within 6 days. In each day one complete pen of the PW slaughter strategy and several animals from three of the SM strategy were slaughtered. The SM pens were slaughtered in a total of three batches. Age of sacrifice for the trial 2 was in the range of 159 to 180 days.

The slaughter procedure was the same for both trials: standard ante mortem procedure to minimise the stress and stunning with CO₂ 85%.

2.3. Carcass and meat quality data

The weight of each half carcass was recorded within 45 min post-mortem following the standard European presentation. Cold carcass weight was also recorded 24 h post-mortem. Carcass lean meat percentage was predicted using the equation published by Font-I-Furnols and Gispert (2009) using the Fat-o-Meat’er (FOM, Carometec, Herlev, DK) measurements (i.e. backfat thickness LR3/FOM and muscle depth (MFOM) both measured 6 cm away from the midline at the intercostal space between the 3rd and 4th ribs, starting from the last rib). Moreover the fat thickness at 8 cm of the midline between the 3rd and 4th lumbar vertebrae (VL FOM) was also measured with FOM. The minimum fat thickness over the Gluteus medius muscle (MLOIN) was taken with a ruler.

During the evisceration process, the weight and dimensions of the reproductive organs were recorded. Testicles and bulbourethral glands were separated from the rest of the reproductive tract. The left and right testicles were weighed separately, epididymus included. The length of testicles and bulbourethral glands was measured using a 30-cm ruler. Bulbourethral glands were cleaned by removing the surrounding connective tissue using a scalpel and afterwards weighed.

To determine the skatole and androstenedione content a full thickness subcutaneous fat sample (approximately 50 g) between the 3rd and 4th ribs, including all fat layers. Another sample of 200 g of Longissimus thoracis (LT) muscle was also collected at the last rib level for the determination of intramuscular fat content. Both samples were vacuum packed and frozen until processed. Androstenedione and skatole levels were measured following the methodology described by García-Reguero and Rius (1998) and Rius, Hortós and García-Reguero (2005). Intramuscular fat (%) was determined using the NIT (Near Infrared Transmittance, Infratec, 1265 TECATOR, DK) equipment.

![Fig. 1. Distribution of the different genders (trial 1 and trial 2), slaughter weights (105 or 130 kg, trial 1) and slaughter strategies (Penwise or Split Marketing, trial 2).](image-url)
Forty five minutes after slaughter, meat pH was determined using a portable pH metre equipped with a Xerolyt probe on the LT muscle (pH45 LT) at the level of the last rib, and on the Semimembranosus (SM) muscle (pH45 SM). Both measures were determined on the left half carcass. Carcasses were stored in a chilling room for 24 h at 3 °C. Afterwards, pH measurements on LT at the last rib level (pH24 LT) and on SM muscle (pH24 SM) were carried out. Electrical conductivity with the Pork Quality Meter (PQM.I-INTEK, Gmbh, Germany) was measured as well and the colour of the loins in the transverse cut on the LT muscle was also evaluated using the Commission Internationale de l’Eclairage (CIE, 1976) values (L*, a*, b*) with the colorimeter Minolta CR200 (Minolta Co., LTD., Osaka, Japan). Marbling was also evaluated by two technicians using the NPPC pattern on the LT muscle at the last rib level.

2.4. Statistical analysis

Data were analysed using SAS v9.1. (SAS Institute, Cary, NC, USA). Carcass and meat quality traits were analysed using the GLM procedure, with housing system, slaughter weight or slaughter strategy and their interaction as fixed effects. Interactions were not significant. Least squares means were compared using the PDIF option and applying Tukey option. Androstenone and skatole data were neparian logarithm transformed to obtain a normal distribution. Results were turned to the originalis to be included in the tables.

Pearson correlations between androstenone levels and sex organs measurements were calculated. Pooled data of the two trials was used to calculate the correlations, to obtain a wider range of live weights. Differences in the distribution of the androstenone or skatole levels between the different housing systems, slaughter weights or slaughter strategies were analysed by a Chi-Square test. The mean levels of androstenone of the different batches of split marketing pigs were also compared by GLM procedure considering carcass weight as a covariate. The distribution of androstenone levels of the different batches of the split marketing group was analysed by chi-square test.

Differences were regarded as significant if P<0.05.

3. Results

3.1. Effect of housing system, slaughter weight or slaughter strategy on carcass quality and sex organs measurements

For trial 1, pigs were slaughtered at 104.36 kg (± 6.66) and 126 kg (± 9.60) for the 105 kg and 130 kg slaughter weight target groups, respectively. For trial 2, penwise pigs were slaughtered at the target mean weight of 120 kg (± 8.12), but for the split marketing group the mean was 118 kg (± 5.65).

The effect of housing system on carcass quality and sex organ measurements is shown in Table 1 (Trial 1) and Table 2 (Trial 2). Housing system significantly affects only MFOM measurement in trial 1, presenting MF a higher value compared to MM. Testicle length and bulbothecal gland weight were affected by housing system in trial 2, presenting MF longer testicles and heavier bulbothecal glands (P<0.05).

Slaughter weight (trial 1, Table 1) significantly affected all carcass traits and sex organs measurements, except for VLFOM As expected, pigs slaughtered at a mean live weight of 130 kg presented heavier carcasses with a lower lean percentage and heavier or longer sex organs compared to pigs slaughtered at 105 kg mean live weight (P<0.001).

Carcass traits and sex organs measurements of pigs slaughtered following different strategies differed significantly only in cold carcass weight (Table 2), penwise slaughtered pigs being heavier than split marketing pigs (P<0.05).

Table 1

<table>
<thead>
<tr>
<th>Housing system</th>
<th>Slaughter weight</th>
<th>SEMa</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF</td>
<td>MM</td>
<td>105</td>
<td>130</td>
</tr>
<tr>
<td>Cold carcass weight (kg)</td>
<td>88.1</td>
<td>88.9</td>
<td>79.8</td>
</tr>
<tr>
<td>KILOTT (%)</td>
<td>77.7</td>
<td>79.5</td>
<td>77.1</td>
</tr>
<tr>
<td>MLON (mm)</td>
<td>14.8</td>
<td>15.4</td>
<td>13.6</td>
</tr>
<tr>
<td>MFOM (mm)</td>
<td>55.2</td>
<td>53.2</td>
<td>51.6</td>
</tr>
<tr>
<td>LR434MM (mm)</td>
<td>18.4</td>
<td>18.9</td>
<td>16.5</td>
</tr>
<tr>
<td>VLFOM (mm)</td>
<td>30.2</td>
<td>30.6</td>
<td>31.4</td>
</tr>
<tr>
<td>Lean FOM (%)</td>
<td>58.4</td>
<td>53.6</td>
<td>59.5</td>
</tr>
</tbody>
</table>

Sex organs

| Testicle weight (g) | 338.4 | 350.9 | 280.6 | 408.7 | 58.86 | 0.38 | <0.001 |
| Testicle length (cm) | 13.6 | 15.5 | 14.6 | 16.3 | 1.05 | 0.57 | <0.01 |
| Bulbothecal gland weight (g) | 88.7 | 78.1 | 62.2 | 101.6 | 25.88 | 0.09 | <0.001 |
| Bulbothecal gland length (cm) | 13.2 | 12.4 | 11.9 | 13.7 | 1.71 | 0.06 | <0.001 |
| Androstenone (μg/g) | 0.82 | 0.75 | 0.60 | 1.02 | 2.39 | 0.69 | 0.022 |

Note: SEM = Standard Error of the mean.

3.2. Effect of housing system, slaughter weight or slaughter strategy on meat quality

Table 3 (trial 1) and 4 (trial 2) summarise the effect of housing system and slaughter weight or slaughter strategy on meat quality parameters. In trial 1, drip loss was significantly higher for MF compared to MM (P<0.01). In trial 2, housing system affected marbling, presenting MF a significantly higher value compared to MM (P<0.01). Pigs slaughtered at 105 kg presented a significantly higher L* value and drip loss percentage (P<0.001 and P<0.05, respectively, Table 3). Table 4 shows that pigs slaughtered by penwise strategy presented a significantly higher pH45 SM (P<0.001) and LT (P<0.05), pHu LT (P<0.05) and marbling (P<0.05). On the contrary, pigs slaughtered by split marketing showed a significantly higher L* Minolta value and drip loss (P<0.05 and P<0.001, respectively).

Table 2

<table>
<thead>
<tr>
<th>Housing system</th>
<th>Slaughter weight</th>
<th>SEMa</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF</td>
<td>MM</td>
<td>PW</td>
<td>SM</td>
</tr>
<tr>
<td>Cold carcass weight (kg)</td>
<td>95.3</td>
<td>97.7</td>
<td>97.6</td>
</tr>
<tr>
<td>KILOTT (%)</td>
<td>80.2</td>
<td>80.3</td>
<td>80.2</td>
</tr>
<tr>
<td>MLON (mm)</td>
<td>15.4</td>
<td>15.8</td>
<td>16.0</td>
</tr>
<tr>
<td>MFOM (mm)</td>
<td>58.2</td>
<td>59.0</td>
<td>59.5</td>
</tr>
<tr>
<td>LR434MM (mm)</td>
<td>20.05</td>
<td>19.50</td>
<td>20.25</td>
</tr>
<tr>
<td>VLFOM (mm)</td>
<td>35.1</td>
<td>32.5</td>
<td>32.1</td>
</tr>
<tr>
<td>Lean FOM (%)</td>
<td>57.3</td>
<td>57.9</td>
<td>57.3</td>
</tr>
</tbody>
</table>

Sex organs

| Testicles weight (g) | 431.2 | 414.8 | 423.0 | 422.9 | 64.06 | 0.26 | 0.09 |
| Testicles length (cm) | 19.6 | 16.5 | 15.7 | 15.9 | 0.99 | 0.03 | 0.37 |
| Bulbothecal gland weight (g) | 94.6 | 79.2 | 79.6 | 94.2 | 36.01 | 0.05 | 0.07 |
| Bulbothecal gland length (cm) | 12.7 | 12.3 | 12.3 | 12.9 | 1.78 | 0.33 | 0.10 |
| Androstenone (μg/g) | 0.74 | 0.67 | 0.68 | 0.74 | 2.53 | 0.66 | 0.67 |
| Skatole (μg/g) | 0.08 | 0.08 | 0.08 | 0.08 | 2.34 | 0.84 | 0.96 |

Note: SEM = Standard Error of the mean.

a SME: Standard error of the mean.
b Housing system.
c Slaughter system.
3.3. Levels and distribution of androstenone and skatole levels and correlations between androstenone levels and sex organs measurements

The levels of androstenone and skatole were not significantly affected by housing system or slaughter strategy (Tables 1 and 2). Pigs slaughtered at 130 kg presented a significantly higher level of androstenone compared to pigs slaughtered at 105 kg (P<0.05, Table 1).

Figs. 2 (trial 1) and 3 (trial 2) summarise the distribution of androstenone levels for each housing system and slaughter weight or slaughter strategy. A significant difference in the percentage of samples with the highest concentration of androstenone (>2 μg/g melted fat) between the two slaughter weights was observed. Males slaughtered at 130 kg mean live weight had a higher percentage compared to males slaughtered at 105 kg mean live weight (Fig. 2, P<0.05). A similar pattern of distribution was observed for the two housing systems and slaughter strategies.

The mean value of androstenone levels between the three different batches of split marketing pigs in trial 2 did not significantly differ.

### Table 3
Effect of housing system and slaughter weight on the meat quality parameters in trial 1 (Lsmeans).

<table>
<thead>
<tr>
<th>Housing system</th>
<th>Slaughter weight</th>
<th>SEM*</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF</td>
<td>MM</td>
<td>105</td>
<td>130</td>
</tr>
<tr>
<td>pH45 SMBR</td>
<td>6.45</td>
<td>6.45</td>
<td>6.47</td>
</tr>
<tr>
<td>pH45 LB</td>
<td>6.48</td>
<td>6.48</td>
<td>6.49</td>
</tr>
<tr>
<td>pHu SM</td>
<td>5.49</td>
<td>5.49</td>
<td>5.48</td>
</tr>
<tr>
<td>pHu LT</td>
<td>5.45</td>
<td>5.46</td>
<td>5.44</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>7.30</td>
<td>6.84</td>
<td>6.79</td>
</tr>
<tr>
<td>SM (mS)</td>
<td>4.78</td>
<td>4.61</td>
<td>4.55</td>
</tr>
<tr>
<td>NT (mS)</td>
<td>1.64</td>
<td>1.84</td>
<td>1.83</td>
</tr>
<tr>
<td>pHu Minolta</td>
<td>50.86</td>
<td>50.59</td>
<td>52.04</td>
</tr>
<tr>
<td>pHu Minolta</td>
<td>5.48</td>
<td>5.52</td>
<td>5.64</td>
</tr>
<tr>
<td>Drip loss (%)</td>
<td>3.63</td>
<td>2.80</td>
<td>3.63</td>
</tr>
<tr>
<td>Intramuscular fat (%)</td>
<td>1.36</td>
<td>1.61</td>
<td>1.56</td>
</tr>
</tbody>
</table>

* SEM: Standard error of the mean.
\( \beta \): Housing system.
\( \alpha \): Slaughter Strategy.

3.4. Correlation between androstenone level and sex organs measurements

The Pearson correlations between androstenone levels, sex organ measurements and live weight are presented in Table 5. All correlations were found to be significant, except for the one between androstenone and live weight.

### Table 4
Effect of housing system and slaughter strategy on the meat quality parameters in trial 2 (Lsmeans).

<table>
<thead>
<tr>
<th>Housing system</th>
<th>Slaughter strategy</th>
<th>SMEb</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF</td>
<td>MM</td>
<td>PW</td>
<td>SME</td>
</tr>
<tr>
<td>pH45 SMβ</td>
<td>6.62</td>
<td>6.55</td>
<td>6.67</td>
</tr>
<tr>
<td>pH45 LB</td>
<td>6.58</td>
<td>6.59</td>
<td>6.63</td>
</tr>
<tr>
<td>pHu SM</td>
<td>5.51</td>
<td>5.50</td>
<td>5.52</td>
</tr>
<tr>
<td>pHu LT</td>
<td>5.52</td>
<td>5.50</td>
<td>5.53</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>4.60</td>
<td>4.81</td>
<td>4.58</td>
</tr>
<tr>
<td>SM (mS)</td>
<td>3.98</td>
<td>3.91</td>
<td>4.01</td>
</tr>
<tr>
<td>NT (mS)</td>
<td>1.61</td>
<td>1.20</td>
<td>1.55</td>
</tr>
<tr>
<td>pHu Minolta</td>
<td>49.30</td>
<td>48.94</td>
<td>48.42</td>
</tr>
<tr>
<td>pHu Minolta</td>
<td>6.65</td>
<td>6.83</td>
<td>6.68</td>
</tr>
<tr>
<td>Drip loss (%)</td>
<td>2.27</td>
<td>2.41</td>
<td>2.24</td>
</tr>
<tr>
<td>Intramuscular fat (%)</td>
<td>1.63</td>
<td>1.69</td>
<td>1.73</td>
</tr>
</tbody>
</table>

* Housing system.
\( \beta \): SEM: Standard error of the mean.
\( \alpha \): Slaughter Strategy.
\( \beta \): SM: Semimembranosus.
\( \alpha \): LT: Longissimus thoracis.

### Fig. 2
Distribution of androstenone levels (μg/g melted fat) in each housing system or slaughter weight in Trial 1.

The levels of skatole were not significantly different either between the three batches of the SM slaughter strategy.

### Fig. 3
Distribution of androstenone levels (μg/g melted fat) in each housing system or slaughter weight in Trial 1.

### Fig. 4
Distribution of skatole levels according to housing system and slaughter strategy for trial 2 are represented in Fig. 4. No significant differences between housing systems or slaughter strategies were observed.

The Pearson correlations between androstenone levels, sex organ measurements and live weight are presented in Table 5. All correlations were found to be significant, except for the one between androstenone and live weight.

### 4. Discussion

The results presented in this paper are part of a bigger investigation in which the effect of housing system and slaughter strategy on the behaviour, welfare and meat and carcass quality of entire male pigs is being evaluated. The results discussed below summarise the effects on meat and carcass quality, boar taint levels and sex organ development.

#### 4.1. Carcass traits and meat quality results

The effect of housing system (males in visual contact or not with females) on carcass and meat quality traits was found to be limited in both trials. A higher drip loss percentage in loins from males in visual contact with females in trial 1 was found. This result, however, was not confirmed in trial 2. Drip loss percentage may be associated to the tendency to produce PSE meat, and this, in turn, has been found to be related to stress specially associated to pre-slaughter conditions.
factors like the lack of an harmonised analytical method may in
levels between studies have to be always cautious because random
published results on split marketing have focused so far on its in
mixing, and the effects on carcass and meat quality traits of this study
visual contact or not with females differed. Up to our knowledge, only
pigs of the present study were taken and are being analysed to
on meat quality grounds. Lastly, physiological measurements of the
slaughtered penwise. Day of sacrifi
trial 2 this was possible for split marketing pigs, but not for those
trial 1 all housing systems were present in each slaughter day, but for
some extent, from independent pre-rigour biological phenomena (De
colour brightness and water-holding capacity may result, at least to
consistent.Salmon and Edwards (2006) in a similar study to the present
one, allowing visual contact of males and females and with modern
genotypes finished to heavy weights, found that boars with gilt visual
contact were less physiologically mature at slaughter and showed
reduced levels of sexual behaviours. Contradictory to this, Patterson and
Lightfoot (1984) found that rearing boars with gilt contact increased
androstenone concentration and Andersson et al. (1999) found that
males raised in mixed sex groups to a slaughter weight of 107 kg were
more sexually mature (heavier epididymis weights) than males from
single-sex groups, but androstenone concentrations were not different.
Similar to the present study, Zamaratskaia et al. (2005) found that androstenone levels were higher in
mixed compared to single-sex pens in pigs of a low weight group
(90 kg), but this difference was not found at heavier weights (110 kg and
115 kg). These authors suggested that the exposure of female to male
pigs might be responsible for the differences in the age/weight when
levels of testicular steroids increase, but not the intensity of this increase
afterwards. The discrepancies between studies may be related to the
complexity of the puberty process itself and its regulation combining
several factors such as weight, age, genetics, nutrition and social
environment.

Pigs slaughtered at 130 kg average live weight presented a higher
development of all the four measurements taken on the sex organs
compared to the pigs slaughtered at 105 kg. Size of sex organs is
considered a puberty-related factor, but investigations on the relation-
ship between boar taint and reproductive organ size have yielded
variable results. Whereas Bonneau and Russell (1985) suggested that
the measurement of bulbourethral glands could be used as an indirect
estimation of androstenone levels in fat, Squires and Lou (1995) found the
highest androstenone levels in a breed with the shortest glands.
More recently, Zamaratskaia et al. (2005) suggested that testis \( \approx 565 g \) and bulbourethral gland length \( \approx 90 mm \) could be used as a threshold
level to detect pig carcasses with low levels of skatole, but high
androstenone levels could not be predicted by measuring the size of sex
organs. In the present study, slaughter weight was the only factor
significantly affecting the pattern of distribution of the androstenone
levels, presenting pigs slaughtered at 130 kg average live weight around
a 15% of clearly tainted samples (level \( \approx 2 \mu g/g, \text{Fig. 2} \)) compared to the
0% of the pigs slaughtered at 105 kg. However, when pooling data from
both trials, the correlation between body weight and androstenone was
not significant. On the contrary, the rest of the correlations between
androstenone and sex organs size or between sex organs were significant.
As mentioned previously, no general agreement about the relationship

| Table 5 Pearson Correlations between androstenone levels and sex organ measurements. |
|---------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Testicle weight | Testicle length | Bulbourethral gland weight | Bulbourethral gland length | Live weight |
| Androstenone | 0.42*** | 0.51*** | 0.57*** | 0.54*** | 0.09*** |
| Testicle weight | 0.76*** | 0.49*** | 0.47*** | 0.52*** | 0.001*** |
| Testicle length | 0.46*** | 0.48*** | 0.46*** | 0.46*** | 0.001*** |
| Bulbourethral gland weight | 0.77*** | 0.22*** | 0.22*** | 0.22*** | 0.001*** |
| Bulbourethral gland length | 0.22*** | 0.22*** | 0.22*** | 0.22*** | 0.001*** |

** Significance level: \( P<0.01 \).
*** Significance level: \( P<0.001. \)
between boar taint and sex organs size has been reported in previous studies. The complexity of pubertal onset and of boar taint compounds metabolism may underlie such discrepancies.

Another factor which should be taken into account are the potential effects of split marketing (used in trial 2) on androstenedione levels. In the present study the androstenedione and skatole levels were not associated with slaughter strategy. However, when analysing the androstenedione levels for the three batches of the split marketing group, there was a tendency for pigs being delivered first to present higher levels of androstenedione. Previous studies have reported an increase of unwanted behaviours (specially fighting) amongst pigs that remain in a pen after split marketing (Fredriksen & Hxeber, 2009), but no published results on androstenedione levels after split marketing are available. The link between androgens and aggressive behaviour is well documented, but not all the results are coincident (Zamaratskaia, Rydhmer, et al., 2005).

In the present study, the regrouping process after split marketing did not lead to higher levels of androstenedione in the remaining pigs compared to the removed. As discussed by Zamaratskaia, Rydhmer, et al. (2005), the relationship between gonadal hormones and aggressive behaviour is complex and involves a variety of factors such as age, puberty stage and environment. An aspect for future investigation would be to try to determine androstenedione in samples of the remaining pigs before and after the split marketing process, in order to disentangle potential individual variation.

5. Conclusions

No significant effects on carcass and meat quality between the two groups of entire male pigs were found in the present study. Pigs slaughtered by split marketing presented higher drip loss levels compared to those slaughtered penwise. Sex organ size was mainly affected by target slaughter weight, with heavier and longer organs for those pigs slaughtered at 130 kg compared to 105 kg. MF presented longer testicles and heavier bulbourethral glands compared to MM. The distribution of androstenedione or skatole levels or the mean concentrations were not associated either with the housing system or slaughter strategy, presenting both MM and MF a percentage of samples with androstenedione >1 μg/g ranging from 16 to 22%. According to the present results, the housing systems and slaughter strategies tested did not reduce the risk of boar tainted carcasses.

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