Boar taint

Josef Kameník[1], Jaroslav Kratochvíl[2]

[1]Department of Meat Hygiene and Technology
Faculty of Veterinary Hygiene and Ecology
University of Veterinary and Pharmaceutical Sciences Brno
Brno, Czech Republic
[2]Pfizer Prague
Prague, Czech Republic

Abstract

Boar taint is caused by a high concentrations of two compounds: androstenone and skatole. The threshold value of androstenone is between 0.5 – 1.0 $\mu g.g^{-1}$ of fat, and that of skatole 0.2 – 0.25 $\mu g.g^{-1}$ of fat. Both substances affect each other; they have a synergistic effect. In the adipose tissue of boars, the concentration of androstenone is in the region up to 5 $\mu g.g^{-1}$, in the USA the maximum value was established as 15 $\mu g.g^{-1}$ and the content of skatole reaches maximum values of up to 1 $\mu g.g^{-1}$. The level of skatole can be reduced by modifying the diet using prebiotics, and that of androstenone solely through castration. The detection of boar taint is carried out in the abattoir using sensory assessment involving different heating methods.

Castration, androstenone, skatole, sensory assessment

Introduction

In recent years articles devoted to the issue of boar taint have appeared with relative frequency on the pages of professional and scientific journals from the field of meat processing. The reason for this is the wide debate which has opened up on the subject of surgical castration of young boars in EU countries. This method of castration is not desirable from the welfare point of view and also in part for economic reasons. The production of young boars yields leaner meat during a higher intensity of fattening. Production costs for the fattening of boars are significantly lower than is the case with castrated animals, the feed conversion efficiency is better and the nitrogen content in the manure is lower (Prusa et al. 2011).

A disadvantage of the fattening of boars is the occurrence of off-odour in the lard and meat, which are referred to as boar taint (Babol et al. 2004). In the past it was surgical castration which became the most common method of eliminating boar taint. Its origins can be traced back to 4 500 years ago (Chen 2007). In the majority of EU countries, castration is performed on 80-100% of young boars, the most common form being surgical castration without anaesthesia (Blanch et al. 2012). An exception is the United Kingdom and Ireland, where castration is not carried out, and in some states (Cyprus, Portugal and Spain) castration is used only to a limited extent. Increasingly, however, the issue of welfare is being discussed in the use of surgical castration without anaesthesia. Norway and Switzerland have already prohibited this practice by law. In 2010 the "Brussels Declaration" came into being, in which EU countries voluntarily undertake to end castration by 2018 and from 2012 only castration with anaesthesia is to be accepted. At present there is no EU legislation to regulate this state of affairs. Individual countries are guided by their own requirements or by pressure from consumers or retail chains. Holland, for example, wants a ban on castration from as early as 2015.

Two possibilities are currently offered as an alternative to surgical castration – the use of "immunocastration" (Kratochvíl et al. 2011) or the fattening of boars without

Address for correspondence:
MVDr. Josef Kameník, CSc., MBA
University of Veterinary and Pharmaceutical Sciences Brno
Faculty of Veterinary Hygiene and Ecology
Department of Meat Hygiene and Technology
Palackého tř. 1/3, 612 42 Brno, Czech Republic
Phone: +420 541 562 008
E-mail: kamenikj@vfu.cz
www.maso-international.cz

any kind of castration. The Improvac® vaccine against the formation of boar taint has been approved for use in 55 countries including Japan and the EU (Whittington et al. 2011). By contrast, the production of entire boars is common in only a few EU countries. An expansion of this practice is prevented by fear of the occurrence of boar taint.

The chemical nature of boar taint

Boar taint is a sensory deviation in pork evident upon heating, especially of the adipose tissue of some specimens of the male sex. It is caused by a high concentration of two substances, androstenone (in chemical terms: 5α-androst-16-en-3-one; see Fig. 1) and skatole (3-methylindole; see Fig. 2). Which of the two compounds is more significant for the manifestation of boar taint is the subject of discussion (Whittington et al. 2011). However, they influence each other – they have a synergistic effect. The effect of skatole on boar taint increases in the presence of androstenone (Annor-Frempong et al. 1997a). The action of androstenone and skatole is also affected by other compounds in animal tissue. Indole and other 16-androstene steroids also contribute to a lesser extent to the manifestation of boar taint (Andresen 2006). Where there is a low concentration of skatole, a higher concentration of indole can contribute to the odour (Annor-Frempong et al. 1997a). Only approximately 50% of odour deviations can be explained by androstenone and skatole concentrations. The correlation coefficients between the concentration of compounds causing boar taint and the sensory properties of meat are generally low (Annor-Frempong et al. 1997b).

Threshold concentrations for the detection of boar taint are reported in the range of 0.50 – 1.00 μg of androstenone·g^{-1} of fat and 0.20 – 0.25 μg of skatole·g^{-1} of fat (Prusa et al. 2011; Haugen et al. 2012). Above this level, consumers perceive both substances negatively. The majority of people are sensitive to skatole, but the odour of androstenone may not be perceived by a sizeable proportion of consumers (Bonneau and Chevillon 2012). People respond differently to boar taint depending on their country, sex, age and individual sensitivity (Blanch et al. 2012). The ability to perceive androstenone is genetically determined and is generally greater in women than in men. Depending on geographical region, 11 – 66% of women do not perceive androstenone, and with men the percentage is higher – 18 to 74%. Not only does the sensitivity vary, but also the preference – around 8% of highly sensitive individuals (3.3% of women and 16.2% of men) perceive the odour of androstenone positively.

However, the gender difference in the ability to perceive boar taint may not be applicable as a general rule. In an extensive study whose aim was to examine the sensory perception of meat from boars in 3 European countries (France, Spain and the United Kingdom), Blanch et al. (2012) did not detect differences between men and women in the perception of the odour of androstenone in Spain and France, while in the United Kingdom women were more sensitive. The study involved 392 consumers from the 3 countries mentioned. Gender distribution was approximately 50 : 50, and all of the subjects regularly incorporated pork into their diet. Samples of meat were divided as follows:

- Gilts
- Det - : boar meat with androstenone level < 0.5 ppm and skatole level < 0.1 ppm
- Det + : boar meat with androstenone level > 0.5 ppm and skatole level > 0.1 ppm

In France, the concentration of androstenone measured in the Det+ group was between 0.59 and 5.18 μg.g^{-1} of pure fat, while that of skatole was 0.02 to 0.28 μg·g^{-1} of pure fat.

In Spain and the United Kingdom it was 0.58 – 2.28 μg of androstenone·g^{-1} of pure fat and 0.11 to 0.39 μg of skatole·g^{-1} of pure fat. Established sensitivity: 22.7% of consumers were highly sensitive to androstenone, 28.3% moderately sensitive and 49% of the people tested had low sensitivity or insensitivity. High levels of androstenone reduced the acceptability

of boar meat to consumers. However, it was established that a moderate concentration could actually increase acceptance.

In another experiment Bonneau and Chevillon (2012) examined the effect of the level of androstenone on the acceptability of pork to French consumers. The test subjects perceived boar meat with a low level of androstenone and skatole just as positively as meat from gilts or castrates. Meat with a higher level of androstenone but a lower level of skatole was also at least as acceptable as meat from gilts. The results showed that if levels of skatole are very low, concentrations of androstenone of as much as 2.1 – 3.4 $\mu g.g^{-1}$ of fat has little impact, if any, on the consumer's perception of boar taint. The perceptivity threshold of androstenone in the absence of skatole is higher than 2 or even 3 $\mu g.g^{-1}$ of fat (Bonneau and Chevillon 2012). Whittington et al. (2011) identified the correlation coefficients between concentrations of skatole and androstenone and abnormal boar odour in backfat as higher for skatole. This indicates that this substance could have greater significance for sensory manifestations of boar taint (Zammerini et al. 2012).

In the United Kingdom, Zammerini et al. (2012) tested the impact of chicory on the concentration of skatole in the adipose tissue of boars. During an analysis of samples of backfat from pigs from 30 farms in eastern England, they discovered large differences between individual pig farms. Only 13% of farms produced boars with a level of androstenone exceeding the threshold concentration of 1.0 $\mu g.g^{-1}$ of fat, but boars from 40% of holdings displayed levels of skatole above 0.2 $\mu g.g^{-1}$ of fat. In 10% of farms, both substances exceeded the threshold value. The authors highlighted higher values of skatole in comparison with the concentrations discovered in other European countries; the content of androstenone was comparable. After two weeks of feeding with chicory, the level of skatole sharply decreased. 9% chicory content in the diet provided a drop in skatole content in the adipose tissue to below the threshold value. However, the level of androstenone in the test group increased. In sensory terms, boar taint thus remained evident, even though its characteristics changed as a result of the dominance of androstenone. The authors explain the increase in the content of androstenone in the test group as a consequence of the formation of new hierarchies in test groups of boars. Competition for food may lead to an increase in the concentration of androstenone in blood plasma and, consequently, also in the subcutaneous fat (Zammerini et al. 2012). The study cited, however, did not confirm that skatole increases the sensory perception of androstenone in meat from boars.

In the USA an analysis of 600 samples of pork (loin) and backfat for the presence of androstenone and skatole including sensory assessment was carried out by Prusa et al. (2011). The meat was taken from the carcasses of gilts, barrows, uncastrated boars and sows. The classes of sex and range of slaughter weight are set out in Table 1.

Table 1. Distribution of tested pigs by gender (Prusa et al. 2011)

Gender (category)	number of animals	range of live weight in kg
gilts	180	55 – 159
sows	120	107 – 141
boars	120	65 – 136
castrates	180	53 – 129

Table 2. Percentage of boar taint detection in samples of porcine meat and lard (Prusa et al. 2011)

category	backfat	loin (lean pork)
gilts	1.1%	2.8%
sows	5.0%	9.2%
boars	59.2%	31.7%
castrates	3.3%	7.2%

The following tables show the percentage of boar taint detection through sensory evaluation and the concentration of androstenone and skatole discovered in the meat and fat of pigs.

In the United Kingdom, samples of subcutaneous fat from the neck region of 120 boars (slaughter weight 79.4 ± 7.6 kg) were analyzed by Whittington et al. 2011. The concentrations detected are set out in Table 5.

The threshold value for skatole (0.2 $\mu g \cdot g^{-1}$) was exceeded by 33% of samples, and the threshold of

Table 3. Concentration of androstenone (μg.g^{-1}) in backfat (Prusa et al. 2011)

category	mean	range	% > 0.50 μg.g^{-1}	% > 1.00 μg.g^{-1}
gilts	0.120	≤ 0.200 – 2 020	1.1	1.1
sows	0.100	≤ 0.200	0.0	0.0
boars	2.363	≤ 0.200 – 15 000	70.8	55.8
castrates	0.124	≤ 0.200 – 1 400	2.2	1.7

Table 4. Concentration of skatole (μg.g^{-1}) in backfat (Prusa et al. 2011)

category	mean	range	% > 0.200 μg.g^{-1}
gilts	0.0341	≤0.0187 – 0.1090	0.0
sows	0.0383	≤ 0.0187 – 0.2950	1.7
boars	0.1973	≤ 0.0187 – 0.9760	34.2
castrates	0.0463	≤ 0.0187 – 0.1530	0.0

Table 5. The concentration of skatole and androstenone in μg.g^{-1} of fat in the adipose tissue of 120 boars (Whittington et al. 2011)

	skatole	androstenone
Mean ± standard deviation	0.171 ± 0.173	0.874 ± 0.782
median	0.112	0.643
minimum value	0.009	0.095
maximum value	1.07	5.123

androstenone perception (1.0 μg.g^{-1} by 26%. For both substances the threshold value was higher in 14% of cases.

In addition to backfat, the authors cited also investigated samples from the parotid region of the carcass. These were composite samples composed of 80% fat, 10% cheek muscle and 10% submaxillary salivary gland. In this case, the skatole content was lower, whereas the concentration of androstenone was higher than in backfat (Whittington et al. 2011). Suprathreshold levels of the substances responsible for boar taint can also be detected with gilts and castrates in a low percentage (1-2%). The reason for this may be impaired development of the endocrine glands, intersexuality and in the case of gilts also phases of the sexual cycle (Prusa et al. 2011).

Androstenone

A steroidal substance, which was first discovered in 1968 in the adipose tissue of boars. It was the first mammalian pheromone to be identified (Chen 2007). Androstenone can be detected in men's sweat. It has no hormonal function. It is produced in the testes in the Leydig cells together with other steroids, particularly the male sex hormone testosterone. In the case of boars, androstenone can be transported into the salivary glands, where it is present along with other steroids (3α-androstenol, 3ß-androstenol). These substances bind to the protein pheromaxein there and they pass into the saliva during sexual arousal. In view of the function of androstenone in boars it is unsurprising that a higher concentration of this steroid can be detected in the tissue of the salivary glands and the surrounding adipose tissue in comparison with backfat.

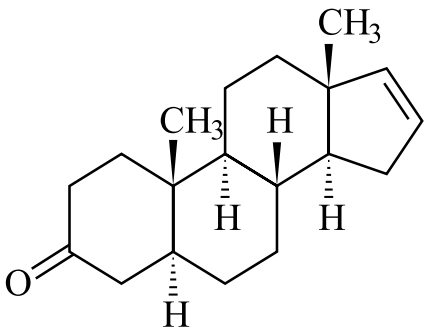

Fig. 1. Androstenone (Haugen 2010)

The liver plays an important role in the metabolism of androstenone in the body (Chen 2007). The biotransformation of androstenone into 3ß-androstenol occurs in hepatic microsomes. The level of androstenone is to a large degree proportional to age and sexual maturity. An early peak in production begins around the age of 2 weeks and a second rise during puberty (Babol et al. 2004).

In sensory terms, the odour of androstenone is described using various expressions, most frequently as an ammonia smell, the smell of sweat or urine.

Skatole

Pigs produce skatole (and also indole) in the large intestine (caecum + colon) through the microbial degradation of the amino acid L-tryptophan (Chen et al. 2007). Both substances are then partially absorbed by the intestinal mucosa and metabolized in the liver by the action of the enzyme cytochrome P450. The unmetabolized portion of skatole accumulates in the fat and causes boar taint. The concentration of skatole and indole is influenced by the composition of the feed.

The administration of raw potato starch (RPS) significantly lowered levels of skatole in the plasma and the fat, while the concentration of indole remained unaffected (Chen et al. 2007). The effect of RPS on the production of skatole in pigs is well known. It is attributed to inhibition of the apoptosis (*N.B.: programmed cell death*) of cells in the intestinal mucosa, thereby reducing the number of dead cells – sources of tryptophan for the synthesis of skatole. The production of indole also ought to be influenced by this. However, this has not been confirmed. There is probably another path which is influenced by the supply of RPS. This may concern the inhibition of bacteria which release skatole, but bacteria synthesizing indole remain unaffected. The production of indole in the large intestine takes place with the participation of many bacteria; the production of skatole requires the presence of highly specific microorganisms (Chen et al. 2007). Tryptophan is first transformed into indole-3-acetic acid, which is then converted into skatole. The first step of the fermentation of tryptophane involves *E. coli* and *Clostridium* spp., and the conversion of indole-3-acetic acid into skatole is brought about by the genera *Lactobacillus* and *Clostridium*. The growth of *E. coli* and *Clostridium* spp. was greatly suppressed by the administration of fructooligosaccharides (FOS). RPS appears to have analogous effects to FOS. The use of FOS in the diet repeatedly lowered the level of skatole in the plasma, fat, liver and intestinal content. A similar effect was also evident with the feeding of chicory (Zammerini et al. 2012).

No difference was established in the level of skatole and indole in pigs slaughtered at a weight of 90 and 115 kg (Chen et al. 2007). The content of both compounds usually rises around the age of sexual maturity and is apparently influenced by testicular steroids. The level of skatole is affected by the activity of enzymes in the hepatic microsomes. In the weight categories of 90 and 115 kg, the activity of these enzymes was the same. An elevated level of skatole is associated with reduced activity of the aforementioned enzymes (Chen et al. 2007).

The positive relationship between the concentration of skatole and the level of sex hormones and androstenone indicates that sexual maturity can influence the amount of skatole in the adipose tissue (Babol et al. 2004). Levels of plasma skatole are relatively low until around the age of 180 – 190 days. There then follows a rise which peaks between 240 – 360 days depending on the breed. Levels of skatole later fall. The effect of differences in skatole levels in individual breeds once more indicates the effect of sexual maturity. In the USA, the Hampshire breed displays the highest concentration of skatole and in Denmark the Landrace.

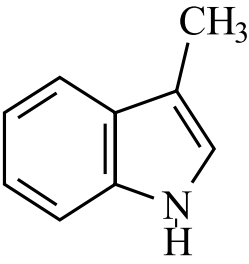

Fig. 2. Skatole (Haugen 2010)

The production of skatole in the large intestine of pigs does not exhibit gender-related differences, i.e. boars release the same concentration as gilts (Andresen 2006). However, in some boars, skatole passes through the liver without being metabolized and subsequently accumulates in the adipose tissue. Skatole

induces the activity of the hepatic enzyme P450, while androstenone has an antagonistic effect in this respect. As a result of the action of androstenone, the metabolism of skatole in the liver is thus reduced. Following the castration of boars, an increase in the level of the enzyme P450 occurs in the hepatic microsomes (Andresen 2006).
The odour of skatole is faecal in nature. Aluwé et al. (2011) attempted to confirm or disprove by experiment the hypothesis that the concentration of skatole can be reduced by keeping pigs clean, as this substance is absorbed by the skin or lungs and passes into the fat. This was confirmed using radioactively labelled skatole: more skatole was absorbed through the skin on the flank (40%) than on the back (6%).

During the actual experiment young boars were divided into 3 groups:

- Standard (reared in a pen which was cleaned every weekend)
- "dirty" (pigs smeared with their own excrement 1× daily, pens cleaned only when absolutely necessary)
- "clean" (pigs washed every day, pens cleaned daily)

Boars were treated in this way from 22 to 26 weeks of age, when they were slaughtered.

No significant differences in concentrations of skatole, indole or androstenone in blood serum or fat were established through sensory evaluation or laboratory analysis (Aluwé et al. 2011).

Boar taint detection

The sensory perception of the abormality of boar taint compared to standard pork is crucial in the assessment of observed deviations and as a rule determines the further use of the whole carcass. According to Regulation 854/2004 ES (annex I, section II, chapter V, article 1) meat is declared as unfit for human consumption if the meat has organoleptic anomalies, especially meat with a pronounced sexual odour. It is therefore necessary to detect boar taint in the abattoir and make a correct assessment based on the intensity of the deviation.

The early detection of boar taint requires the heating of the sample, during which the volatile odorous substances emerge from the tissue and can be captured by the sensory organs of the assessor. Boar taint is perceived more during the heating process than during the actual consumption (Bonneau and Chevillon 2012). In evaluating samples of the adipose tissue (lard) or meat of boars (cryptorchids or other categories), practically any technique involving the application of heat can be used. Whittington and his associates carried out extensive analyses of boar tissue in abattoirs using the following procedures (Whittington et al. 2011):

- heating in a microwave oven (1×1×1 cm cubes of fat on a Pyrex mat, wrapped in aluminium foil; heating for 90 s, 750W)
- rendering test (5x5x5 mm cubes of lard on a Pyrex mat, wrapped in aluminium foil, mat then heated on a cooking plate (surface temperature 185 °C) until the fat began to melt but the cube had not yet browned)
- method using resistance wire (4×4×4 cm cubes of lard in a glass Petri dish, assessors attach a resistance wire heated to 180 °C to the surface and capture the odorous substances by smelling)
- boiling test (1×1×1 cm cubes of lard inserted into a 250 ml Erlenmeyer flask with 90 ml of cold water and covered with kitchen foil, placed on a cooking plate and brought to the boil. When cooled to 75 °C, the samples were submitted to the assessors for evaluation).

All of the methods described can be used to detect boar taint. The best results were obtained by heating in a microwave oven or by the use of resistance wire.

Apart from sensory methods – in practice the most reliable – it is also worth mentioning

instrumental analysis, which is important in the laboratory examination of samples for the content of the aforementioned substances which carry boar taint. Gas chromatography, immunological and colorimetric methods are currently employed (Müller et al. 2012).

Conclusion

Surgical castration of young boars is a reliable way of preventing the occurrence of the boar taint deviation in pork. In recent years, however, this method has been criticized from the welfare point of view. Alternatives to surgical castration are therefore being sought. The fattening of young boars and immunocastration has come under consideration. In both cases, there has been an increased interest in boar taint from processors. Its manifestations in the fat or meat of boars are primarily caused by two substances – androstenone and skatole. The concentration of these compounds in tissues is subject to considerable variability and is affected by numerous factors (breed, method of rearing, nutrition etc.). Both substances affect each other and each has its own influence on the sensory profile of meat. The level of androstenone can be reliably lowered only by castration, while the level of skatole can be reduced by an appropriate modification of the diet (the use of "prebiotics"). Boar taint can be detected in abattoirs using various techniques which involve the heat treatment of a sample. Very good results have been achieved by the use of microwave heating or the application of a resistance wire.

References

Aluwé M, Bekaert KM, Tuyttens FAM,Vanhaecke L, De Smet S, Brabander HF, De Brabander DL, Millet S 2011: Influence of soiling on boar taint in boars. Meat Sci **87**: 175-179

Andresen Ø 2006: Boar taint related compounds: Androstenone/batole/other substances. Acta Vet Scan **48**: S5

Annor-Frempong IE, Nute GR, Whittington FW, Wood JD 1997a: The Problem of Taint in Pork – II. Meat Sci **47**: 49-61

Annor-Frempong IE, Nute GR, Whittington FW, Wood JD 1997b: The Problem of Taint in Pork – III. Meat Sci **47**: 63-76

Babol J, Zamaratskaia G, Juneja RK, Lundström K 2004: The effect of age on distribution of skatol and indol levels in entire male pigs in four breeds: Yorkshire, Landrace, Hampshire and Duroc. Meat Sci **67**: 351-358

Blanch M, Panella-Riera N, Chevillon P, Font I Furnols M, Gil M, Gil JM, Kallas Z, Oliver MA 2012: Impact of consumer´s sensitivity to androstenone on acceptability of meat from entire male pigs in three European countries: France, Spain and United Kingdom. Meat Sci **90**: 572-578

Bonneau M, Chevillon P 2012: Acceptability of entire male pork with various levels of androstenone and skatole by consumers according to their sensitivity to androstenone. Meat Sci **90**: 330-337

Haugen JE 2010: Methods to detect boar taint. State of the art and critical review. EC Workshop on pig welfare – castration of piglets. Brussels. Available at www [cit. 20. 02. 2012] http://ec.europa.eu/food/animal/welfare/seminars/docs/20100602_8%20John-Erik%20Haugen.pdf

Haugen JE, Brunius C, Zamaratskaia G 2012: Review of analytical methods to measure boar taint compounds in porcine adipose tissue: The need for harmonised methods. Meat Sci **90**: 9-19

Chen G 2007: Physiological and Biochemical Factors Responsible for Boar Taint. Doctoral thesis; Swedish University of Agricultural Sciences; Uppsala; 52 s.; ISBN 978-91-85913-09-1

Chen G, Zamaratskaia G, Andersson HK, Lundström K 2010: Effects of raw potato starch and live weight on fat and plasma skatole, indole and androstenone levels measured by different methods in entire male pigs. Meat Sci **101**: 439-448

Kratochvíl J, Steinhauser L, Gallas L, Žižlavský M 2011: Vliv imunokastrace na zmasilost jatečného těla. Maso **22**: 34-36

Müller T, Stiebing A, Dederer I 2012: Rohschinken und Rohwürste aus Eberfleisch. Fleischwirtschaft **92**: 93-98

Prusa K, Nederveld H, Runnels PL, Li R, King VL, Crane JP 2011: Prevalence and relationships of sensory taint, 5α-androstenone and skatole in fat and lean tissue from the loin (Longissimus dorsi) of barrows, gilts, sows, and boars from selected abattoirs in the United States. Meat Sci **88**: 96-101

Whittington FM, Zammerini D, Nute GR, Baker A, Hughes SI, Wood JD 2011: Comparison of rating methods and the use of different tissues for sensory assessment of abnormal odour (boar taint) in pig meat. Meat Sci **88**: 249-255

Zammerini D, Wood JD, Whittington FM, Nute GR, Hughes SI, Hazzledine M, Matthews K 2012: Effect of dietary chicory on boar taint. doi: 10.1016/j.meatsci.2012.01.020