



19 February 1997 (Revised 12.05.97)

Ref. No. 01.705

0110.wp

Report

JRA/LF

Production of Entire Male Pigs; the Danish Perspective

by

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Summary

Danish research results on and experience with production of uncastrated male pigs collected over a period of more than 15 years have all shown that such a production can take place without quality problems for the meat in question. Furthermore, it is advantageous from economical, environmental and animal welfare points of view.

It is, however, mandatory to assay carcasses from uncastrated male pigs for the presence of a deviating odour and/or flavour that exists in some individual carcasses in order to avoid that meat from such animals is used for fresh consumption. The off odour/flavour is known as "boar taint" or "male odour".

Danish experience has documented that the frequency of male carcasses with deviating odour and/or flavour can be kept at a low level, and that chemical analysis for the compound skatole can be utilized to effectively identify and reject tainted carcasses.

Other compounds besides skatole contribute to boar taint; in particular androstenone is often claimed to be at least as, if not more, responsible for the male odour. This claim is not substantiated by Danish experience. On the contrary, numerous sensory panel evaluations and consumer tests carried out on meat from Danish entire male pigs have all indicated that skatole is mainly responsible.

In the present Report is given an account of the experience obtained at the Danish Meat Research Institute with work related to the production of entire male pigs. It includes data from sensory panel assessments and consumer tests, a short characterization of the alternative analytical techniques used in assessing taint, screening results on the levels of both skatole and androstenone found in Danish male pigs, a discussion of rejection criteria and sorting efficiencies, an update on the current European market situation, and finally a brief mention of the EU boar taint project.

Introduction

Incentives

It is a well-known fact that uncastrated male pigs grow faster on less feed compared to castrated ones; this, in turn, leads to a reduction in the output of nitrogen and other pollutants originating from modern pig farming. In addition, the "entire" male pigs yield a 1.5-2.5% higher content of lean meat in the carcass, and they are generally healthier. Consequently, the environmental and economic incentives in avoiding castration are strong; so is, of course, the animal welfare aspect.

Boar taint

On the other hand, meat from a small percentage of uncastrated males exhibit an unpleasant odour when heated and this so-called boar taint has till now if not prevented, then thoroughly complicated, large scale production of entire males. Danish experience gained during more than 15 years of research has documented that the occurrence of tainted carcasses can be kept at a low level, which makes production of entire males with subsequent outsourcing and rejection of tainted carcasses an interesting alternative.

Malodorous compounds

The major compounds responsible for the male odour are known to be skatole and androstenone. Skatole is formed by degradation of the amino acid tryptophan, and androstenone is a pheromone. Both are rather offensive to the human nose; the smell of skatole is described as faecal whereas the smell of androstenone is described as urinous. Only a fraction of all people is capable of smelling androstenone, as this ability is hereditary. Women are reportedly more sensitive to androstenone than men.

For Danish uncastrated male pigs it was determined more than 10 years ago that skatole is by far the dominating odorous substance between the two candidates. Similar results were found in Sweden. Investigations carried out during more recent years have all corroborated that finding. Given below is a summary of Danish research on the issue, including results from sensory panel and consumer tests.

Formation and deposition of skatole and androstenone

Skatole

Skatole is formed in the intestines of both females, castrates and entire males as a result of the metabolism of the amino acid tryptophan. Some of the skatole is absorbed from the intestines to the blood stream and is subsequently partly deposited in fat tissue; the rest of the skatole is excreted with the manure. The deposition of skatole in fat tissue is greater in entire males than in females and castrates, presumably because of a more efficient liver metabolism of skatole in the latter.

High concentrations of skatole in fatty tissues give rise to meat with a deviating odour when heated, long known as boar taint. In severe cases there may also be a deviating flavour of the cooked meat.

Due to their much lower concentrations of skatole in fat, castrates and females only very rarely exhibit deviating odour and taste.

Androstenone

Androstenone is primarily synthesized in the testes and transported via the blood stream to the salivary gland, where it is bound to a specific binding protein. After being released into the saliva, it acts as a pheromone inducing mating response in the oestrus sow. Due to its solubility in fat, androstenone also deposits in fatty tissues.

High concentrations of androstenone in fatty tissues will, just like skatole, give rise to meat with a deviating odour, and boar taint is certainly also associated with androstenone.

In castrates and females very low levels of androstenone may be found; there are, however, reports of conflicting results in which rather high concentrations of androstenone were found in fat from female pigs.

Skatole *versus* Androstenone

From the above it is not at all clear whether skatole or androstenone is more important in boar taint. Some studies indicate skatole and other androstenone; the reason for this is probably that boar taint is influenced by a wide variety of distinctly different parameters including breed of pigs, feed, age, weight, rearing conditions, seasonal variations, etc.

However, all Danish studies carried out on Danish pigs under Danish conditions clearly indicate that skatole is the main culprit.

Sensory panel assessments

In the period 1982-1994 several test series of odour and flavour assessment were carried out by the Danish Meat Research Institute utilizing trained sensory panels of 8 members each. The early investigations only dealt with the impact of skatole content on odour and flavour, as previous experiences indicated skatole to be a better indicator of boar taint than androstenone.

It was found that both odour and flavour deteriorated with increasing skatole concentration. The correlation between skatole content and odour/flavour was -0.7, which was deemed satisfactory considering that a repeat sensory evaluation of the very same samples yielded a correlation of 0.8. A correlation coefficient goes from 0 to

(numerical) 1, where 0 implies no relationship and 1 total agreement between the measurements.

After 1989 androstenone was included in the assessments. In several different studies rather robust results were found: The correlation between skatole concentration and odour/flavour was determined to be -0.74 to -0.76 explaining approximately 60% of the variation. If results from the androstenone analyses were added, the degree of explanation only increased to approximately 70% !! Androstenone content alone only explained about 24% of the variation. (In lay terms, degree of explanation may be perceived as a one-number summary of the strength of the relationship between the variables.)

Consumer tests

In order to complement the sensory panel assessments, consumer tests were conducted. Such studies evaluate the eating quality of pork prepared in-home by consumers, thus bringing the analysis out of the laboratory environment and into the market place.

Three proper consumer tests were carried out as a supplement to the sensory assessments of the trained panels. A preliminary consumer test including 60 families concluded that pork containing more than 0.25 ppm skatole should not be sold as fresh meat and that such meat did not require further evaluation in consumer tests.

The two first tests only included skatole as indicator of boar taint, while androstenone was included in the third.

The two skatole-related tests were including 496 and 269 Danish households, respectively, selected according to social status, town or country location, etc. A total of 2,214 consumers were represented.

Test # 1

In the first test it was found that entire males with a skatole concentration of 0.00-0.14 ppm were assessed to be better than females and castrates. Entire males with a skatole content of 0.15-0.19 ppm were assessed to be equal to females and castrates, and entire males with skatole concentrations of 0.20-0.24 ppm were generally assessed to be slightly inferior to the other entire males, females and castrates.

Test # 2

The objective of the second test was to investigate whether odour and flavour of pork loins and bellies from castrates and entire male pigs differed. Meat from female pigs was omitted in this test. The skatole contents in the entire males ranged from 0.00 to 0.24 ppm, evenly distributed. Comments about a good flavour were a little more frequent for loins from castrates than from entire males. The frequency of comments about good flavour was the same for fried pork belly rashers from castrates and entire males. The frequency of derogatory comments about flavour in loins was very low and boar

taint was not mentioned. The comment "tasteless" was given for 3.3% of the entire males and 2.8% of the castrates. "Piggy flavour" was mentioned for 0.7% of the castrates and 0.5% of the entire males, and "other off flavour" was mentioned for 0.5% of the castrates and 1.4% of the entire males.

The consumers were also asked to compare the samples with the pork they normally ate. 10% of them thought that loin from castrates was a little inferior to their normal purchase, and 2% considered it inferior. 15% considered loins from entire males a little inferior, and 2% considered it inferior to their normal purchase. For fried pork belly rashers the figures for castrates and entire males were alike.

In general, the results from these two consumer tests did not provoke consumer reactions indicating odour and flavour problems with approved entire males (less than 0.25 ppm skatole) compared to females and castrates.

Test # 3

The third test comprised, as mentioned previously, both skatole and androstenone. 550 households participated, and again they were selected to be representative of the average Danish family eating pork regularly. The entire male pigs were chosen in nine groups representing skatole contents in the range 0.00-0.39 ppm and androstenone contents in the interval 0.00-1.99 ppm in such a way that group 1 pigs were low in both skatole and androstenone, and in group 9 both were high. The remaining seven groups had skatole/androstenone combinations of low-high, low-medium, medium-medium and medium-high. The evaluation was done on pork chops from the loin. For comparison, evaluation was also performed on a number of castrates and female pigs.

Sensitive consumers

It was found that at low skatole contents (less than 0.15 ppm) there is no influence of androstenone on the consumers perception of the meat. For loins with higher skatole contents the impact of androstenone becomes noticeable, and skatole above 0.15 ppm in combination with androstenone above 0.50 ppm provoked reactions in "sensitive consumers". The proportion of sensitive consumers was determined to be approximately 10% of the population between 20 and 54 years of age, with a tendency of decreasing sensitivity with increasing age.

In addition, it was established that below 0.15 ppm skatole there was no discrimination between meat from entire males in comparison with meat from castrates or female pigs regardless of the androstenone content. However, even below 0.15 ppm of skatole a few, very sensitive consumers can sense deviating odour.

Rejection limits

Furthermore, a rejection limit based on the contents of androstenone that approves all male pigs with androstenone levels below 0.50 ppm would not restrict the effect of the interaction between low concentrations of androstenone and high concentrations of skatole. Since the vast majority of Danish entire male pigs have low concentrations of both compounds, this illustrates the superiority of skatole in predicting the unpleasant odour of Danish entire males as compared to androstenone.

Finally, it was found that with a rejection limit of 0.25 ppm of skatole, sensitive consumers will sense a distinct off odour in meat from entire males in 5% of all cases as a maximum. Since the proportion of sensitive consumers is approximately 10%, a maximum of 1% , conservatively assessed, of meat from entire males will be perceived as possessing a distinct off odour.

Thus it was concluded that skatole is a more effective parameter than androstenone for identification of the unpleasant odour of some entire male pigs. However, an effect of the entire male pigs odorants on the consumer evaluation of eating quality appears at extreme values of androstenone as the skatole content approaches 0.25 ppm. This situation appears in less than one percent of the Danish population of entire male pigs.

Analysis methods for skatole and androstenone

Skatole

For the analysis of skatole in backfat from pigs a method based on colorimetry was developed in Denmark. It started out as a laboratory method, which through a series of steps was finally developed into a fully automated analysis robot for use in abattoirs.

In the industrial version the robot has a capacity of 180 samples per hour, it is very accurate and precise and has built-in quality control measures and alarms for poor performance. Robots were installed in all authorized slaughter plants in Denmark in the period 1992-1993 and skatole content was determined in the fat of every male pig. The time for each individual analysis is 20 minutes, which means that the result is available when the carcass comes out of the chilling tunnel at the end of the slaughter line. Carcasses with a skatole content above the rejection limit are marked accordingly and kept separate from the other carcasses. This includes also the light carcasses.

Since the German Government in 1993 refused to implement the rules in the fresh meat directive (article 6) on male pigs, the production of entire male pigs has been reduced considerably and consequently only a few of the analysis robots are still in operation. In total, many millions of Danish pigs were tested with the automated equipment.

Androstenone

In the early determinations of androstenone, a radioimmuno assay (RIA) developed in Norway was used. Later a very specific and accurate laboratory method based on high performance liquid chromatography (HPLC) was developed by the Danish Meat Research Institute. This method is actually able to determine both androstenone and skatole in the same run, but it was never refined into an automated equipment for use on abattoirs, partly because of the complexity of the method.

Comparisons

In order to evaluate the performance of analytical methods it is common practice to compare results obtained on the same samples by the different methods. This was also done for the above-mentioned methods, and the results obtained were very satisfactory. The colorimetric method for skatole was compared to HPLC methods, and the androstenone method to other methods based on gas chromatography (GC) and enzyme linked immuno sorbent assays (ELISA). The latter method was developed by professor Rolf Claus at Hohenheim University, Germany.

The result of the intercomparisons was that no systematic differences were found between methods, indicating that both the procedures developed in Denmark and the other ones used in the comparison are analysing correctly.

Skatole and androstenone levels in Danish entire male pigs

A number of screenings of entire male pigs for skatole and androstenone have been completed during the last decade in Denmark. However, the general impression obtained from such screenings was always the same, hence only results from the latest conducted in 1993-94 are given.

2200 male pigs

In this a little more than 2200 male pigs were divided into three (dressed) weight groups: less than 70 kg, 70-80 kg and more than 80 kg. Fat samples were obtained from these pigs and they were all analyzed for skatole and androstenone contents.

The middle group, which is representative of approximately 90% of today's Danish slaughter pigs, had arithmetic averages of skatole and androstenone of 0.09 ppm and 0.63 ppm, respectively. It was further found that skatole levels do not depend on carcass weight; all three groups had an average content of 0.09 ppm. Androstenone levels, on the other hand, do show a significant difference between weight groups. On average, androstenone levels follow carcass weight; the average in the low carcass weight group was 0.52 ppm, whereas the average in the high carcass weight group was 0.72 ppm. A tendency towards a higher standard deviation with higher weight was noted for

androstenone. A slight, but significant, positive correlation of about 0.3 was found between the skatole and androstenone contents.

Weight limit?

Based on these findings it was concluded that the carcass weight by itself is not a measure of the frequency of the deviating smell in some male pigs. However, the positive correlation between carcass weight and androstenone content means that, all other things being equal, the risk of male pigs with a deviant odour increases at greater carcass weights.

Consequently, it was furthermore reasoned that within the normal weight range for Danish slaughter pigs (60-90 kg) it is not relevant to establish an upper weight limit for the purpose of minimizing the risk of producing male pigs that are approved according to the limit, but nevertheless have a deviating smell. The age of the pigs, on the other hand, appears to be significant for the levels of off odour.

Rejection criteria and sorting efficiencies

The results of the tests described above all show that primarily skatole contributes to explaining the deviating smell of meat from a small proportion of entire male pigs. However, androstenone admittedly has some impact on the smell, in particular when the skatole concentration is high. Therefore it may be anticipated that the frequency of male pigs approved after a given rejection limit expressed as concentrations of skatole and/or androstenone will be reduced, if both were included in the sorting criterion.

Linear function

Sensory panel evaluations have established that male pig deviant odour can be described as a linear function of skatole and androstenone, in which the odour is directly proportional to skatole concentration and proportional to the natural logarithm of the androstenone concentration. (In lay terms, skatole is more important for the smell than androstenone.)

A scenario may be set up in which this knowledge is utilized in establishing rejection criteria. In this, it is presumed that all entire male carcasses with skatole contents above 0.25 ppm are rejected. Furthermore, the linear relationship is used as a basis for rejecting entire male carcasses with approved skatole contents (*i.e.* below 0.25 ppm), but with too high androstenone contents. The rejection limit for androstenone thus depends on the skatole contents of the individual male carcasses.

Rejection percentages

Previous tests mentioned above have shown that at a rejection limit of 0.25 ppm skatole, a maximum of 1% of the approved male pig carcasses will have a deviating smell. If the rejection criteria are

supplemented with androstenone limits, the frequency of erroneously approved carcasses can be reduced to 0.5%. The rejection percentage will correspondingly increase from approximately 4% to approximately 8%.

The same frequency of erroneously approved entire male carcasses, 0.5%, may be achieved with a skatole limit of 0.15 ppm, without including androstenone contents. In this case, approximately 10% of all entire male carcasses will be rejected.

If rejection criteria were to be based on androstenone concentrations alone, a rejection limit of 0.5 ppm must be used to obtain the same number of erroneously approved carcasses, approximately 1%, as when using a skatole limit of 0.25 ppm. (The limit of 0.5 ppm of androstenone is incidentally identical to German recommendations.) However, using androstenone at 0.5 ppm as sole criterion would result in a rejection rate of 48%! From a Danish perspective this is equivalent to banning the production of entire males altogether.

Market situation

Meat from entire male pigs is currently produced in a number of countries including Great Britain, Australia, Spain and Denmark; in the three first mentioned, no rejection criteria based on the presence of either skatole or androstenone are implemented. Apparently, consumer reactions to deviating smell or taste are absent or very limited in these countries.

In Denmark, the weekly number of entire male pigs slaughtered is presently close to 10,000 compared to a total weekly kill of slaughter pigs of approximately 400,000. Until recently the situation was somewhat different. All export authorized abattoirs were slaughtering entire male pigs, and a skatole concentration of 0.25 ppm as determined by the automatic, colorimetric procedure was used as sorting limit. When the number of entire male pigs was at its maximum, approximately 100,000 were slaughtered on a weekly basis, and this number was expected to increase to close to 50% of the total kill; in other words, the prognosis was approximately 200,000 entire male pigs each week.

German reactions

Article 6 in the directive 91/497 on fresh meat stipulates that only carcasses from entire male pigs with a dressed weight above 80 kg need be tested by an approved objective method. Carcasses duly tested and approved are subject to free trade. However, in January 1993 the German authorities notified that they would not implement the rules in the directive concerning male pigs.

Only a fraction of Danish male pig carcasses is above 80 kg, and they are as such not subject to mandatory testing. In 1994, 11.6% of the male pigs were above the weight limit, and in 1996 15.1%. However, the Danish position was, and still is, that all carcasses from entire male pigs are analyzed by the automatic skatole method, which is approved by the Danish authorities and EU. Nevertheless, the German refusal to follow common legislation remains, and the result is the dramatic decline in male pig production in Denmark.

The dispute on the implementation of the fresh meat directive is still unresolved; however, the European Commission is in the process of bringing Germany before the European Court on the issue.

The European Union boar taint project

While the market situation still is quite confused and distorted, a European Union project under the Agro-Industrial Research (AIR) programme has taken up the challenge of trying to sort out, which are the salient features for the common European consumer with regard to meat from entire male pigs.

Project title

The title of the project is "Rationalisation and harmonisation of the European pig market, with respect to production of entire males, through an improved knowledge of compounds responsible for boar taint."

Project objectives

The main objective of the project is "to provide scientific evidence for an objective measurement of boar taint in entire male pigs", and the result is expected to be a definition "of scientifically based uniform quality norms for the measurement of boar taint usable throughout the EU". It comprises a survey of the present situation regarding androstenone and skatole levels in a number of entire male pig populations distributed over Europe, a comparison of trained sensory panel responses and consumer reactions to entire male pig meat with known levels of androstenone and skatole, and finally a search for alternative compounds contributing to boar taint.

Seven countries

Seven member states - Spain, France, Great Britain, the Netherlands, Sweden, Germany and Denmark - participate in the project, which realistically is expected to end in 1998. Project coordinator is INRA in France. The objective of the project is very ambitious and may not be achievable at all, so the finalisation of the dispute between the European Commission and Germany on the implementation of the Directive on fresh meat should not await the outcome of the AIR-project.

Conclusion

It appears to be without doubt from the results reported above that for the Danish population of entire male pigs skatole is by far superior as indicator of deviating odour/flavour in comparison with androstenone. However, it must be emphasized that the results are obtained on Danish pigs, and that the situation may be different elsewhere. Boar taint is admittedly influenced by a variety of parameters including breed of pigs, feed, rearing conditions etc.

The results from the sensory panel assessments and consumer tests clearly indicate that a rejection criterion of less than 0.25 ppm skatole in the back fat of entire male pigs only gives rise to a very limited number of consumer reactions. Lowering the criterion to less than 0.15 ppm skatole in essence results in a situation where close to all consumers are unable to discriminate between meat from entire males and meat from castrates or females.

Interestingly, it was also found that at skatole contents below 0.15 ppm there is no influence of androstenone on the consumers perception of the meat. For higher skatole concentrations the impact of androstenone becomes noticeable, and skatole above 0.15 ppm in combination with androstenone above 0.5 ppm will be associated with deviating odour by sensitive consumers. The proportion of such consumers is approximately 10% of the population between 20 and 54 years of age.

With a rejection limit of 0.25 ppm skatole approximately 4% of the Danish male carcasses will be rejected. This number increases to approximately 10% upon lowering the limit to 0.15 ppm skatole. The sorting efficiency, *i.e.* the percentage of erroneously approved carcasses, will as a consequence of the reduced sorting limit increase from approximately 1% to approximately 0.5%.

Were the rejection limit based on androstenone, a limit of 0.5 ppm would result in a similar sorting efficiency, approximately 1%, as a limit of 0.25 ppm skatole. The number of rejected carcasses would, however, increase to 48%.

The final conclusion that must be reached from the results given above is that the only viable route to a Danish production of entire male pigs is by way of rejection criteria based on skatole contents.