

RESEARCH ARTICLE

Organic fattening of entire male pigs from two sire lines under two feeding strategies Part 2: Meat quality and boar taint

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HIGHLIGHTS

- **The use of Duroc or Piétrain sired pigs and the feeding of raw potato starch influenced the content of boar taint-related compounds in pig fat to a different extent.**
- **The contents of androstenone and skatole in the fat influenced the sensory evaluation of the samples.**

KEYWORDS **androstenone, skatole, Duroc, Piétrain, raw potato starch**

Abstract

Fattening of entire male pigs can result in boar taint and affects growing performance as well as meat and carcass traits. The objective of the present study was to test the effect of two terminal sire lines (Duroc, Du vs Piétrain, Pi) and two feeding strategies (without (-) vs with 10 % (+) raw potato starch 28 days (SD: 10.8) prior to slaughter) on meat quality parameters as well as the occurrence of boar taint in meat. Animals were reared under organic housing and feeding conditions using German Landrace*German Large White sows and nine Duroc and seven Pietrain Artificial Insemination-boars. The electrical conductivity 24 h p.m. (EC24) between the 13th and 14th rib, meat colour (L*, a, b), intramuscular fat content (IMF), and fatty acid composition of IMF, as well as the amount of skatole (SKA), indole (IND), and androstenone (AND) in the shoulder fat, were measured in a total of 280 boars (65 Du-, 73 Du+, 68 Pi-, 74 Pi+). A trained sensory panel performed an olfactory evaluation of the fat. No differences were found in terms of the physical parameters of meat quality. The content of the IMF was significantly higher in Duroc than in Piétrain offsprings. Regardless of the diet, AND was higher in Du than in Pi (920 vs 680 ng g^{-1}). The content of IND was similar for Du and Pi, and the use of raw potato starch had a reducing effect on IND compared to the control diet (3.6 vs 7.8 ng g^{-1}). The content of SKA was the highest in Pi- (94.0 ng g^{-1}), while its levels in Pi+, Du-, and Du+ were similarly low (38.0 ng g^{-1}). Concentrations of IND and SKA were generally low in the samples. Sensory evaluation of the fat samples showed no difference between the trial groups. In conclusion, the use of Piétrain as terminal sire line seems suitable to reduce the level of androstenone in boar meat. Although the use of raw potato starch reduced the amount of indole, feeding the diet containing 10 % of potato starch led to inconsistent results regarding skatole contents in Piétrain and Duroc due to a significant genotype*feeding interaction.

1 Introduction

Boar taint is an off-odour that can decrease consumer liking of pig meat. To avoid boar taint, castration of male pigs is a standard procedure. To minimise the pain during castration, the use of analgesia is mandatory, while anaesthesia is (as per today) not legally required. However, the ban of castration without anaesthesia in Germany was already planned for

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the end of 2018 but has been postponed until 2021 because the existing alternatives were deemed as non-applicable to the common practices in pig meat production. One alternative to castration is the fattening of entire male pigs. While advantages of fattening entire male pigs under conventional conditions can be found for growth performance and carcass quality, negative consequences on the fat composition and meat quality due to the occurrence of boar taint are also well known (Bonneau, 1998). Studies on the consequences of fattening entire male pigs on growth performance, carcass, and meat and fat quality under organic conditions, which differ from conventional pig farming mainly concerning feed composition (use of roughage, no synthetic amino acids) and husbandry conditions (spatial requirements, outdoor access) are scarce.

The occurrence of boar taint is mainly attributed to skatole and/or androstenone, and, to a lesser extent, indole that accumulate in the fat of entire male pigs (Lundström et al., 2009). The amount of skatole in the fat of entire male pigs is higher than in gilts and barrows (Zamaratskaia et al., 2006) due to reduced skatole degradation in the liver caused by the negative feedback of the male sex hormone testosterone (Babol et al., 1999). Skatole and indole are produced by microbial degradation of L-tryptophan in the caecum and colon (Jensen et al., 1995). However, skatole formation in the large intestine can be reduced by feeding strategies that provide non-praeceacally-available dietary energy for the growth of skatole-associated large intestine microbiota. This results in the available tryptophan being used for the synthesis of microbial protein and not for the production of skatole (Zamaratskaia and Squires, 2009). Among others, raw potato starch has such an effect (Chen et al., 2007; Lösel and Claus, 2005; Pauly et al., 2008; Zamaratskaia et al., 2005). Androstenone is an androst-16-ene steroid, produced in Leydig cells of testes (Squires et al., 1991), and functions via saliva as a pheromone between the boar and the sow during reproduction (Perry et al., 1980). Breed types differ in androstenone content. For instance, Duroc genotypes are associated with higher androstenone concentrations in fat than growing-finishing pigs of other origins (Fredriksen et al., 2006; Xue et al., 1996).

Therefore, the aim of this study was to compare entire male pigs of the two terminal sire lines Duroc (Du) and Piétrain (Pi) and the use of raw potato starch and their combination in terms of their influence on meat quality and the occurrence of boar taint in meat under organic conditions. Thereby, we tested the hypothesis that the use of Piétrain as the terminal sire and offering a diet containing 10 % potato starch in the finishing phase can reduce the occurrence of boar taint in organic pigs.

2 Materials and methods

2.1 Trial design

The trial was performed at the eco-certified research farm of the Thünen Institute of Organic Farming (Trenthorst, Germany) from September 2012 until October 2015. We split 280 entire male growing-finishing pigs into four treatments representing the combination of two different feeding strategies, use (+) vs non-use (-) of raw potato starch before slaughter, and two different terminal sire lines (Duroc, Du vs Piétrain, Pi). Due to restrictions in the availability of organic potato starch and male progeny in some farrowing seasons, the four treatment groups could not be distributed equally among the eight trial runs. This led to unbalanced trial design. For a detailed description of the trial design, see our companion paper "Performance of organic entire male pigs from two sire lines under two feeding strategies. Part 1: Growth performance, carcass quality, and injury prevalence" (Werner et al., 2020).

2.2 Animals, housing, feeding, and slaughtering

The 280 male growing-finishing pigs originated from the institute's sow herd consisting of 50 German Large White x German Landrace crossbreds via artificial insemination (AI) using nine and seven individual Duroc and Piétrain AI-boars, respectively.

The feeding regime consisted of pelleted diets of 100 % organic origin with the aim of a maximised amount of farm-grown feed ingredients (cereals, grain legumes).

All pigs received a grower and finisher diet similar in nutrient density and composition until the first pig of the experimental group reached 95 kg live body weight. From this point on, pigs of the experimental groups received a finisher diet with 10 % raw potato starch for the rest of the fattening period, whereas the control groups received the finisher diet without the raw potato starch continuously. For a detailed description of the animals used and their keeping, feeding, and slaughtering, see our companion paper, part 1 (Werner et al., 2020).

2.3 Meat quality

Collection of meat quality data followed the federal standard of German pig testing stations (ZDS, 2007). The day after slaughter, the left carcass side was used to assess meat quality traits. The pH of the loin muscle (Musculus longissimus thoracis et lumborum (LTL)) was measured 24 h after slaughter near the 13th rib using Knick Portamess 913. Electrical conductivity (EC24) was measured between the 13th and 14th rib using Matthäus® LF-star pistol. Minolta® CR-300 was used to record meat lightness (L*) and colour values (a, b) of the LTL at the 13th rib level. To determine the intramuscular fat (IMF) content of the LTL, the muscle was withdrawn at the 13th rib and analysed according to the German Code for Food (LFBG 2014, §64). Fatty acid composition of IMF and subcutaneous shoulder backfat (SF) was analysed by gas chromatography with flame ionisation detection after extraction with chloroform/methanol according to Nürnberg et al. (1997) and transesterification into fatty acid methyl esters with trimethylsulfonium hydroxide as described by Schulte and Weber (1989).

Drip loss was determined using 10 g of the LTL obtained at the 14th rib following the EZ-DripLoss method (Rasmussen and Anderson, 1996). Samples were stored for 48 hours.

2.4 Boar taint and olfactory assessment of fat samples

Subcutaneous SF including rind (15 cm x 25 cm from the dorsal split line) was extracted one day after slaughter. It was vacuum-packed and stored at -20 °C until further analyses.

Androstenone, skatole, and indole contents in the SF were analysed by SPE-GC–MS (solid-phase extraction and gas chromatography/mass spectrometry) using deuterium-labelled internal standard as described by Meier-Dinkel et al. (2016a). Inter- and intra-day variation coefficients ranged from 3.8 to 9.1 % and 1.2 to 14.6 %, respectively, and therefore complied with the recommendation of the European Commission (< 15 %).

The SF of each animal was assessed by a group of 10 panellists that were selected based on their ability to perceive boar taint compounds (androstenone and skatole) and trained to detect off-odours characteristic to "boar taint" (androstenone and skatole odour) as described before (Meier-Dinkel et al., 2015; Mörlein et al., 2016). The olfactory acuity of the panellists towards androstenone and skatole was assessed using smell tests (repeated discrimination of the odorants in a triangle test; 10 ng androstenone or 5 ng skatole diluted in 20 µg propylene glycol vs odourless propylene glycol presented on smelling strips). All training and evaluation sessions were completed in the Laboratory for Sensory Analysis of the Göttingen University. For olfactory assessment of SF samples per assessor, individual subsamples of about 3 g (all fat layers, skin, hair, and meat removed) were heated for 80 s at 450 W in a microwave and immediately served. Each sample was labelled with a 3-digit code, and samples were served randomly. Samples were scored on a scale from 0 (no deviation from standard) to 5 (very strong deviation from standard). A sample was classified as olfactory tainted if the mean score was > 2. In each assessment session, 10 assessors out of a pool of 12 scored 30 fat samples individually; samples were presented in random order to each panellist.

2.5 Testes weight

Testes, including the epididymis, were removed after exsanguination and scalding and weighed immediately.

2.6 Statistical analysis

Data analysis of meat quality was carried out as ANOVA with the General Linear Model (Proc GLM, SAS software package version 9.4) considering genotype, feeding, and the interaction of genotype*feeding as fixed effects. For meat quality assessment, slaughter weight was used as a covariate. For boar taint analysis, slaughter weight, age, and testes weight were used as covariates. The LSQ-means were compared using the Tukey-Kramer test (significance level $p < 0.05$). Due to an extremely skewed distribution, data on androstenone, skatole, and indole concentrations were transformed (androstenone: reciprocal, skatole and indole: decadic logarithm). The interpretation of the results is based on the back-transformed values.

The chi-square test was used to compare the sensory prevalence of boar tainted fat samples between sire lines or feeding regimes.

3 Results and discussion

3.1 Meat quality

Table 1 shows the results for meat quality parameters. Slaughter weight as a covariate had a significant effect on all meat quality parameters except for electrical conductivity, mono- and polyunsaturated fatty acids in the muscle, and mono-unsaturated fatty acids in the SF.

Significant sire line x feeding interactions were found for pH 24 h p.m., redness, yellowness, drip loss, and mono- and polyunsaturated fatty acid content in the muscle. Sire line and feeding both significantly influenced intramuscular fat content of the muscle as well as the content of mono- and polyunsaturated fatty acids in the SF. Sire line significantly influenced meat lightness and the content of SFA of the muscle.

pH 24 h p.m. was significantly higher for both sire lines when feeding the control diet, with Pi sire lined pigs yielding the highest values. This is in contrast to Pauly et al. (2008) and Fang et al. (2014), who found no influence on muscle pH when feeding potato starch to entire male pigs or barrows. In any case, the measured pH values do not indicate inferior meat qualities in all trial groups.

Results for meat colour are inconsistent. While the meat of Du sire line pigs had higher a-values and lower b-values when fed the potato starch diet compared to the control diet and therefore slightly darker meat, it was vice versa in Pi sired pigs. Nevertheless, the meat of Du sired pigs was lighter than the meat of Pi sired pigs under both feeding regimes, whereas feeding raw potato starch had no significant influence on meat lightness. Latorre et al. (2009) also found that Du pigs had lighter meat when compared to Pi sired pigs, whereas a-values were distinctly lower and b-values higher than measured in this study.

Drip loss in control-fed Du pigs was significantly higher when compared to all other trial groups, whereas in Pi origins drip loss in control fed pigs was lower when compared to potato starch fed pigs. While Fang et al. (2014) found lower drip losses in pigs fed raw potato starch, Pauly et al. (2008) found higher drip losses in pigs fed raw potato starch. There were no significant differences in electrical conductivity between the sire lines or feeding strategies, and the measured values do not indicate inferior meat qualities.

Du origins significantly exceeded Pi origins in intramuscular fat content by 0.5 percentage points, and the test diet generated intramuscular fat contents that were 0.4 percentage points higher than those generated by the control diet. This is in accordance with several studies showing that including Du genotypes in fattening pigs can lead to higher IMF contents of the meat (Alonso et al., 2009; Alonso et al., 2015; Morales et al., 2013; Mörlein et al., 2007). As protein and/or lysine deficiency can lead to higher IMF contents in the muscle (D'Souza et al., 2008; Pires et al., 2016), the influence of feeding on IMF in this study can be ascribed to the lower content of protein and lysine in the trial vs control diet (15.1 % vs 17.7 % and 8.3 % vs 10.2 %, respectively). The IMF contents found in this study mostly exceeded the range of 1.5 to 2.5 %, which is regarded as optimal in terms of palatability (Fortin et al., 2005).

TABLE 1

Meat quality (LSQ) of entire male pigs depending on two different genotypes of the terminal sire line (Duroc, Du vs Piétrain, Pi) and two different feeding strategies (with (+) vs without (-) raw potato starch at the end of the finishing period)

	Du	Pi	-	+	Du-	Du+	Pi-	Pi+	SEM	Sire line	Feeding	Sire line x feeding
Animals *(n)*	*138*	*142*	*133*	*147*	*65*	*73*	*68*	*74*				
Ec 24 h p.m.	3.21	3.03	3.13	3.11	3.29	3.12	2.96	3.11	0.07–0.10	0.067	0.903	0.097
pH 24 h p.m.	**5.55**	**5.58**	**5.60**	**5.53**	**5.57**[b]	**5.53**[c]	**5.63**[a]	**5.52**[c]	0.01–0.01	**0.003**	**< 0.001**	**0.001**
L*	**52.20**	**51.20**	51.80	51.60	52.14	52.17	51.44	50.93	0.21–0.30	**0.001**	0.430	0.363
a	10.60	10.63	10.55	10.67	**10.20**[b]	**11.00**[a]	**10.90**[a]	**10.40**[ab]	0.15–0.22	0.901	0.583	**0.005**
b	**2.15**	**3.21**	2.77	2.59	**2.70**[bc]	**1.60**[d]	**2.80**[b]	**3.60**[a]	0.14–0.20	**< 0.001**	0.349	**< 0.001**
DI (%)	3.65	3.32	3.60	3.37	**4.11**[a]	**3.19**[b]	**3.08**[b]	**3.55**[b]	0.14–0.23	0.122	0.285	**0.001**
Animals *(n)*	*91*	*83*	*79*	*95*	*39*	*52*	*40*	*43*				
IMF (%)	**3.03**	**2.45**	**2.58**	**2.89**	2.89	3.16	2.28	2.62	0.09–0.14	**< 0.001**	**0.019**	0.790
SFA IMF (%)	**39.30**	**38.40**	38.80	38.80	39.31	39.26	38.35	38.37	0.15–0.24	**< 0.001**	0.945	0.892
MUFA IMF (%)	53.56	53.50	**52.99**	**54.07**	**52.60**[c]	**54.60**[a]	**53.40**[b]	**53.60**[b]	0.19–0.30	0.858	**0.001**	**0.001**
PUFA IMF (%)	**7.16**	**8.14**	**8.18**	**7.12**	**8.10a**	**6.20 b**	**8.20**[a]	**8.10**[a]	0.21–0.33	**0.003**	**0.001**	**0.005**
SFA SF (%)	37.00	36.60	36.80	36.80	37.05	37.04	36.64	36.58	0.18–0.28	0.114	0.899	0.947
MUFA SF (%)	**45.10**	**46.70**	**45.30**	**46.50**	44.33	45.79	46.33	47.15	0.19–0.26	**< 0.001**	**< 0.001**	0.248
PUFA SF (%)	**17.90**	**16.60**	**17.80**	**16.70**	18.61	17.18	17.02	16.26	0.17–0.27	**< 0.001**	**< 0.001**	0.188

EC: Electrical conductivity; L*: Luminosity; a: Redness; b: Yellowness; DI: Drip loss; IMF: Intramuscular fat; SF: Shoulder fat; SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids
Different indices (a,b,c,d) indicate significant differences within sire line x feeding interaction

The content of SFA in the IMF of Du origins was significantly higher than in Pi origins and did not differ between feeding regimes. Percentage of MUFA in the muscle was significantly higher in Du pigs that were fed the test diet, while the content of PUFA was significantly lower in this group when compared to all other trial groups. This is in accordance with the results of Fischer et al. (2010), who found lower PUFA levels in the IMF when the IMF content of the muscle increased. Contents of PUFA in IMF were generally low compared to values found by Schwalm et al. (2013) and Grela et al. (2013) for organically kept pigs.

3.2 Boar taint and olfactory assessment of fat samples

Table 2 shows the results of the analyses of boar taint components in the SF samples. Androstenone content in SF of Du origins significantly exceeded its content in Pi origins, whereas the feeding strategy had no significant effect on androstenone content.

Breed differences for androstenone contents are known (Frieden et al., 2011), with Du breeds yielding higher values than others (Tajet et al., 2006; Xue et al., 1996). As the formation of androstenone is linked to the sexual maturation of pigs, this is ascribed to the earlier onset of puberty in Du origins. The levels of androstenone in Du origins found in this study are lower than those reported by Tajet et al. (2006) and Xue et al. (1996). Age at slaughter as a covariate had a significant effect on androstenone levels found in this study. Older animals (> 180 d) had slightly lower androstenone contents in fat than younger ones. This is in contrast to Thomsen et al. (2015), who found no influence of age on androstenone levels in boars. While Bonneau et al. (1987) found an effect of age on androstenone levels in young, light boars, in older boars the influence of body weight was more pronounced than the age effect. An effect of slaughter weight can be ruled out as it was fixed at 115 kg live weight, see our companion paper, part 1 (Werner et al., 2020). As the formation and metabolisation of androstenone are usually not influenced by dietary factors, an effect of feeding potato starch on androstenone levels was unlikely.

The content of skatole in the SF differed between sire line and feeding regime. In contrast to results of Dalmau et al. (2019), Babol et al. (2004) and Xue et al. (1996), skatole content in the SF of Du origins was lower compared to Pi origins and did not differ between feeding strategies. Values for Pi origins fed with the control diet significantly exceeded (2.45 times) the values of all other trial groups. Pi origins had a lower daily feed intake and the lowest daily gain when fed the control diet (Werner et al., 2020). Therefore, the age at slaughter was higher for those animals. Although not significant, the slightly higher age (191 d) of Pi origins fed the control diet compared to all other groups might have contributed to those values. Zamaratskaia et al. (2004) described an age-related rise in skatole values in pigs from 180 d upwards. Hence, it is unclear whether the lower skatole values of the Pi origins in the trial group are due to the feeding of potato starch. Furthermore, skatole values of Du origins did not differ between feeding strategies. Lösel and Claus (2005) found

TABLE 2

Contents (ng g^{-1} shoulder fat) of androstenone, skatole, and indole in entire male pigs from two different sire lines (Duroc, Du vs Piétrain, Pi) and two different feeding strategies (with (+) vs without (-) raw potato starch at the end of the finishing period)

	Du	Pi	-	+	Du-	Du+	Pi-	Pi+				
Animals *(n)*	*138*	*142*	*133*	*147*	*65*	*73*	*68*	*74*				
Mean									**SD**			
Androstenone	1152	958	1122	992	1187	1122	1062	863	802–994			
Skatole	29	67	69	29	30	28	107	30	50–140			
Indole	6	5	8	4	8	5	8	3	5–19			
LSQ Means (transformed values)									**SEM**	**Sire line**	**Feeding**	**Sire line x feeding**
Androstenone†	**522**	**595**	551	567	514	530	587	603	15–23	**0.001**	0.467	0.970
Skatole‡	**12**	**26**	**25**	**12**	$\mathbf{12^{b}}$	$\mathbf{12^{b}}$	$\mathbf{39^{a}}$	$\mathbf{12^{b}}$	3–4	**0.002**	**0.023**	**0.002**
Indole‡	3	2	3	1	3	2	3	1	0.5–0.7	0.456	**0.009**	0.481

† transformed with reciprocal value, ‡ transformed with the decadic logarithm
Significant differences within sire line or feeding ($p < 0.05$ Tukey-Kramer test), different indices (a,b,c,d) within row indicate significant differences between sire line x feeding groups

a reducing effect of feeding potato starch on skatole levels with application rates from 20 % onwards, which is twice as high as in this study. Taking into account that Aluwé et al. (2009) found no effect of feeding 10 % potato starch on skatole levels of boars, it can be assumed that the percentage of potato starch fed in this study was too low to show a reducing effect on skatole levels. Yet, in this trial, skatole values were low compared to other studies carried out under conventional conditions (Aldal et al., 2005; Borrisser-Pairó et al., 2016; Claus et al., 1994). This could be ascribed to the offering of roughage, which is mandatory in organic pig feeding. Silage is known to have positive effects on intestine health due to its fibre content, and fibre-rich feedstuffs can reduce the formation of skatole in the large intestine (Hansen et al., 2008). As the skatole contents in this study were already low due to the feeding of roughage, it is possible that the feeding potato starch showed no further reducing effect. A further trial was conducted recently to answer this question.

Similar contents of indole in subcutaneous SF were found in both sire lines, whereas feeding raw potato starch before slaughter reduced indole content by 54 % compared to the finishing diet without raw potato starch. This is in contrast to results of Aluwé et al. (2009), Pauly et al. (2008), and Chen et al. (2007), who found no effect of feeding potato starch on indole levels. The authors of those studies assumed that the various types of bacteria responsible for the synthesis of indole were not affected by raw potato starch, as it was the case for skatole in these experiments. The question remains whether the feeding of silage in this trial interacted with the content of potato starch in the experimental diet. This could have an influence on the composition of bacteria in pig's intestines and therefore on the formation of indole.

The prevalence of boar taint depends on the method of categorisation. Rejection thresholds for taint in meat products are often the result of consumer studies, where chemical analyses and sensory evaluation are collated. Chemical rejection thresholds between 0.15 and 0.25 µg g^{-1} fat for skatole and between 0.5 and 3.0 µg g^{-1} fat for androstenone have been discussed (Bonneau and Chevillon, 2012; Lunde et al., 2010; Lundström et al., 2009). *Figure 1* shows the distribution of the analysed contents of androstenone and skatole in the fat depending on the sire line and feeding regime in this trial.

Mostly Pi origins fed the control diet exceed the chemical cut off values for skatole content (e.g. low cut-off = androstenone < 1.50 or skatole < 0.20 µg g^{-1} liquid fat and high cut-off = androstenone < 2.00 or skatole < 0.25 µg g^{-1} liquid fat). Values higher than the cut-off values for androstenone were found in samples from all origins and feeding regimes. Comparing these results to other studies is difficult as breed, feeding system, and different methods of laboratory analyses may have an influence on androstenone and skatole levels (Ampuero Kragten et al., 2011; Mörlein et al., 2015). However, as results of sensory analyses and chemical composition often differ (Meier-Dinkel et al., 2015) and the sensitivity to boar taint is highly variable between individuals, the classification of boar tainted meat for consumer purposes only based on chemical composition could be deceptive. *Table 3* shows the percentage of the taken fat samples classified as having deviant odour by assessors highly sensitive to androstenone or skatole odour. In total, 21.8 % of all samples were classified as deviant (sensory mean ≥ 2; scale ranges from 0 to 5), i.e. with noticeable androstenone or skatole odour. No significant differences were found for the prevalence of boar taint in fat between sire lines or feeding regime.

According to the distribution of chemical analyses (see *Figure 1*), the percentage of skatole-tainted samples was significantly higher in Pi origins. Androstenone and skatole contents in fat clearly influenced the sensory scoring thereof.

However, the comparison of chemical analyses and sensory evaluation scores reveals that for this study sensory classification of up to 10 % of the samples was a false positive or false negative. Furthermore, the classification of boar

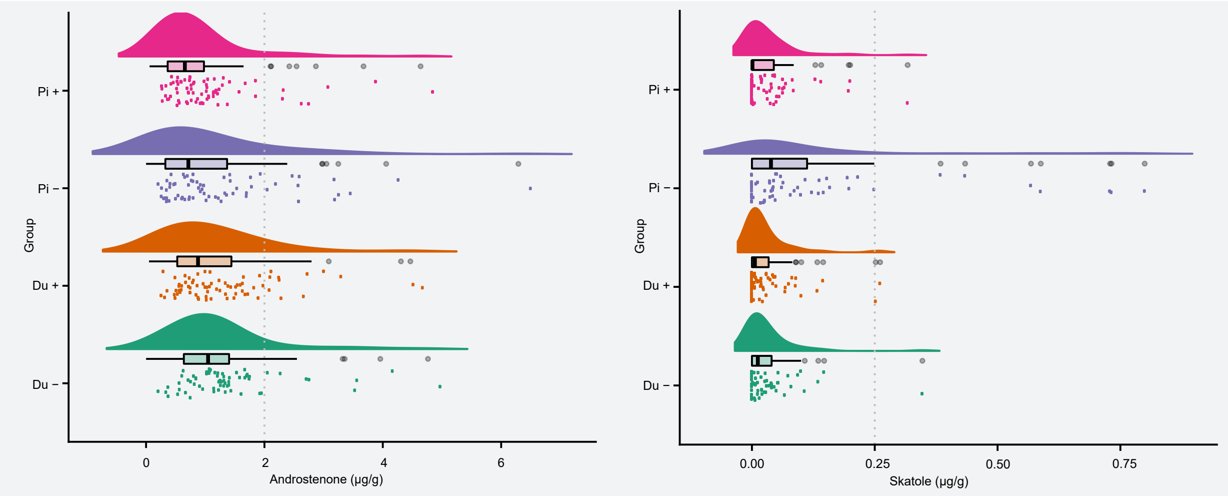

FIGURE 1
Distribution of androstenone and skatole concentrations (µg g^{-1} shoulder fat) according to sire line and feeding group (Du: Duroc; Pi: Pietrain; -: without potato starch; +: with potato starch) within chemical cut-off values (dotted line) of 2 µg g^{-1} for androstenone and 0.25 µg g^{-1} for skatole respectively

TABLE 3
Percentage of fat samples without/with noticeable boar taint depending on sire line (Duroc, Du vs Piétrain, Pi) or feeding strategies (with (+) vs without (-) raw potato starch) as classified by trained sensory assessors

	Du % [n]	Pi % [n]	Total % [n]	- % [n]	+ % [n]	Total % [n]
X^2	*(1, N = 280) = 0.095, p = 0.758*			*(1, N = 280) = 0.00005, p = 0.99*		
Standard	79.0 [109]	77.5 [110]	78.2 [219]	78.2 [104]	78.2 [115]	78.2 [219]
Deviant †	21.0 [29]	22.5 [32]	21.8 [61]	21.8 [29]	21.8 [32]	21.8 [61]
Total	49.3 [138]	50.7 [142]	100 [280]	47.5 [133]	52.5 [147]	100 [280]

† Deviant = Sensory value (mean) ≥ 2. Original scale from 0 (0 = no aberrant odour) to 5 (5 = very strong aberrant odour) compared to standard fat. Scale point 2 (noticeable smell of androstenone or skatole) was referenced using a smelling strip

carcasses based on chemical cut-off values or sensory panels by trained assessors might lead to the rejection of a higher percentage of boar carcasses than necessary due to consumer sensitivity towards boar-tainted meat. Meier-Dinkel et al. (2016b) showed that consumers seemed to be less sensitive to sensory defects of meat than trained panellists. Overall, consumer liking of the boar meat presented in a tasting decreased if the expert panel fat score was ≥ 3. Considering above-mentioned chemical and sensory categorisations of the fat samples, e.g. low cut-off, high cut-off, and deviant odour (≥ 2), 21.8 % or 14.3 % of the boar carcasses from this trial would be considered at risk for decreased consumer acceptance due to noticeable off-odours. Raising the threshold for the definition of sensory deviant to a mean value of 2.5 or 3.0 would lead to a reduction to 11.8 or 6.4 % of rejected carcasses, respectively (see *Table 4*).

TABLE 4
Prevalence of deviant fat samples (with boar taint) depending on different classification levels (sensory assessment and analytical cut-off values), n = 280

Classification	Definition of "deviant"	% [n]
SENS *	Mean of assessment ≥ 2	21.8 [61]
	Mean of assessment ≥ 2.5	11.8 [33]
	Mean of assessment ≥ 3	6.4 [18]
CHEM LOW	Androstenone ≥ 1.5 or Skatole ≥ 0.20 µg g^{-1}	21.8 [61]
CHEM HIGH	Androstenone ≥ 2.0 or Skatole ≥ 0.25 µg g^{-1}	14.3 [40]

* Original scale from 0 (0 = no aberrant odour) to 5 (5 = very strong aberrant odour) compared to standard fat. Scale point 2 (noticeable smell of androstenone or skatole) was referenced using a smelling strip

3.3 Testes weight

No significant differences were found for testes weight between sire lines or feeding regime and their interaction. Mean testes weight was 688 g and 704 g for Du and Pi origins, respectively. Boars fed the control diet had lighter testes than boars fed potato starch (689 g vs 703 g). A highly significant but weakly positive correlation ($p < 0.001$; $r=0.25$) was found between testes weight and analysed androstenone content in the SF. Aldal et al. (2005) found that testes weight was higher for pigs with high androstenone values at slaughter and that testes weight was correlated with testes volume. Bekaert et al. (2012) and Bernau et al. (2018) found that testes volume was correlated with the chemical and sensory content of androstenone in fat, respectively, but stressed that time of measurement has to be taken into account and additional factors could improve the accuracy of prediction. To use testes weight as a precise predictor for the occurrence of boar taint, individual on-farm correlations would have to be calculated as breed, environment, and management clearly influence the development of both factors.

4 Conclusion

Skatole levels in the fat of entire male pigs were considerably low in this study, which might be attributed to the organic feeding conditions. The feeding of roughage in particular could weaken the reducing effect of potato starch on skatole levels. As Pi origins had significantly lower androstenone contents compared to Du origins and the meat qualities of boars in this study were satisfactory considering the extensive feeding regime, the use of this breed under organic conditions without additional measures concerning feeding strategies seems feasible.

The contents of androstenone and skatole in the fat influenced the sensory evaluation of the samples, whereas the sire line and feeding had no significant influence on sensory classification. The percentage of animals exceeding the frequently used chemical or sensory cut-off values for potentially boar-tainted meat was high in this study (up to 21.8 %).

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