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Predicting the likelihood of developing boar taint: Early physical indicators in entire male pigs

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ABSTRACT

Three potential early-age predictors of which boars are likely to develop boar taint (testes volume, skin lesions and dirtiness) were measured on 102 boars every fortnight from 10 weeks of age until slaughter. These predictors were correlated with the level of boar taint according to the hot iron method and the concentrations of skatole and androstenone as determined by chemical analysis. The chance of no/low boar taint according to the hot iron method decreased with higher testes volume (weeks 22 and 24) and increased with skin lesion score (weeks 12, 16 and 18). For the concentrations of androstenone and skatole, the strongest correlation was found with testes volume in week 12. Skin lesions in week 16 were negatively correlated with skatole levels. Dirtiness was negatively correlated with skatole concentrations (week 18) but positively correlated with androstenone concentrations (weeks 20 and 22). Testes volume has the greatest potential for predicting the likelihood of developing boar taint.

1. Introduction

In most European countries between 80 and 100% of male pigs are surgically castrated in order to prevent boar taint. Boar taint is an unpleasant odour and flavour in heated boar meat and fat (Fredriksen et al., 2009). Ongoing societal pressure against the routine practice of surgical castration without anaesthesia (EFSA, 2004) has spurred researchers to study alternative strategies to prevent and reduce boar taint. Until now, the only measures considered have been to apply surgical castration or alternative strategies (such as immunocastration or the use of anaesthesia during surgical castration) to every male pig of the herd. But only a minority of the entire male pigs will actually develop boar taint by the age they are usually slaughtered. In Belgium, for example, only 4% of the entire male pigs could be classified as strongly tainted and another 25% as moderately tainted (Aluwe et al., 2009). The costs of these strategies (in terms of money, labour, animal suffering, reduction in growth efficiency, and public image) could be reduced substantially if treatment could be limited to the minority of boars that actually develop boar taint by slaughter age. The objective of this study is to investigate if any physical risk factors can be observed in living young entire male pigs that reliably predict whether or not they will develop boar taint at slaughter age. Such early predictors could allow low-risk animals to be left entire while high-risk animals could be surgically castrated, immunocastrated, or slaughtered at a young age.

We investigated three potential early physical predictors for the presence of boar taint at slaughter age: testes volume, skin lesions and dirtiness. These predictors were selected based on the feasibility of measuring or scoring them on living entire male pigs and on the knowledge about the development of boar taint (Babol, Squires, & Gullett, 1995). The main components responsible for boar taint are androstenone and skatole (EFSA, 2004). Androstenone is a pheromone secreted in boar testes along with testosterone and is involved in the communication of sexual status (Booth & Baldwin, 1980). The levels of androstenone in fat and plasma have found to be positively correlated with the stage of sexual maturity (Babol et al., 1995). In several studies, a positive correlation between the size of accessory sex glands (the Cowper's glands) and the concentration of androstenone at slaughter has been documented (Bonneau & Russeil, 1985). In this study we use testes volume as an alternative indicator of sexual development because the size of the Cowper's glands is not easy to measure non-invasively on living animals. Moreover, Aldal et al. (2005) reported that at slaughter, entire male pigs with higher androstenone levels also have heavier testes and that testes weight is correlated with testes volume. We predict, therefore, that the size of the testes of male pigs measured at various ages during the growing period is positively related with the level of boar taint, and of androstenone in particular, after slaughter.

The second physical predictor we investigated was skin lesions, an easy-to-score indicator of aggression received and sexual behaviour

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(mounting). Turner et al. (2006) reported that the number of skin lesions on a pig is associated with the number of aggressive attacks that this pig received from penmates. There are two kinds of aggression that has been observed for pigs (Rydhmer et al., 2006). A first kind is a brief period of intense fighting when unfamiliar pigs are mixed, a second kind is competition over feed and resources; this aggression is more a long-term aggression. Fast growing and heavy pigs will attack more than light pigs and entire male pigs are known to be more aggressive than female pigs. Entire male pigs that have a higher growth rate and bodyweight are never involved in mounting behaviour (sexual behaviour). As a result heavier pigs will have fewer scratches than lighter pigs, which are involved in mounting. This aggressive and sexual behaviour is stimulated by 16-androstene steroids (i.e., the group of steroids to which androstenone belongs) (Booth & Baldwin, 1980). We predict, therefore, that the number of skin lesions is associated with the development of boar taint and with the level of androstenone in particular.

The third predictor investigated was cleanliness. Hansen, Larsen, Jensen, Hansenmoller, and Bartongade (1994) found that the concentration of skatole in the fat of pigs that are kept in pens with high faeces deposition is higher than in pigs kept in pens with low faeces deposition. There are also indications that skatole is absorbed directly through the skin from faeces and urine and/or by inhalation in a gaseous form through the lungs (Hansen, 1998). We wanted to test if dirtiness of boars is associated with the level of boar taint, and of skatole in particular.

2. Materials and methods

2.1. Animals and management

The entire male pigs used for this experiment were experimental control pigs used in various ILVO experiments to reduce boar taint by manipulating diet (Aluwe et al., 2009), hygienic conditions (Aluwé, Bekaert, et al., 2011), and breed combined with slaughter age (Aluwé, Millet, et al., 2011). For the feeding and hygiene experiments, the breed used was Piètrain × Hybrid cross. The breed experiment involved three pure breeds: Belgian Landrace stress-negative, Large White and Piètrain.

At nine weeks of age (average bodyweight of 24 kg ± 2.5) the pigs were divided over several pens so that littermates belonged to different groups. The diet, breed and hygiene experiments had three control groups of eight entire male pigs, twelve control groups of six entire male pigs and three control groups of seven entire male pigs, respectively. This yielded a total of 117 entire boars at the beginning of the experiment. However, the first 8 pigs were used in a pilot study and another 7 pigs died during the experiment. The final total sample size was thus 102 entire male pigs. Between 22 and 24 weeks of age the Belgian Landrace stress-negative and Large White were slaughtered since they had reached the slaughter weight of 110 kg. Consequently, only 52 boars remained up to the age of 24 weeks.

All entire male pigs were given a two-phase feed ad libitum: feed I from 20 until 50 kg and feed II from 50 kg until slaughter and they had continual free access to water. The pigs were slaughtered when the average weight of the pigs housed in a pen reached the intended slaughter weight of 110 kg. Pigs were fasted for 24 h before slaughter. After 1 h of transport and about 3 h of lairage the pigs were slaughtered by exsanguination after electric stunning. The back fat layer was sampled, cut into pieces and vacuum stored at −80 °C up to chemical analysis of the concentration of skatole and androstenone.

2.2. Physical predictors

Testes volume, skin lesions and dirtiness of every entire male pig were scored each fortnight from the start of the experiment (10 weeks of age) until slaughter (around 24 weeks of age). Width and length of the testes were measured using callipers (Ricca 50 cm). These measurements were used to calculate testes volume using the following formula: $\text{volume} = \text{length}^2 \times \text{width} \times (\pi/6)$. Nine body regions were examined for skin lesions and dirtiness: head/neck, back, ear (left and right), shoulder and for limb (left and right), flank (left and right) and hindquarter. For each of these nine regions the number of scratches and the amount of soiling were scored on a 5-point scale (Tables 1, 2).

2.3. Level of boar taint

No gold standard exists to quantify the level of boar taint (Haugen, Brunius, & Zamaratskaia, 2011). So we used two methods: chemical analysis of the concentration of skatole and androstenone in fat samples and sensory evaluation of fat heated with a hot iron at the slaughterhouse as described by Jarmoluk, Martin, and Fredeen (1970). The latter was assessed in the cooling cell during the slaughter process. The odour released by heating the neck fat with a 30 W soldering iron was scored by two experts, on a scale from 1 (neutral) to 4 (very bad) (Aluwe et al., 2009). For the chemical analysis, a liquid-chromatographic multiple–mass-spectrometric (LC-MS^n) method was used for simultaneous determination of skatole (3-methylindole) and androstenone (5α-androst-16-en-3-one) in pig fat samples. See Verheyden et al. (2007) for a detailed description of this method. In brief, the sample was prepared by extracting the analytes from the fat-matrix using methanol, followed by freezing the extract in liquid nitrogen and a filtration step. Subsequently, analyses were carried out on a LTQ linear ion trap mass analyser (Thermo Electron, San José, CA, USA) equipped with an atmospheric pressure chemical ionisation (APCI) interface. Using chromatographic separation and mass spectrometric detection of the analytes, they were identified in the samples. Quantification was performed based on calibration curves for each individual analyte in a fat matrix.

2.4. Statistical analyses

The statistical analyses were performed with SAS® version 9.2 for Windows. The Spearman's rank correlation coefficient between the two boar taint methods (hot iron method and the concentration of skatole and androstenone) was determined to investigate the internal consistency between both methods. An average score for all nine body regions was calculated for skin lesions and dirtiness. The associations between the three predictor variables (testes volume, skin lesions of total body region, and dirtiness of total body region) and the outcome of the various boar taint detection methods were calculated using the Spearman's rank correlation coefficient. The effect of the predictor variables on the scores of the hot iron method was analysed with a cumulative logit model using the genmod procedure. The spearman's rank correlation was also used to look to the correlation between skatole and androstenone

3. Results

Two methods, the hot iron method and chemical analysis, were used during this study because no gold standard exists for determining boar

Table 1
Scale used for scoring skin lesions of boars.

Score	
0	No lesions or injuries
1	1–3 lesions < 5 cm, 1–2 lesions of 5–15 cm, no other injuries
2	4–6 lesions < 5 cm, 3–4 lesions of 5–15 cm, 1–2 lesions > 15 cm, no other injuries
3	> 6 lesions < 5 cm, > 4 lesions of 5–15 cm, > 3 lesions > 15 cm, no other lesions
4	Severe injuries on one part of the body

Table 2
Scale used for scoring dirtiness of boars.

Score	
0	0% of the body region is soiled
1	0–20% of the body region is soiled
2	20–40% of the body region is soiled
3	40–60% of the body region is soiled
4	80–100% of the body region is soiled

taint. The determination of boar taint using the hot iron method was significantly correlated with the concentration of skatole ($r = 0.388$, $P < 0.001$) and androstenone ($r = 0.392$, $P = 0.0021$) in fat as determined by chemical analysis. Also the concentration of skatole and androstenone in fat determined by chemical analysis was significantly correlated ($r = 0.374$, $P = 0.0039$).

Testes volume from the age of 12 weeks onwards was highly significant and positively correlated with the concentration of skatole in fat (Table 3). A positive correlation was also observed between the concentration of androstenone and testes volume at week 12 and a trend for such a correlation was noticed at weeks 14 and 16 (Table 3). For both compounds, the correlation coefficient was highest for testes volume measured when the boars were 12 weeks old. When using the hot iron method, the chance of falling in a category with no or little boar taint increased with lower testes volume measured on boars of 22 ($P = 0.001$) and 24 ($P = 0.024$) weeks old. A trend for such an association was also found when testes volume was measured when the boars were aged 16 ($P = 0.052$) and 20 ($P = 0.099$) weeks.

A negative correlation was observed between the number of skin lesions (average of the nine body regions) on 16-week-old boars and the concentration of skatole in fat (Table 4). The correlations between the number of skin lesions on 20- and 24-week-old boars and skatole, and between skin lesions of 16-week-old boars and androstenone, approached statistical significance (Table 4). The chance of detecting no boar taint using the hot iron method increased with the number of skin lesions during weeks 12 ($P = 0.027$), 16 ($P = 0.008$) and 18 ($P = 0.041$).

Dirtiness of 18-week-old boars was negatively correlated with the concentration of skatole in fat (Table 5). However, a positive correlation between dirtiness and the concentration of androstenone in fat was observed at week 20 and 22. Dirtiness had no significant effect on the scores from the hot iron method (all $P > 0.05$).

4. Discussion

This study evaluated whether testes volume, skin lesions and dirtiness have potential as early-age parameters to predict which entire male pigs are likely to have boar taint at slaughter age.

We predicted that early-maturing male pigs, as determined by the size of the testes during development, would be more likely to have boar taint (and a high fat concentration of androstenone in particular) by the time they are slaughtered. This hypothesis was largely confirmed. Positive correlations were found between testes volume of growing entire male pigs and boar taint level at slaughter as determined by the fat concentrations of the main boar taint compounds and by the hot iron method. For the hot iron method, this association was strongest when testes volume was measured on 22-week-old boars, whereas the correlations with skatole and androstenone levels were strongest when testes volume was measured on boars aged 12 weeks old. To our surprise, the strength of these correlations was not higher for androstenone than for skatole levels. Moreover, the correlation with skatole remained highly significant until the boars had reached slaughter age, whereas the strength of the correlation with androstenone declined as the boars grew older. The latter does not agree with Aldal et al. (2005) who reported that entire male pigs with higher androstenone levels also have much heavier testes at slaughter, nor does it support the theory of the inter-dependency of androstenone and skatole metabolism. Zamaratskaia et al. (2005) also investigated whether an association between the incidence of boar taint and pubertal changes (testes weight and length of bulbourethral glands) may exist. However, they did not observe a significant correlation between testes weight (at slaughter) and androstenone or skatole concentrations. But the multivariate analysis showed that, including the reproductive organ size slightly improved the percentage of explained variation and the correlation with androstenone and skatole concentrations.

Skin lesions and dirtiness did not show equally strong associations with boar taint, and were only significant when measured on entire male pigs older than 14 weeks of age. We observed a tendency toward a correlation – which was negative as predicted – between androstenone level in fat and skin lesions at week 16. We were surprised to find a negative correlation with skatole, because we expected aggression to be linked more directly with androstenone than skatole. The interplay between androstenone and skatole metabolism may have contributed to these findings.

Table 4
Mean value (± SD) of skin lesions of entire male pigs aged between 10 and 24 weeks and its correlation with fat concentration of skatole and adrostenone after slaughter.

Week	Skin lesion score	Correlation with skatole	Correlation with androstenone
10	1.2 ± 0.4	0.07	−0.05
12	1.3 ± 0.5	0.10	−0.20
14	1.3 ± 0.5	−0.15	−0.17
16	1.4 ± 0.5	−0.21*	−0.32*
18	1.5 ± 0.5	−0.23*	−0.18
20	1.4 ± 0.4	−0.25*	−0.18
22	1.5 ± 0.5	−0.02	−0.12
24°	1.4 ± 0.4	−0.28(*)	0.11

(*): 0.1 > p > 0.05; *: 0.05 > p > 0.01.
°Sample size was reduced from 102 to 52 boars.

Table 3
Mean value (± SD) of testes volume of entire male pigs aged between 10 and 24 weeks and its correlation with fat concentration of skatole and adrostenone after slaughter.

Week	Testes volume (cm^3)	Correlation with skatole	Correlation with androstenone
10	61 ± 31	0.17	0.09
12	85 ± 28	0.32**	0.41**
14	123 ± 45	0.26*	0.24
16	193 ± 67	0.32**	0.22
18	276 ± 106	0.40***	0.12
20	370 ± 119	0.39***	0.12
22	476 ± 142	0.41**	0.10
24°	562 ± 170	0.41**	0.07

(*): 0.1 > p > 0.05; *: 0.05 > p > 0.01; **: 0.01 > p > 0.001; ***: p < 0.001.
°Sample size was reduced from 102 to 52 boars.

Table 5
Mean value (± SD) of dirtiness of entire male pigs aged between 10 and 24 weeks and its correlation with fat concentration of skatole and adrostenone after slaughter.

Week	Dirtiness score	Correlation with skatole	Correlation with androstenone
10	0.9 ± 0.4	−0.21*	0.07
12	0.9 ± 0.3	0.07	0.02
14	1.1 ± 0.6	−0.13	−0.07
16	1.1 ± 0.5	−0.06	0.05
18	1.0 ± 0.4	−0.24*	−0.07
20	1.1 ± 0.3	−0.06	−0.002
22	1.2 ± 0.5	−0.13	0.12
24°	1.1 ± 0.2	0.37*	0.23

(*): 0.1 > p > 0.05; *: 0.05 > p > 0.01.
°Sample size was reduced from 102 to 52 boars.

As it has been reported that skatole can be absorbed directly through the skin and/or by inhalation in gaseous form through the lungs (Hansen, 1998), we hypothesised that dirtier entire male pigs would have a higher fat concentration of boar taint compounds, skatole in particular. Contrary to this prediction, we found that the concentration of skatole in the fat decreased with the amount of soiling in 18-week-old male pigs. At the other ages the degree of soiling was not associated with skatole levels. Nor did the hot iron scores indicate any effect from soiling. No clear reason can be given for the positive correlation between androstenone levels and degree of soiling of boars aged 20 and 22 weeks.

A lot of research has been reported in which attempts are made to reveal a possible correlation and interplay between skatole and androstenone. In this study a significant correlation was found between skatole and androstenone in fat, which supports earlier research of e.g. Babol, Squires, and Lundstrom (1999) and Zamaratskaia and Squires (2009). Skatole levels in fat have been shown to be correlated with androstenone levels (Babol et al., 1999). Nevertheless, the mechanisms that relate the levels of skatole and androstenone have not yet been clarified entirely. Doran, Whittington, Wood, and McGivan (2002) suggest that androstenone reduces the catabolism of skatole, while Claus, Weiler, and Herzog (1994) suggest that androstenone increases the production of skatole. Rasmussen, Zamaratskaia, and Ekstrand (2011) found that one of the main enzymes involved in the metabolism of skatole can be inhibited by physiological concentrations of androstenone, but also of oestradiol. However the activity of the enzyme in female pigs was not affected. Similar results were also found in previous studies: Zamaratskaia and Squires (2009) and Babol et al. (1999).

These results of the present study suggest for the first time that it may be possible to predict which entire male pigs have a higher risk of developing boar taint starting at the age of 12 weeks. Testes volume at week 12 seems to have the greatest potential as early predictor of the fat concentrations of the two main boar taint compounds in boars at slaughter. A larger study is needed to determine whether the specificity and sensitivity of differentiating high and low risk animals, on the basis of the size of their testes (possibly in conjunction with other predictor variables), are sufficiently high so that preventive actions against boar taint can be restricted to the high-risk animals only. The determination of the specificity and sensitivity will only be possible once consensus on the operational definition of boar taint has been reached.

Whatever the operational definition though, we realise that a boar taint control strategy based on early identification and remediation of high risk boars will never be free of error. However, early physical predictors can also be seen as a guideline for the farmers to have an indication of the prevalance of boar taint during the fattening period. Preventive actions of management strategies can be taken to lower the prevalance of boar taint on farm. Management strategies may include slaughter at a younger age, and dietary alterations to reduce skatole in particular (Zamaratskaia & Squires, 2009). To conclude, further research seems warranted to investigate further the potential application in practice of using testes size (possibly in conjunction with other early predictors) for predicting the likelihood of boar taint at the level of both the individual pig and the group.

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