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Relationship between Carcass Weight, Skatole Level and Sensory Assessment in Fat of Different Boars

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Abstract

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The purpose of this study was to investigate the relationship between the carcass weight and the level of skatole in boar back fat samples with descriptive sensory profiles (trained sensory panel) immediately after heating the fat samples (warm). A weak correlation was found between the carcass weight and skatole level in fat ($P > 0.05$). Between skatole levels in the fat of boars, whose carcass weight was below 70 kg, and of those with the carcass weight equal or above 70 kg, there was a statistically significant difference ($P < 0.05$). The average content of skatole in the fat tissue of the boars < 70 kg, (0.18 ± 0.09 mg/kg fat, respectively) was below the commonly used respective thresholds for tainted meat (0.20 mg/kg fat), 53% of the samples showed the values of ≤ 20 mg/kg, and 73% of the samples the values of ≤ 25 mg/kg. In the group ≥ 70 kg (0.40 ± 0.39 mg/kg fat, respectively), 80% of the samples revealed the values of ≥ 20 mg/kg, and 66% of the samples the values of ≥ 25 mg/kg. Our results show that a positive, compelling and statistically highly significant correlation exists between the skatole level and the sensory assessment of skatole intensity in fat.

Keywords: boar; skatole; weight; sensory assessment

Breeding entire male pigs has a number of productional, environmental, and animal welfare benefits when compared with the production of castrated animals. Entire male pigs have a better feed conversion rate and a higher growth rate, both of which reduce the production costs (Andersson *et al.* 1997; Fowler *et al.* 1981).

A critical point in the production of entire male pigs is the slaughter weight. On one hand, the production of heavy carcasses is desirable since it reduces the total animal production cost and hence improves on the competitiveness on the pork market. On the other hand, an increase in the slaughter weight can result in an increased risk of boar taint. Therefore, one of the challenges for the pork industry is to produce heavy-weight entire male pigs with a reduced incidence of boar taint.

The production of young entire males is a common practice in various European countries, including Spain, where it is usual for carcasses to be obtained at the weight under 80 kg (Walstra *et al.* 1999; Banon *et al.* 2000). This lessens the possibility of pigs reaching sexual maturity and prevents tainted meats, although it does entail other specific prob-

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lems. The main limiting factor on the use of heavier entire males is a boar taint in unprocessed meat, this defect being better tolerated in the meat products (Diestre *et al*. 1990; Bonneau *et al*. 1992; Banon *et al*. 2003). This would allow heavier males to be sent for the meat processing.

Boar taint is one of the major meat quality defects in pigs, which is manifested as an unpleasant odour and flavour in pork and pork products during cooking (Gower 1972; Lundström & Bonneau 1996). Boar taint may lead to an unpleasant experience during the consumption of the meat with subsequent negative economic repercussions for the meat industry. Boar taint occurs at puberty in some entire male pigs due to excessive accumulation of mainly two compounds, androstenone and skatole, in adipose tissue (Lundström & Bonneau 1996).

However, the literature shows that the results in regard to the relationship between the carcass weight and skatole and androstenone deposition are inconsistent. Thus, positive correlations ($P < 0.05$) between the carcass weight and skatole and/or androstenone levels have been reported by Mortensen *et al.* (1986), Walstra *et al*. (1999), and Sinclair *et al*. (2001). Other authors did not find a significant relationship ($P > 0.05$) between the skatole and androstenone levels and carcass weight (Hennessy *et al*. 1995). A European Union-wide study on boar taint (Matthews *et al*. 2000) defined skatole as a major contributor to the manifestation of boar taint in fresh meat and recommendations were given to optimise the production factors to reduce the skatole level as a short-term solution to boar taint (Bonneau *et al*. 2000).

Skatole is a product of bacterial activity in the intestines, hence its levels in fat are influenced by the diet as well as by the environmental factors that can affect bacterial activity or availability of the substrate, tryptophan (Hawe *et al*. 1992; Hansen *et al*. 1994; Jensen & Jensen 1997). The levels of skatole may also be influenced by the age of the pigs, as indicated by both the increased skatole levels in the fat of heavier pigs (Hansen *et al*. 1997) and positive correlation with the live weight (Babol *et al*. 1996; Walstra *et al*. 1999). The positive relationship between skatole concentrations and the levels of sex hormones and androstenone (Babol *et al*. 1999) indicates that sexual maturity may affect the levels of skatole. Further evidence linking skatole concentrations with the age of entire male pigs is, however, lacking. A majority of the studies have been performed on pigs at the slaughter age and little is known about skatole levels variation at other ages. In addition, it is not known why it is mainly the uncastrated male pigs, and not the other sexes, that show high levels of skatole.

There are strong indications of genetic influences on skatole levels in pigs. These include differences in skatole levels between breeds (Squires & Lou 1995; Xue *et al*. 1996; Pedersen 1998; Hortos *et al*. 2000; Doran *et al*. 2002), significant heritability estimates for skatole levels in fat (Pedersen 1998), as well as indications of the presence of a major gene affecting boar taint due to skatole (Lundström *et al*. 1994). The reasons for this and the timing of skatole increases in pigs are important for the development of methods aimed at reducing its levels and thus the occurrence of boar taint. The skatole levels in plasma are excellently correlated with those in fat if the measurements are taken at the same time (Tuomola *et al*. 1996; Hansen-Møller 1998) and can therefore be used to estimate skatole concentrations in fat.

Cut off levels of androstenone and skatole in fat to sort out "tainted" boar carcasses have been proposed. In Denmark, Godt *et al*. (1996) found that the proportion of negative reactions in consumers increased from 1.5% to 5.4% when the level of skatole increased from 0.15 mg/kg fat to 0.39 mg/kg fat. In Norway, the skatole levels of ≥ 0.21 mg/kg fat have been used as cut off levels (Frøystein *et al*. 1993). Regarding androstenone, both levels of 0.5 mg/kg fat and 1.0 mg/kg fat have been considered as the cut off levels (Rhodes 1971; Claus *et al*. 1994). For trained sensory panels, group thresholds for skatole and androstenone of 0.026 mg/kg and 0.426 mg/kg fat, respectively, have been reported (Annor-Frempong 1997). During the last decades, a lot of work has been performed in order to avoid the problem of boar taint (Claus *et al*. 1994; Jensen 1998; Bonneau & Squires 2000).

The aim of this study was to examine the relationships between the carcass weight, skatole level in fat, and sensory assessment of skatole odour in different boars.

MATERIAL AND METHODS

Animals. A total of 30 young boars, born in the winter of 1999, were raised under normal farm conditions. The young boars were free from sarcoptic mange, swine dysentery, and atrophic rhinitis. Young boars were a cross breed of Swedish landrace (SL)

and Large Yorkshire (LY). In order to avoid interactions with other factors, all the animals were reared on the same intensive farm (0.8 pigs/m^2, natural ventilation), receiving feed consisting of cereals (corn, barley, and wheat), molasses, and soya *ad libitum*. The animals were slaughtered at the age of six months. They were transported to the abattoir, a distance of 80 km (1.5 h). There, after one hour of rest and a cold water shower, they were stunned with carbon dioxide and slaughtered.

The weights of the carcasses of the slaughtered young boars were between 52 kg and 108 kg (N = 30). The carcass weight was measured one hour after slaughtering and before cooling, using Mettler scales with an automatic scale, on the slaughter line, with an accuracy of ± 0.5 kg.

Depending on the weights of the carcasses of slaughtered boars, two groups were formed: a group whose carcasses weighed less than 70 kg, and a group whose carcasses weight was equal to or above 70 kg.

Fat samples for determination of skatole level. Subsequent to primary processing on the slaughter line and cooling of carcass sides for 18–24 h, 300 g of fat tissue was taken from the loin part of the carcass sides by industrial cutting, to be used for the determination of skatole content.

Thirty samples of fat were taken from the loin region (lumbar sacrum region) of boars and allocated numbers ranging from 1 to 30 corresponding to the boar numbers. Each sample was ground, weighed on an analytical weight scale, and prepared for further analysis. All samples were frozen and stored at –20°C until analysis.

Determination of skatole level in fat. For the determination of skatole content (3-methyl-indol) in pig fat, a spectrophotometric method was used based on Chernoff modification of Ehrlich indol reaction with 4-dimethylaminbenzaldehyde (Mortensen & Sørensen 1984). The main advantages of this method are the simplicity in the experimental procedure and a satisfactory detection level (bellow 0.01 μg/kg).

A standard straight line, i.e. the dependence of absorbance on skatole concentration (in solution of acetone: 0.1M TRIS), was determined in the interval of concentrations from 0.1–1.0 μg/ml. All skatole determinations for the standard straight line as well as in samples were done in duplicates.

Sensory analysis. Fat samples from 30 carcasses were evaluated in duplicates by the trained sensory panel. The sensory panel consisted of 10 trained assessors (5 female and 5 male) who had been selected based on their expertise in identifying skatole. The assessors selection and training procedure were performed according to ISO 8586-1: 1993.

For the sensory assessment of the skatole intensity in fat from young boars, the lumbale part of back, the loin region (lumbar sacrum region) from boars was used, cut out from the carcasses, labelled and frozen. The samples were stored frozen prior to the evaluation of the skatole intensity. For the evaluation, the samples were thawed and cut into pieces of approximately the same size (50 g). The frozen pork fat portions were partially thawed for 30 min at room temperature (± 18°C). The rind of each fat tissue portion was removed using a sharp knife and was cut into cubes (10 × 10 × 10 mm). Each cube was placed in an aluminium foil container and covered tightly with an aluminium foil square. The samples were heated for 5 minutes in an AEG oven preheated to 180°C and were then served to the panel. After removing the samples from the oven, these were kept warm on heated sand baths that were placed on solid hot plates. The samples were evaluated immediately after heating (65°C). One minute waiting period was observed between the smelling of successive samples allowing for the recovery of the olfactory system.

The sample of fat from young boars which was defined by the group of 10 evaluators using *rank test* as the least acceptable of four samples with the skatole contents of over 0.300 mg/kg of fat (samples with skatole content of 0.317 mg/kg, 0.367 mg/kg, 0.400 mg/kg and 0.433 mg/kg), was used as the reference sample. (ISO 5495: 1983). The evaluation of the skatole intensity was done using the intensity *scale test* (Popov-Ralјić 1999).

On the evaporation spot, the determination of the skatole intensity was performed. The evaluation of intensity was recorded on the structural scale with six points (ISO 4121: 1987). A six-point sensory scale was used: (1) like strongly, (2) like moderately, (3) like slightly, (4) dislike slightly, (5) dislike moderately, (6) dislike strongly.

The samples were grouped according to the level of skatole:

– Samples with values below cut off value for skatole (< 20 mg/kg);
– Samples with values above cut off value for skatole (≥ 20 mg/kg);
– Samples with values below cut off value for skatole (< 25 mg/kg);

– Samples with values above cut off value for skatole (≥ 25 mg/kg).

The selection criteria were chosen according to the limits suggested for sorting boars in Europe.

Statistical analyses. Analysis of variance (ANOVA), the principal component analysis (PCA), and Correlation-Regression analysis using Statistica Ver. 6.0. (Stat Soft Inc. 2003; Faculty of Agriculture, Zemun) were used to analyse the mean sensory ratings provided by the evaluation panel of the pork fat samples.

Significant differences were further analysed using the least significant difference (LSD) test method. Multivariate statistical techniques such as PCA are therefore useful in interpreting the sensory impression, incorporating all the descriptive terms simultaneously. Pearson's product moment correlations were used to investigate linear relationships between the weights of carcasses, skatole concentrations, and sensory ratings.

RESULTS

Weights of carcasses and skatole levels

The weights of 30 carcasses (group $N = 30$) varied within the range of 52 kg to 108 kg. The average carcass weight was 71.13 kg ($CV = 21.03\%$). The coefficient of variation indicates that the respective weights of carcasses and, therefore, the weights of live animals, were uneven (Table 1).

The mean value with the standard deviation of the skatole content of 30 carcasses was 0.29 ± 0.30 mg/kg fat, and the measures of variation indicated that the skatole content was very variable ($CV = 101.28\%$). The correlation between carcass weights and skatole levels indicated a weak correlation dependence and is presented in Table 2.

The results of skatole levels in the fat of boars with the carcass weight below 70 kg and of those with the carcass weight equal and above 70 kg are presented in Table 1. The average carcass weight in the first group of boars (< 70 kg) was 59.27 kg and in the second (≥ 70 kg) 83.00 kg. The average skatole level in the fat of boars whose carcass weight was below 70 kg was 0.18 ± 0.09 mg/kg, and in that of boars with carcass weight equal and above 70 kg 0.40 ± 0.39 mg/kg. Between the average skatole levels in the fat of boars with the carcass weight < 70 kg and of those with the carcass weight ≥ 70 kg was a statistically significant difference ($P < 0.05$). The correlation between the weights of carcasses < 70 kg, ≥ 70 kg and skatole levels indicated a weak correlation dependence and is presented in Table 2.

The skatole levels in fat of the tested boars were grouped into four groups according to the limits

Table 1. Mean values and standard deviation (M ± S.D.) of carcass weights of entire male pigs, skatole levels and sensory scores of skatole intensity

Item	Group ($N = 30$)	Group	
		< 70 kg ($N = 15$)	≥ 70 kg ($N = 15$)
Carcass weight (kg)	71.13 ± 14.96^{ac}	59.27 ± 5.39^{c}	83.00 ± 11.52^{ac}
Skatole content (mg/kg)	0.29 ± 0.30^{ns}	$0.18 \pm 0.09^{ns\ a}$	$0.40 \pm 0.39^{ns\ a}$
Sensory score	2.89 ± 0.57^{ns}	$2.61 \pm 0.47^{ns\ b}$	$3.17 \pm 0.54^{ns\ b}$

Means values in a row with different letters (a, b, c,) differed significantly at the indicated significance level: $^{a}P < 0.05$, $^{b}P < 0.01$, $^{c}P < 0.001$, ns – no significant

Table 2. Correlation between carcass weight, skatole content, and sensory score intensity of skatole

Correlation between	Group ($N = 30$)		Group < 70 kg ($N = 15$)		Group ≥ 70 kg ($N = 15$)	
	r	P-value	r	P-value	r	P-value
Carcass weight (kg) – Skatole content (mg/kg)	0.13	0.49	–0.13	0.63	–0.33	0.22
Carcass weight (kg) – Sensory score	0.27	0.15	–0.14	0.62	–0.32	0.24
Skatole content (mg/kg) – Sensory score	0.78***	–	0.91***	–	0.82***	–

$^{***}P < 0.001$

Table 3. Sorting out of carcasses of young boars by four different levels of skatole according to chosen limit, mean value, and standard deviation of skatole level[a]

Value skatole (mg/kg)	Group (N = 30)			Group < 70 kg			Group ≥ 70 kg		
	n	%	(M ± SD)	n	%	(M ± SD)	n	%	(M ± SD)
< 0.20	11	36.66	0.12 ± 0.05	8	53.33	0.13 ± 0.06	3	20	0.13 ± 0.03
≥ 0.20	19	63.33	0.39 ± 0.34	7	46.66	0.26 ± 0.06	12	80	0.47 ± 041
< 0.25	16	53.33	0.15 ± 0.05	11	73.33	0.14 ± 0.06	5	33.33	0.17 ± 0.05
≥ 0.25	14	46.66	0.46 ± 0.37	4	26.66	0.30 ± 0.02	10	66.66	0.52 ± 0.44

n – number of samples; % – percentage of samples in the presence of the investigated groups; [a]no significantly difference

suggested for sorting boars in Europe: < 20 mg/kg, ≥ 20 mg/kg, < 25 mg/kg, ≥ 25 mg/kg (Table 3):

– in the first group (N = 30), 63% of the samples had values equal or above, the cut off for skatole ≥ 20 mg/.kg, and 53% had values below the cut off for skatole < 25 mg/kg,
– in the group of 15 boars with carcass weight below 70 kg, 53% of the samples had values below the cut off for skatole < 20 mg/kg, and 73% had values below the cut off for skatole < 25 mg/kg,
– in the group of 15 boars with the carcass weight equal and above 70 kg, 80% of the samples had values equal or above the cut off for skatole ≥ 20 mg/kg, and 67% had values equal or above the cut off for skatole ≥ 25 mg/kg.

Sensorial study

The results of the sensory assessment of skatole intensity in fat of boars are presented in Table 1. The average grades for the group N = 30 varied from 1.55 to 4.33. The total average grade of the sensory assessment of skatole intensity in fat tissue of boars was 2.89 ± 0.57. The variation measures, i.e. variation coefficient (CV = 19.73%), showed that the scores for the intensity of skatole in fat have a low variability.

The total average sensory assessment of skatole intensity in fat of boars with the weight of carcasses < 70 kg was 2.61 ± 0.47, while it was 3.17 ± 0.54 for the boars with carcass weight ≥ 70 kg. The differences between these groups were statistically significant (P < 0.01).

In Table 2, the correlation between the sensory assessment and the carcass weight demonstrated in all three groups a relatively weak correlation. In groups < 70 kg and ≥ 70 kg, the correlations were negative.

The relation between the sensory assessment of skatole intensity and skatole level in fat from boars in the group N = 30 can be expressed using the equation $y = 2.448 + 1.482x$ (R^2 = 0.610) and presented graphically (Figure 1). The correlation coefficient was r = 0.78 (strong correlation, P < 0.001) (Table 2). The dependence of the intensity of the sensory assessment of skatole on skatole level in fat from boars of carcass weight < 70 kg can be

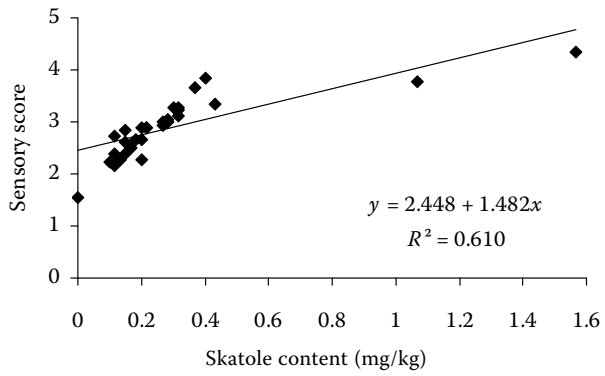

Figure 1. Correlation between skatole content and sensory scores (group N = 30)

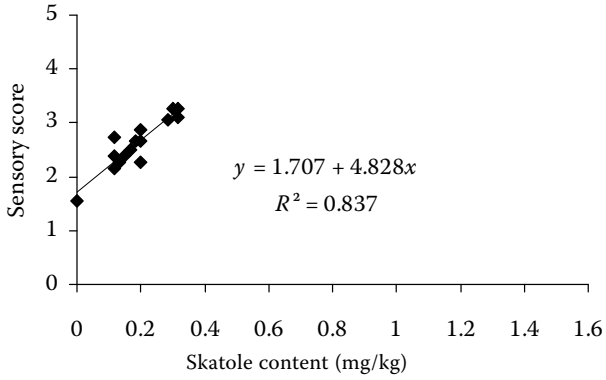

Figure 2. Correlation between skatole content and sensory scores (weight of carcasses < 70 kg)

Table 4. Distribution of assessors (%) in the different skatole sensitivity classes

Group	Sensory scores				
	1–1.99	2–2.99	3–3.99	4–4.99	5–6
N = 30	3.33	53.33	40.00	3.33	–
< 70 kg (N = 15)	6.66	66.66	26.66	–	–
≥ 70 kg (N = 15)	–	40	53.33	6.66	–

expressed using the equation y = 1.707 + 4.828x (R^2 = 0.837) (Figure 2). For boar carcasses weighing ≥ 70 kg, the dependence can be expressed using the equation y = 2.706 + 1.133x (R^2 = 0.685) (Figure 3). The correlation coefficient in both groups was strong (r = 0.91; r = 0.82; P < 0.001).

The distribution of the fat samples depending on sensory assessment of skatole intensity is presented in Table 4. Most of the samples in group N = 30 had been assessed in an interval from 2.00 to 2.99 (53.33%), and in an interval from 3.00 to 3.99 (40.00%). Only one sample was assessed from 1 to 1.99 (3.33%) and 4 to 4.99 (3.33%). Most of the fat samples of the boar carcasses weighing < 70 kg had been assessed in an interval from 2.00 to 2.99 (66.66%), while the boar carcasses weighing ≥ 70 kg had been assessed in an interval from 3.00 to 3.99 (53.33%).

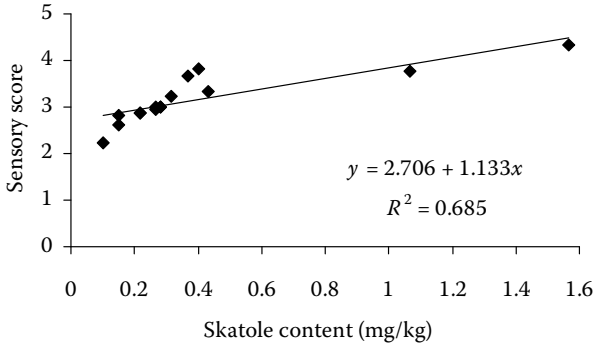

Figure 3. Correlation between skatole content and sensory scores (weight of carcasses ≥ 70 kg)

DISCUSSION

The advantages and disadvantages of the use of entire or castrated pig males are well known. It is generally accepted that the production of boars is limited mainly by off odours and off flavours of unprocessed meat. However, other studies indicate that it is possible to produce boars with minimal loss of pork quality (Jeremiah *et al*. 1999a,b). Castration reduces boar taint but increases the meat production costs and fatness (Babol & Squires 1995; Bonneau 1998).

The overall results of the European boar taint study confirm the important contribution of skatole and androstenone to the undesirable flavour and odour in pork from entire males. It is possible to estimate the degree of consumer dissatisfaction based on the fat concentration of these compounds (Matthews *et al*. 2000). Skatole has a lower detection threshold and a greater impact on the odour than androstenone, while both contribute equally to the flavour (Dijksterhuis *et al*. 2000; Matthews *et al*. 2000).

The mean level of skatole in group N = 30 was 0.29 ± 0.30 mg/kg fat, which is more than that found in much heavier pigs in the mentioned European study where the mean values varied from 0.10 mg/kg to 0.17 mg/kg fat. Regarding the skatole levels, group N = 30 was outstanding as nearly 63% of the animals had skatole values exceeding 0.20 mg/kg fat and 46% had values equal to or above the cut off for skatole ≥ 25 mg/kg. In Denmark, the frequency of carcasses with skatole content > 0.25 mg/kg was 5%, in the UK from 7% to 10% (Babol & Squires 1995), in Norway 14.4% (Froystein *et al*. 1993), or 20% (Andersen *et al*. 1993), in the Netherlands, 5–13%, EU 7.3% in summer and winter, 10.9% in 30% of South Africa (Potgieter *et al*. 1996). The average value of skatole in fat tissue of entire male pigs < 70 kg, (0.18 ± 0.09 mg/kg fat, respectively) was below the commonly used respective thresholds for tainted meat. (0.20 mg/kg fat). (Bonneau *et al*. 1992). In this group, 73% of the samples had values below the cut off for skatole 25 mg/kg and 53% below the cut off for skatole 20 mg/kg. Using the cut off level for skatole content of ≥ 20 mg/kg fat for the group ≥ 70 kg (0.40 ± 0.39 mg/kg fat, respectively), 80% of the pigs would have been sorted out, while 46% would have been sorted out in the group < 70 kg. Depending on the chosen cut off values for skatole, 26% to 80% of carcasses would

have been sorted out in different group (Table 3). Between the average skatole content in the fat tissue of boars, whose carcass weight was < 70 kg or ≥ 70 kg is a statistically significant difference ($P < 0.05$). The coefficient of correlation in both groups indicates a weak correlation dependence ($r = -0.13$; $r = -0.33$). Lundström and Malmfors (1993) reported a correlation coefficient of –0.17 ($P < 0.001$). According to the research by Weiler *et al.* (1997), the frequency of carcasses with a higher skatole content was 2.2% in boars with the carcass weight under 80 kg, and 12.3% of boars with the carcass weight above 80 kg. According to Bonneau (1998), there is no scientific evidence that 80 kg is the maximum weight for a carcass free of boar taint.

Recent studies (Walstra *et al.* 1999) have established the average androstenone and skatole fat contents for entire males in EU countries (including Spain) as 0.99 and 0.14 mg/kg, respectively. These values were determined by quick methods (ELISA and colorimetry) in 4313 pigs with the average carcass weight of 79 kg. The percentages of tainted carcasses were 61% (androstenone above 0.5 mg/kg fat) and 11% (skatole above 0.25 mg/kg fat). For skatole, about 85% of the entire males demonstrated levels below 0.2 mg/kg, while about 4% between 0.20 and 0.25 mg/kg. On the other hand, a Canadian study (Jeremiah *et al.* 1999b) conducted on 179 pig males slaughtered at 96 kg live weight and 150 days old, showed that 24% and 20%, respectively, of entire males exceeded androstenone and skatole in the acceptable fat levels (determined by ELISA and colorimetry). In contrast, only 3.4% and 2.5% of castrated males exceeded the contents 0.5 mg/kg for androstenone or 0.25 mg/kg for skatole.

The incidence of carcasses with detectable levels of skatole is low, probably due to the improvements on pork meat production methods (Neuper *et al.* 1995; Jinliang *et al.* 1996; Gibis *et al.* 1998; Walstra *et al.* 1999; Bonneau *et al.* 2000; Font-i-Furnols *et al.* 2000; Matthews *et al.* 2000). Androstenone and skatole can vary with the pig genotype, age, and rearing, and it is possible to reduce their fat levels (Squires *et al.* 1992; Hansen *et al.* 1993; Jinliang *et al.* 1996; Xue *et al.* 1996; Bonneau 1998). For this, the boar taint studies must be referred to specific pig genotypes, age of slaughter, feeding, and rearing.

The present study has also investigated the relationship between skatole content and carcass weight and has shown that the relationship between these two parameters is not significant. Our results are similar to the references mentioned above and have found a weak relationship between the skatole content in fat tissue and the carcass weight of boars. The opinions concerning the impact of animals age and weight on the skatole content in fat tissue of boars are different. Brennan *et al.* (1986), Weiler *et al.* (1995) and Moss *et al.* (1997) note that the skatole content in fat tissue of boars increases with the age. Bonneau (1990) and Mortensen (1991) believe that there is no direct relation between the weight of young boars and skatole content in their fat tissue. The variations in the skatole content in fat tissue of pigs are numerous which is understandable if we take into account the fact that the skatole content in fat tissue is affected by a great number of mutually dependent factors.

In recent years, as an indicator of the frequency of sexual odour of meat has been used skatole content of 0.25 mg/kg fat (Weiler *et al.* 1992; Annor-Frempong *et al.* 1997; Matthews *et al.* 1997; Mc Cauley *et al.* 1997; Siret *et al.* 1997) and this value is used in the European Union for sorting carcasses of boars, those that can be put on the market without restrictions (0.25 mg/kg) and those that are intended for processing (> 0.25 mg/kg). The level of 0.20 ppm of skatole equivalent in fat, as measured by the colorimetric method (Mortensen & Sørensen 1984), is currently used in Sweden as a threshold level for sorting out tainted carcasses.

In our research, acceptable samples were those with the intensity described on the scale as "like slightly expressed skatole" and corresponding to grade 3. According to the criteria defined in this way, 40% of the samples of fat tissue from boars coming from group $N = 30$ in our trial had distinct skatole as well as 53% of those from the group ≥ 70 kg. Our results show that there is a positive, very strong and statistically highly significant correlation ($r = 0.78$; $r = 0.91$; $r = 0.82$) between the skatole content in fat tissue and sensory evaluation of the skatole intensity in fat tissue. This correlation varied in literature references from 0.53 to 0.73 (Lundström *et al.* 1984; Mortensen & Sørensen 1984). In the group < 70 kg, 66% of samples of the fat tissue from boars were assessed between 2–2.99 (like moderately) and also 53% from boars group $N = 30$. The correlation between the sensory evaluation and the carcass weight in all three groups, proved to be relatively weak. In

groups < 70 kg and ≥ 70 kg, the correlations were negative.

The dissatisfaction with odour was mostly associated with high skatole levels, while androstenone had a little influence on it. On the other hand, androstenone and skatole had similar contributions to the level of dissatisfaction with flavour. The higher contribution of skatole than that of androstenone can be ascribed to the existence of anosmia to androstenone in a substantial proportion of consumers (Weiler *et al*. 2000). The frequency of the incidence of sex odour in meat based on sensory evaluation varied from 2.5% to 42.8% (Mortensen & Sørensen 1984; Kempster *et al*. 1986; Warkup & Kempster 1995). The level of dissatisfaction differed greatly between countries. British consumers were equally satisfied with entire male and gilt pork, for both odour and flavour. Danish and Dutch consumers were less critical of the flavour whereas they objected to the odour of entire male pork. In the remaining countries (France, Germany, Spain, and Sweden), consumers were clearly more dissatisfied with entire male than with gilt pork, for both flavour and odour.

CONCLUSION

The main conclusion to be drawn from the present study is that high levels of skatole can be found in fat from young boars, causing the occurrence of boar odour and boar taint. A weak correlation dependence was found between the carcass weight and skatole level in fat tissue. The high occurrence of skatole concentrations above the mentioned cut-off levels of 0.2 mg/kg and 0.25 mg/kg, respectively, as found in this study, is not very promising for the production of entire males in the markets where boar taint is perceived as a problem, at least without further incentives. The fact that in our study the percentage of boars with skatole levels exceeding the commonly used threshold for boar taint was higher than the percentage of animals with an elevated skatole level might indicate that skatole accumulation might be a primary event in the development of boar taint. A high correlation was found between the skatole levels and sensory assessment of skatole odour intensity in fat.

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Reference

Andersen O., Froystein T., Rodbotten M., Mortensen H.P., Eik-Nes O., Lea P. (1993): Sensoric evaluation of boar meat with different levels of androstenone and skatole. In: Bonneau M. (ed.): Measurement and Prevention of Boar Taint in Entire Male Pigs. INRA Editions, Paris: 69.

Andersson K., Schaub A., Andersson K., Lundström K., Thomke S., Hansson I. (1997): The effect of feeding system, lysine level and gilt contact on performance, skatole levels and economy of entire male pigs. Livestock Production Science, **51**: 131–140.

Annor-Frempong I.N. (1997): The problem of taint in pork: I. Detection thresholds and odour profiles of androstenone and skatole in a model system. Meat Science, **46**: 45–55.

Babol J., Squires E.J. (1995): Quality of meat from entire male pigs. Food Research International, **28**: 201–212.

Babol J., Squires E.J., Gullett E.A. (1996): Investigation of factors responsible for the development of boar taint. Food Research International, **28**: 573–581.

Babol J., Squires E.J., Lundström K. (1999): Relationship between metabolism of skatole and androstenone in intact male pigs. Journal of Animal Science, **77**: 84–92.

Banon S., Granados M.V., Cayuela J.M., Gil M.D., Costa E., Garrido M.D. (2000): Calidad de la grasa obtenida a partir de cerdos magros. Anales de Veterinaria Murcia, **16**: 77–88.

Banon S., Costa E., Gil M.D., Garrido M.D. (2003): A comparative study of boar taint in cooked and dry-cured meat. Meat Science: 389–395.

Bonneau M. (1990): Sexual odors in pork from intact males. In: In: Proceedings Workshop on the Production and Marketing of Pork from Entire Males. June, Ottawa: 34–44.

Bonneau M., Denmat M., Vaudelet C., Veloso-Nunes J.R., Mortensen A.B., Mortensen H.P. (1992): Contribution of androstenone and skatole to boar taint I. & II. Sensory attributes of fat and pork meat. Eating quality of cooked hams. Livestock Production Science, **32**: 63–88.

Bonneau M . (1998): Use of entire males for pig meat in the European Union. Meat Science, **49** (Suppl. 1): 257–272.

Bonneau M., Squires E.J. (2000): Use of entire males for pig production. In: Conferencia Virtual Internacional sobre Qualidade de Carne Suı'na, 16. 11–16. 12. 2000.

Bonneau M., Walstra P., Claudi-Magnussen C., Kempster A.J., Tornberg E., Fischer K., Diestre

A., Siret F., Chevillon P., Claus R., Dijksterhuis G., Punter P., Matthews K.R., Agerhem H., Beague M.P., Oliver M.A., Gispert M., Weiler U., Von Seth G., Leask H., Font-I-Furnolls M., Homer D.B., Cook G.L. (2000): An international study on the importance of androstenone and skatole for boar taint. IV. Simulation studies on consumer dissatisfaction with entire male pork and the effect of sorting carcasses on the slaughter line, main conclusions and recommendations. Meat Science, **54**: 285–295.

Brennan J.J., Shand P.J., Fenton M., Nicholls L.L., Aherne F.X. (1986): Androstenone, androstenol and odour intensity in backfat of 100- and 130-kg boars and gilts. Canadian Journal of Animal Science, **66**: 615–624.

Claus R., Weiler U., Herzog A. (1994): Physiological aspects of androstenone and skatole formation in the boar- a review with experimental data. Meat Science, **38**: 289–305.

Diestre A., Oliver M.A., Gispert M., Arpa I., Arnau J. (1990): Consumer responses to fresh and meat products from barrows and boars with different levels of boar tain. Animal Production, **50**: 519–530.

Dijksterhuis G.B., Engel B., Walstra P., Font-I-Furnolls M., Agerhem H., Fischer K., Oliver M.A., Claudi-Magnussen C., Siret F., Beague M.P., Homer D.B., Bonneau M. (2000): An international study on the importance of androstenone and skatole for boar taint. II. Sensory evaluation by trained panels in seven European countries. Meat Science, **54**: 261–269.

Doran E., Whittington F.W., Wood J.D., Mc Givan J.D. (2002): The relationship between adipose tissue skatole levels, rates of hepatic microsomal skatole metabolism and hepatic cytochrome P450IIE1 expression in two breeds of pig. Animal Science, **72**: 461–468.

Font-I-Furnols M., Guerrero L., Serra X., Rius M.A., Oliver M.A. (2000): Sensory characterization of boar taint in entire male pigs. Journal of Sensory Studies, **15**: 393–409.

Fowler V.R., Mc William T., Aitken R. (1981): Voluntary feed intake of boars, castrates and gilts given diets of different nutrient density. Animal Production, **32**: 357 (abstr.).

Froystein T., Thornwittussen H., Roe M., Bye M., Bjornstad A. (1993): Entire male pig production in small scale slaughterhouses based on manual analysis of skatole. In: Bonneau M. (ed.): Measurement and Prevention of Boar Taint in Entire Male Pigs. INRA Editions, Paris: 145–149.

Gibis M., Hilmes C., Discher A. (1998): Off-flavour in pork caused by skatole. Fleischwirtschaft, **78**: 727–730.

Godt J., Kristensen K., Poulsen C.S., Juhl H.J., Bech A.C. (1996): A consumer study of Danish entire male pigs. Fleischwirtschaft, **76**: 518–520.

Gower D.B. (1972): 16-Unsaturated C19 steroids. A review of their chemistry, biochemistry and possible physiological role. Journal of Steroid Biochemistry, **3**: 45–103.

Hansen L.L., Larsen A.E., Jensen B.B., Hansen-Moller J., Barton-Gade P. (1993): In: Bonneau M. (ed.): Measurement and Prevention of Boar Taint in Entire Male Pigs. INRA Editions, Paris: 151–157.

Hansen L.L., Larsen A.E., Jensen B.B., Hansen-Moller J., Barton-Gade P. (1994): Influence of stocking rate and faeces deposition in the pen at different temperatures on skatole concentration (boar taint) in subcutaneous fat. Animal Production, **59**: 99–110.

Hansen L.L., Lundström K., Laue A., Jensen M.T., Agergaard N., Bæk C.Æ., Hansen-Møller J. (1997): Skatole and androstenone pattern during the growth period from 90 to 120 kg live weight in pigs with high or low skatole levels in back fat at slaughter. In: Bonneau M., Lundström K., Malmfors B. (eds.): Boar Taint in Entire Male Pigs. Proceedings Meeting of the EAAP Working Group Production and Utilisation of Meat from Entire Male Pigs. 1.–3. 9. Stockholm, Sweden. EAAP Publication No. 92. Wageningen Pers, Wageningen: 131–134.

Hansen-Møller J. (1998): Analytical methods for determination of boar taint compounds. In: Jensen W.K. (ed.): Skatole and Boar Taint. Danish Meat Research Institute, Roskilde: 21–40.

Hawe S.M., Walker N., Moss B.W. (1992): The effects of dietary fiber, lactose, and antibiotic on the levels of skatole and indole in faeces and subcutaneous fat in growing pigs. Animal Production, **54**: 413–419.

Hennessy D., Salvatore L., Sali L. (1995): Incidence and nature of boar taint in Australian pigs. In: Proceedings Meeting of the EAAP Working Group Production and Utilization of Meat from Entire Male Pigs. Session III, Milton Keynes: 5.

Hortos M., Rius M.A., De Vries A., Lacoste A., Gispert M., Diestre A. (2000): Variation in boar taint compounds in backfat from divergent genetic lines. In: Proceedings 46th International Congress of Food Science and Technology, 27. 8.–1. 9. 2000, Buenos Aires, 1: 98–99.

ISO 4121 (1987): Sensory analysis methodology. Evaluation of food products by methods using scales. International Standards Organisation, Geneva.

ISO 5495 (1983): Sensory analysis methodology. Paired comparison test. International Standard Organization, Geneva.

ISO 8586-1 (1993): Sensory analysis methodology. General guidance for the selection and training and monitoring of assessors. Part 1. Selected assessors. International Standards Organisation, Geneva.

Jensen M.T., Jensen B.B. (1997): Tasty meat through diet design. Feed Mix, **5**(4): 8–12.

Jensen W.K. (1998): Skatole and boar taint. Results from an Integrated National Research Project Investigating Causes of Boar Taint in Danish Pigs.

Jeremiah L.E., Gibson J.P., Gibson L.I., Ball R.O., Aker C., Fortin A. (1999a): The influence of breed, gender and PSS (Halothane) genotype on meat quality, cooking loss and palatability of pork. Food Research International, **32**: 59–71.

Jeremiah L.E., Squires E.J., Sather A.P. (1999b): Gender and diet influence on pork palatability and consumer acceptance. II. Sex taint compounds and their relationships to sensory properties. Journal of Muscle Foods, **10**: 317–331.

Jinliang X., Dial G.D., Morrison R.B. (1996): Comparison of accuracies of chemical and sensory test for detecting taint in pork. Livestock Production Science, **46**: 203–211.

Kempster A.J., Dilworth A.W., Evans D.G., Fisher K.D. (1986): The effects of fat thickness and sex on pig meat quality with special reference to the problems associated with overleanness. Animal Production, **43**: 517–533.

Lundström K., Malmfors B., Malmfors G., Petersson H., Stern S., Mortensen A.B., Sørensen S.E. (1984): Boar taint and bitter taste as affected by androstenone and skatole. In: Proceedings 30th European Meeting of Meat Research Workers. Bristol, 9.–14. 9. 1984: 397–398.

Lundström K., Malmfors B. (1993): Skatole levels as affected by of boar taint in entire male pigs. INRA, Paris, Les inheritance and season. In: 39th ICoMST, Calgary, Canada, 6 Colloques: 87–92.

Lundström K., Malmfors B., Stern S., Rydhymer L., Eliasson-Selling L., Mortensen A.B., Mortensen H.P. (1994): Skatole levels in pigs selected for high lean tissue growth rate on different protein levels. Livestock Production Science, **38**: 125–132.

Lundström K., Bonneau M. (1996): Off-flavour in meat with particular emphasis on boar taint. In: Tylor S., Raimundo A., Severini M., Smulders F.J.M. (eds): Meat Quality and Meat Packaging. ECCEAMST, Utrecht: 137–154.

Matthews K.R., Homer D.B. (1997): The effect of sex on the eating quality of British style sausages prepared from individual entire male and female pigs. In: Bonneau M., Lundström K., Malmfors B. (eds.): Boar Taint in Entire Male Pigs. Proceedings Meeting of the EAAP Working Group Production and Utilisation of Meat from Entire Male Pigs. 1.–3. 9. Stockholm, Sweden. EAAP Publication No. 92. Wageningen Pers, Wageningen: 169–172.

Matthews K.R., Homer D.B., Punter P., Beague M.P., Gispert M., Kempster A.J., Agerhem H., Claudi-Magnussen C., Fischer K., Siret F., Leask H., Font-I-Furnols M., Bonneau M. (2000): An international study on the importance of androstenone and skatole for boar taint. III. Consumer survey in seven European countries. Meat Science, **54**: 271–283.

Mc Cauley D.P., Hennessy V., Boghossian L., Sali L., Salvatore J., Reynolds J., Mawson R. (1997): Effect of methods of cooking and processing pork on the perception of boar taint. In: Bonneau M., Lundström K., Malmfors B. (eds): Boar Taint in Entire Male Pigs. Proceedings Meeting of the EAAP Working Group Production and Utilisation of Meat from Entire Male Pigs. 1.–3. 9. Stockholm, Sweden. EAAP Publication No. 92. Wageningen Pers, Wageningen: 156–160.

Mortensen A.B., Sørensen S.E. (1984): Relationship between boar taint and skatole determined with a new analysis method. In: Proceedings 30th European Meeting of Meat Research Workers, Bristol 9.–14. 9. 1984: 394– 396.

Mortensen A.B., Bejerholm C., Pedersen J.K. (1986): Consumer test of meat from entire males, in relation to skatole in backfat. In: Proceedings of 32nd European Meeting of Meat Research Workers, Ghent, Belgium: 23.

Mortensen H.P. (1991): Effect of testosterone and estradiol added in the feed on skatole and boar taint level in entire male backfat. In: Proceedings 37th International Congress of Meat Science and Technology, Kulmbach, Germany: 161–164.

Moss B., Beattie V.E., Weatherup N. (1997): Effect of increasing slaughter weight on meat quality and boar taint. In: Bonneau M., Lundström K., Malmfors B. (eds.): Boar Taint in Entire Male Pigs. Proceedings Meeting of the EAAP Working Group Production and Utilisation of Meat from Entire Male Pigs. 1.–3. 9. Stockholm, Sweden. EAAP Publication No. 92. Wageningen Pers, Wageningen: 100–103.

Neuper B., Claus R., Herbert E., Weiler U. (1995): Influence of sex, energy supply and light on fattening traits and carcass composition and their relation to androstenone and skatole concentrations in adipose tissue of pigs. Züchtungskunde, **67**: 317–331.

Pedersen B. (1998): Heritability of skatole in back fat. In: Jensen W. K. (ed.): Skatole and Boar Taint. Danish Meat Research Institute, Roskilde: 129–136.

Popov-Raljić J. (1999): Tehnologija i kvalitet gotove hrane. Tehnološki fakultet – Univerzitet u Novom Sadu.

Potgieter C.M., Heeinze P.H., Anderson J., Viljoen J., Snyman J.D., Greebe R., Kruger J., Sereto D. (1996): Androstenona and skatole levels in South African pigs as influenced by sex type, season, stocking density and diet. Meat for the Consumer – 42nd ICoMST.

Rhodes D.N. (1971): Consumer testing of bacon from boar and gilt pigs. Journal of the Science of Food and Agriculture, **22**: 485–490.

Sinclair P.A., Squires E.J., Raeside J.I. (2001): Early postnatal plasma concentrations of testicular steroid hormones, pubertal development, and carcass leanness as potential indicators of boar taint in market weight intact male pigs. Journal of Animal Science, **79**: 1868–1876.

Siret F., Béague M.P., Fischer K., Chevillon P. (1997): Consumer acceptability and characterization of the cooking odour of lardons produced from pork with different androstenone and skatole contents. In: Bonneau M., Lundström K., Malmfors B. (eds.): Boar Taint in Entire Male Pigs. Proceedings Meeting of the EAAP Working Group Production and Utilisation of Meat from Entire Male Pigs. 1.–3. 9. Stockholm, Sweden. EAAP Publication No. 92. Wageningen Pers, Wageningen: 161–164.

Squires E.J., Lou Y. (1995): Level of boar taint in purebred entire male pigs in Canada. In Proceedings of a meeting of the production and utilization of entire male pigs. Milton Keynes, UK (Session III), 5.

Squires E.J., Deng, H., Wu L. (1992): In Measurement and Prevention of Boar Taint in Entire Male Pigs. Paris: Bonneau Editions, 41–48.

Statistica Ver.6.0. (2003). StatSoft, Inc., Faculty of Agriculture, Zemun.

Tuomola M., Vahva M., Kallio H. (1996): High performance chromatography determination of skatole and indole levels in pig serum, subcutaneous fat, and submaxillary salivary glands. Journal of Agricultural and Food Chemistry, **44**: 1265–1270.

Walstra P., Claudi-Magnussen C., Chevillon P., Von Seth G., Diestre A., Matthews K.R., Homer D.B., Bonneau M. (1999): An international study on the importance of androstenone and skatole for boar taint: Levels of androstenone and skatole by country and season. Livestock Production Science, **62**: 5–28.

Warkup C.C., Kempster A.J. (1995): A review of MLC research on the eating quality of meat from entire males and gilts. In: Proceedings European Association for Animal Production Working Group. Milton Keynes, Regne Unit.

Weiler U., Claus R., Hofacker S. (1992): Ebermast und geschlechtsgeruch: eine physiologische Analyse. Lohmann Information, 1–10: 220.

Weiler U., Dehnhard M., Herbert E., Claus R. (1995): Einfluß von Geschlecht, Genotyp und Mastendgewicht auf die Androstenon- und Skatolkonzentrationen im Fett von Mastschweinen. Die Ebermast, Angewandte Wissenschaft, No. 449. Landwirtschaftsverlag, Münster: 14–33.

Weiler U., Fischer K., Kemmer H., Dobrowolski A., Claus R. (1997): Influence of androstenone sensitivity on consumer reactions to boar meat. In: Bonneau M., Lundström K., Malmfors B. (eds.): Boar Taint in Entire Male Pigs. Proceedings Meeting of the EAAP Working Group Production and Utilisation of Meat from Entire Male Pigs. 1.–3. 9. Stockholm, Sweden. EAAP Publication No. 92. Wageningen Pers, Wageningen: 147–151.

Weiler U., Font I Furnols M., Fischer K., Kemmer H., Oliver M.A., Gispert M., Dobrowolski A., Claus R. (2000): Influence of differences in sensitivity of Spanish and German consumers to perceive androstenone on the acceptance of boar meat differing in skatole and androstenone concentrations. Meat Science, **54**: 297–304.

Xue J., Dial G.D., Holton E.E., Vickers Z., Squires E.J., Lou Y., Gotbout D., Morel N. (1996): Breed differences in boar taint: relationship between tissue levels of boar taint compounds and sensory analysis of taint. Journal of Animal Science, **74**: 2170–2177.

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