USE OF ENTIRE MALES FOR PIG MEAT IN THE EUROPEAN UNION

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ABSTRACT

The aim of the present paper is to review the present knowledge concerning the possible use of entire male pigs for meat production, with particular emphasis on the current situation in EU countries. Raising entire male pigs has a number of advantages including lower production costs, leaner carcass, reduction of the output of pollutants in the manure and improved welfare of the animals. However, it has also a number of drawbacks, most of them concerning meat quality, with boar taint being the most serious problem. A recent international study involving 7 EU countries has shown that a higher proportion of consumers is dissatisfied with entire male than with gilt pork (31.9 vs 26.0% for odour; 21.5 vs 18.5% for flavour). However, the perception of boar taint differs widely between countries. Skatole, a compound with intense faecal odour, and androstenone, a steroid with intense urinary odour, are held as responsible for boar taint. The above-mentioned international study demonstrated that skatole has a higher contribution than androstenone for consumer perception of unpleasant odours, while both compounds have similar contributions to unpleasant flavours. In the current situation, a high proportion of the entire male pigs reared in EU countries exhibit skatole/androstenone levels that result in a significant increase in consumer dissatisfaction, comparatively to gilt pork. Fat skatole levels are mostly dependent on feeding and rearing factors, while fat androstenone content is mostly determined by genetic factors.

Besides the economic advantages associated with the production of entire males, the animal welfare issue may result some day in EU regulations prohibiting the castration of male piglets as it is currently performed. This would lead to a degradation of meat quality unless something is done to control the boar taint problem. An integrated approach should be considered with actions taken at the three levels of animal production, slaughter and processing. On the short range, immunocastration may offer a viable way for a drastic reduction of the incidence of boar taint in entire male pig populations. On the long range, selection against skatole/androstenone may be cheaper and more readily acceptable. Artificial noses and related techniques offer interesting possibilities for the assessment of boar taint on the slaughter line, however further developments are needed in order to determine whether they can be used in industrial conditions. Tainted meat can be used through processing, however specific studies have to be conducted for each of the many products that can be processed from pig meat.

INTRODUCTION

Castration of meat producing male animals has been widely used for a very long time, for a number of reasons including an easier control of their behaviour and the higher propensity of castrates to deposit fat, a commodity that has been in high demand until quite recently. The change of consumer attitudes towards a higher demand for leaner meat and the lower production costs associated with entire males have led to abandon castration for most of the cattle and sheep. Concerning pigs, the rearing of entire males have been hampered by the existence of boar taint, a problem that is encountered only in that species. In Europe, most of the entire males are left uncastrated in Great Britain, Ireland, Spain and Portugal, whereas most of them are castrated at a young age in the remaining countries. A recent attempt of Denmark to export entire male pigs was opposed by its main customers, particularly in Germany and France, although an EU directive allows the trade of meat from entire male pigs between member countries, with no restriction for carcass weights lower than 80 kg and provided that they have been assessed for boar taint with an objective method for carcass weights higher than 80 kg. The problems with that directive are that there is no scientific evidence supporting the 80 kg limit for carcass weight and that there is no universally accepted objective method for the assessment of boar taint on the slaughter line.

The aim of the present paper is to review the present knowledge concerning the possible use of entire male pigs for meat production. The advantages and disadvantages associated with the production of entire male pigs will first be examined. The main compounds held as responsible for boar taint will then be presented, considering their respective contributions to boar taint and their main factors of variation. In a third section, the paper will review the possible ways of dealing with the problem of boar taint at different levels, including reduction of the incidence of boar taint in the animals, assessment of boar taint on the slaughter line, and use of tainted meat in processed products.

ADVANTAGES AND DISADVANTAGES ASSOCIATED WITH THE PRODUCTION OF ENTIRE MALE PIGS

Numerous studies have established the advantages and disadvantages associated with the production of entire males (see for instance the reviews of Walstra, 1974 and Walstra and Vermeer, 1993). On the side of advantages are lower productions costs, reduced excretion of pollutants in the manure, leaner carcasses, suppression of suffering to the animals and improvement of some aspects of meat quality. However, rearing entire male pigs also have a number of negative aspects concerning meat quality, particularly the existence of boar taint.

Reasons for not castrating male pigs

Production factors are more favourable in entire males

The productions costs are substantially lower for entire males than for castrates. The labour costs involved in performing castration are suppressed. Possible animal losses and temporary decrease in performance following castration are also avoided. Entire males need less feed to grow and may sometimes grow faster than castrates (e.g. Walstra and Kroeske, 1968; Fowler et al., 1981; Andersson et al., 1997). They may also be more resistant to diseases that negatively affect performance. Because they require less feed and have a better efficiency for nitrogen retention (e.g. Desmoulin et al., 1974), the output of nitrogen in manure is less with entire males than with castrates. Since the operation of castration may be painful, leaving the males entire results in improved welfare of the animals.

Carcass quality and some aspects of meat quality are generally more favourable in entire males

The smaller development of adipose tissue is another important advantage associated with entire male pigs (e.g. Prescott and Lamming, 1967; Hansson et al., 1975; Fortin et al., 1983; Hansen and Lewis, 1993). Thinner backfat results in a higher grading for carcasses, however the superiority of entire males over castrates may be underestimated unless special equations are used for them in carcass grading systems (Andersson et al. 1997). Because of the smaller development of intermuscular (in between muscles) adipose tissue, meat cuts from entire males are more appealing to the consumer.

The characteristics of muscle and adipose tissue differ between entire males and castrates (e.g. Malmfors and Nilsson, 1978; Wood and Enser, 1982; Ellis et al., 1983; Desmoulin et al., 1983; Barton-Gade, 1987). The lower lipid content and the more unsaturated fatty acids in adipose tissues of entire males may be regarded as favourable from the dietetic point of view.

Reasons for castrating male pigs

The reduction in dressing percentage (e.g. Prescott and Lamming, 1967; Fortin et al., 1983; Hansen and Lewis, 1993) due to the presence of a fully developed genital tract, is one of the drawbacks associated with the production of entire males. Too lean carcasses may also sometimes be a problem. However, most of the problems with entire males have to do with meat quality.

Entire males in lean strain of pigs may be excessively lean

With lean genotype of pigs, the smaller development of adipose tissue in entire males may be considered as a disadvantage. Indeed, the processing industry do need a minimum quantity of good quality fat and extreme leanness results in a lack of cohesion between backfat and the underlying muscle (Wood, 1984).

A number of important aspects of fat quality are adversely affected in entire males

Depending on conditions before slaughter, the proportion of DFD meat may be higher in entire males which are more active (Moss and Robb, 1978; Ellis et al., 1983). The lower intramuscular lipid content of entire males may be related to the observation that their meat if often found to be less tender than that of castrates (Martin et al., 1968; Bonneau et al., 1979; Barton-Gade, 1987).

Because adipose tissues of entire males have higher water content and more unsaturated fatty acids, the processing quality of fat is worst in entire males. Entire male fat is softer and less resistant to oxidation. The poorer quality of fat is not really a characteristics of the entire males per se, but rather results from their greater leanness. The problems associated with fat quality in entire males are increasingly important in increasingly lean genotypes and are further worsened by the use of diets with high contents in unsaturated lipids.

The problem of boar taint

Although the above-mentioned problems with meat quality may be of significant importance, particularly in lean strains of pigs, the most important limitation to the use of entire males is the existence of boar taint.

Boar taint is an objectionable odour that is often perceived during the cooking of meat from mature boars. It can also affect the flavour of meat during eating, although to a lesser extent than for cooking odour. At usual slaughter weights, the incidence of boar taint is very variable, ranging from 10 to 75% according to studies (e.g. Williams et al., 1963; Desmoulin et al., 1971; Rhodes and Patterson, 1971; Malmfors and Hansson, 1974). Because of the large variation in the incidence of boar taint, and because of the variety of culinary habits between countries, the acceptability of boar meat, as measured in consumer surveys, can be quite inconsistent between studies (Malmfors and Lundström, 1983).

From the results of a recent international study on boar taint (Bonneau et al., 1998a, Matthews et al., 1998) the proportion of consumers which would be dissatisfied with the odour or with the flavour of entire male pork has been calculated (Bonneau et al., 1998b; Fig. 1) under the assumption that they consumed meat from entire male pigs produced from all over Europe and exhibiting the currently observed levels of androstenone and skatole (Walstra et al., 1998). Overall, 6.5% more consumers would be dissatisfied with the odour of entire male pork than with that of gilt pork. The corresponding difference for flavour would be 3.0%. Large variations were observed between countries. The difference in acceptability between entire male and gilt pork was very small in Great Britain for both odour and flavour and in Denmark and the Netherlands for flavour. In all other cases, substantially more consumers would be dissatisfied with entire male than with gilt pork, the difference ranging from 6.1 to 10.2% for odour and from 2.4 to 6.3% for flavour.

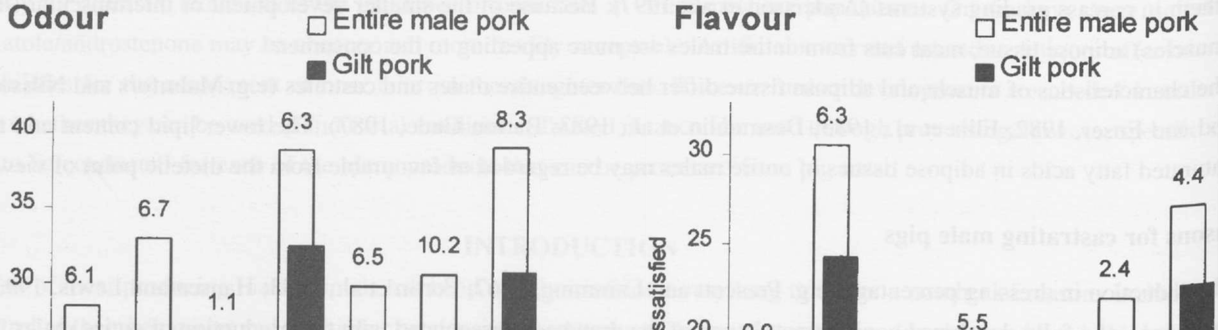

Fig. 1. Calculated proportion of consumers which would be dissatisfied with the odour or flavour of entire male pork, comparatively to gilt pork, under the hypothesis that they ate pork from entire male pigs exhibiting skatole/androstenone levels as observed in 6 EU countries (adapted from Bonneau et al., 1998b; DK: Denmark; FR: France; GB: Great Britain; GE: Germany; NL: Netherlands; SP: Spain; SW: Sweden; The differences between entire male and gilt pork are reported above the bars)

COMPOUNDS RESPONSIBLE FOR BOAR TAINT IN ENTIRE MALE PIGS

Two compounds, androstenone (5α-androst-16-ene-3-one; Patterson, 1968) and skatole (3-methyl indole; Vold, 1970; Walstra and Maarse, 1970), mainly associated with fat, are held as responsible for boar taint in entire male pigs. Androstenone is a testicular steroid with a definite urinary odour. Skatole, a breakdown product from tryptophan, exhibits an intense faecal odour.

Contributions of androstenone and skatole to boar taint

Studies with laboratory panels

The contributions of androstenone and skatole to boar taint have been investigated in many studies. Coefficients of correlation between fat androstenone or skatole levels and boar taint intensity, assessed by laboratory panels, range between 0.4 and 0.8 (Bonneau, 1993). Taking into account the lack of precision inherent in the subjective assessment of odour intensity, such relationships suggest that both compounds have a significant contribution to boar taint. Cut-off levels have been proposed for each compound, as an attempt to define a limit between untainted and tainted samples. Cut-off levels for skatole are considered to be 0.20 or 0.25 ppm (e.g. Hansen-Møller and Godt, 1995). Due to systematic differences between the various methods used for the measurement of fat androstenone, cut-off levels for androstenone range between 0.5 and 1 ppm.

According to Berg et al. (1993), androstenone and skatole have similar contributions to boar taint. In a number of studies (Lundström et al., 1984; Mortensen and Sorensen, 1984; Walstra et al., 1986; Lunström et al., 1988; Andresen et al., 1993; Bejerholm and Barton Gade, 1993), skatole has been reported to have a higher contribution to boar taint than androstenone. In some cases, this can be explained by the fact that few animals exhibited high androstenone levels, therefore leaving skatole as the main contributor to off-odours. However, Bejerholm and Barton Gade (1993) demonstrated that, although androstenone alone significantly decreased odour score, skatole contribution to boar taint was more important. On the contrary, Bonneau et al. (1992) demonstrated that androstenone contribution to boar taint was larger than that of skatole. Moreover, androstenone and skatole odours may strengthen each other synergistically (Lundström et al., 1980; Walstra et al., 1986; Bonneau et al., 1992).

The lack of consistency between the results obtained in the various studies may result from differences in the androstenone and skatole characteristics of the animal populations from which the samples were drawn and also from differences in the methodology used for the sensory assessment of odours (Bonneau, 1993), including selection and training of the panel members and preparation and presentation of the samples.

Studies based on consumer surveys

Very little published information has been available so far concerning the influence of skatole and androstenone on the consumer perception of the odour and flavour of meat from entire male pigs. Further to the above mentioned differences in the level of malodorous compounds of the meat samples and in the methodology used for sensory assessment, another origin for inconsistencies lies in the consumer characteristics, such as ability to smell compounds or culinary habits, that may vary widely between countries. It has been demonstrated, for instance, that the proportion of people that are anosmic to androstenone is not the same in the various area of the world (Gilbert and Wysocki, 1987)

An international study has been recently conducted, aiming at resolving the controversy around the respective contributions of androstenone and skatole to boar taint (Bonneau et al., 1998a). A pool of entire male pigs with known concentrations of androstenone and skatole was selected from a larger population of entire male pigs raised in 6 European countries (Walstra et al., 1998). Meat samples from the selected animals were used for consumer surveys conducted in 7 European countries (Matthews et al., 1998). The results of the overall study, including data from all 7 consumer surveys, show that skatole contributes more than androstenone to the proportion of consumers which are dissatisfied with the odour of entire male pork (Fig. 2). Concerning flavour, skatole and androstenone have a similar contribution, which is additive. The higher contribution of skatole than androstenone to unpleasant odours perceived by consumers can be related to the observation that a rather high proportion of people (in the range of 15-30% depending on sex and geographical area) are unable to smell androstenone (Griffiths and Patterson, 1970; Gilbert and Wysocki, 1987) whereas no such anosmia is observed for skatole (Weiler et al., 1997).

The absence of any difference with gilt pork for the proportion of dissatisfied consumers cannot be achieved unless entire males exhibit very low levels of both skatole and androstenone (Table 1). Unfortunately, only a small proportion of the animals currently fall in the categories with low levels for both compounds. Therefore, for most countries, it seems difficult to envisage any generalisation of entire male pig production without sorting out the tainted boars on the slaughter line. Moreover, for the production of entire males to be economically feasible, the proportion of sorted out animals would have to be relatively small. This means that the incidence of animals with high levels of skatole/androstenone would have to be reduced quite dramatically.

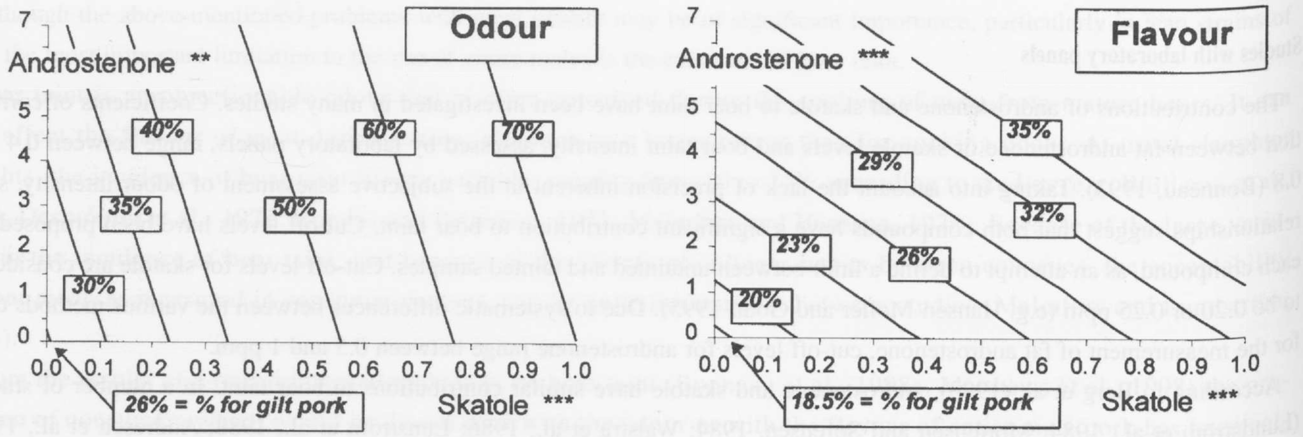

Fig. 2. Isoresponse curves for the proportion of dissatisfied consumers for odour (26 to 70%) or flavour (18.5 to 35%) according to skatole and androstenone levels in entire male pork. The proportion of consumers dissatisfied with gilt pork was 26% for odour and 18.5% for flavour. The significance of the effects of skatole and androstenone on the proportion of dissatisfied consumers is given as ** for P<0.01 and *** for P<0.001. Overall results from a consumer study performed in 7 European countries (adapted from Matthews et al., 1998).

Table 1. Difference between the calculated proportion of consumers which would be dissatisfied with entire male pork and the observed proportion of consumers dissatisfied with gilt pork, according to skatole and androstenone levels. The proportion of animals in every skatole/androstenone category is also indicated (results of an international study conducted in 7 EU countries, adapted from Bonneau et al., 1998b)

Androstenone level (ppm)		*Skatole level (ppm)* ≤ 0.10	*0.11-0.20*	*0.21-0.30*	*0.31-0.50*	*> 0.50*	*Overall*
≤ 0.10	Odour[1]	2	5	9	19	-	3
	Flavour[1]	0	1	3	5	-	1
	% of animals	1.6	0.5	0.05	0.1	0.0	2.2
0.11-0.20	Odour	2	5	9	-	23	3
	Flavour	1	1	3	-	7	1
	% of animals	4.7	1.3	0.2	0.0	0.02	6.2
0.21-0.50	Odour	3	5	10	17	34	4
	Flavour	1	2	3	5	11	2
	% of animals	19.8	8.1	1.3	0.8	0.3	30.2
0.51-1.00	Odour	3	6	10	17	36	6
	Flavour	2	2	4	6	14	2
	% of animals	19.4	9.3	2.3	1.1	0.8	33.0
1.01-2.00	Odour	4	7	12	18	34	8
	Flavour	3	4	5	7	13	4
	% of animals	8.9	5.3	1.8	1.3	1.1	18.4
2.01-5.00	Odour	6	9	14	20	38	14
	Flavour	5	6	8	10	18	8
	% of animals	3.0	2.6	1.1	1.4	1.1	9.1
> 5.00	Odour	11	14	19	28	43	23
	Flavour	14	14	18	22	28	19
	% of animals	0.2	0.3	0.1	0.2	0.2	0.9
Overall	Odour	3	6	11	19	36	6
	Flavour	2	3	5	8	15	3
	% of animals	57.5	27.3	6.7	4.9	3.5	100.0

[1] Difference between the calculated proportion of dissatisfied consumers for odour or flavour of entire male pork and the corresponding observed proportion for gilt pork.

Factors of variation of fat androstenone levels in entire male pigs

At usual slaughter weights, fat androstenone levels are very variable between animals and follow a log-normal distribution. As an example, the distribution of fat androstenone levels in 4293 entire male pigs raised in 6 European countries is presented in Fig. 3. The proportions of animals with androstenone levels ≤0.2, between 0.2-0.5, 0.5-1.0, 1.0-2.0, 2.0-5.0 and >5.0 ppm were 7, 24, 28, 22, 14 and 5%, respectively. All the 220 contemporary gilts exhibited androstenone levels ≤0.2 ppm with 98% of them ≤0.1 ppm.

Androstenone and other 16-androstene steroids are synthesised in the testis, together with androgens and oestrogens. It is released in the blood stream and, due to its lipophilic properties, stored in fat. Detailed presentations of biosynthesis and metabolic pathways, and of factors of variation of androstenone levels in fat have been previously published (e.g. Gower, 1972 ; Bonneau 1982 ; Brooks and Pearson, 1986).

The intensity of androstenone synthesis is low in the young piglet, then increases steadily during the establishment of puberty, concomitantly to the sharp elevation in the production of the other testicular steroids, androgens and oestrogens, which are responsible for the better performance of entire males. Because the same regulatory systems control the synthesis of all steroids, it is very difficult to decrease androstenone without affecting androgens and oestrogens as well.

The large variation in androstenone contents results from two different mechanisms : differences in sexual maturity are responsible for differences in the age when the elevation in fat steroid levels occurs, whereas differences in the potential for androstenone production are responsible for the magnitude of the elevation (Bonneau et al., 1987a,b). Both mechanisms are genetically determined. This is why the heritability of fat androstenone content is high (review by Willeke, 1993). Using a statistical approach, Fouilloux et al. (1997) demonstrated the existence of a major gene for fat androstenone level. On a different set of data, Bidanel et al. (1997) found a genetic linkage between fat androstenone content and a marker on chromosome 7. It may be hypothesised that the major gene is the one which is situated on chromosome 7, and that it is associated with the abundance of a low molecular weight isoform of cytochrome b5 controlling the synthesis of 16-androstene steroids in male pigs (Edwards et al., 1997). However, this remains to be demonstrated.

Factors of variation of fat skatole levels in entire male pigs

At usual slaughter weights, fat skatole levels are also very variable between animals. The distribution of fat skatole levels in 4293 entire male pigs raised in 6 European countries (Walstra et al., 1998) is presented in Fig. 3. The proportions of animals with skatole levels ≤0.05, between 0.05-0.10, 0.10-0.20, 0.20-0.50, and >0.50 ppm were 15, 42, 27, 12 and 4%, respectively. All the 220 contemporary gilts exhibited androstenone levels lower than 0.20 ppm with 36 and 85% of them ≤0.05 and ≤0.10 ppm, respectively.

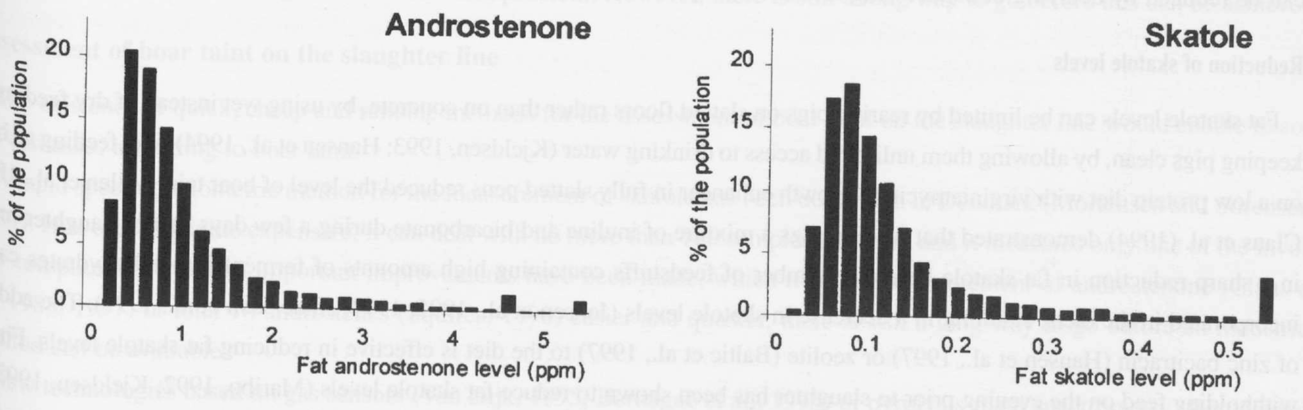

Fig.3. Distribution of androstenone and skatole levels in 4293 entire male pigs raised in 6 European countries (adapted from Walstra et al., 1998)

Skatole is formed in the hind gut of the animals, from the microbial degradation of the amino acid tryptophan. While the reason why androstenone level is sex dependent is quite obvious, due to its testicular origin, it is still not fully understood why fat skatole levels are higher in entire males than in castrates or gilts. Two hypothesis have been considered. According to Claus et al. (1994), the higher anabolic potential of entire males is associated with an increase in the turn-over of intestinal cells, and cell debris are a source of tryptophan for skatole formation in the hind gut. According to Friis (1995), the potential for degrading blood skatole is decreased in some entire male pigs, in connection with an inhibitory effect of sex hormones on the enzyme systems responsible for the breakdown of skatole in the liver (Babol et al., 1997a,b).

According to Kjeldsen (1993), wet feeding and unlimited water supply elicit a reduction in fat skatole contents. The same author also established that pigs on slatted floors exhibited lower skatole levels comparatively to animals on concrete, likely because they were less dirty (Hansen et al., 1994).

Feeding plays an important role in the control of fat skatole. Feedstuffs with a high fibre content (Agergaard et al., 1995), and more generally those containing a high level of non digestible carbohydrates which can be degraded in the hind gut (Claus et al., 1994), elicit a reduction in skatole production and storage. Indeed, a large availability in energy in the hind gut stimulates the proliferation of bacteria using tryptophan for protein synthesis to the detriment of the flora degrading it to skatole.

Thus, fat skatole levels are highly dependent on rearing factors. However, a preliminary study suggests that there could be a major gene controlling fat skatole content, which is not expressed phenotypically unless some environmental conditions are met (Lundström and Malmfors, 1993). It can be hypothesised that this major gene is associated with the potential for degrading blood skatole (Friis, 1993, 1995), particularly with cytochrome P450IIE1 (Babol et al., 1997a).

In conclusion, both androstenone and skatole contribute to boar taint in entire male pigs, with skatole having a higher contribution to unpleasant odour. In the current situation, a high proportion of the entire males exhibit skatole/androstenone levels that result in a significant increase in consumer dissatisfaction. Fat skatole levels are mostly dependent on feeding and rearing factors, while fat androstenone content is mostly determined by genetic factors. For both compounds, high levels cannot be obtained unless the animals have reached some degree of sexual maturity.

HOW TO DEAL WITH BOAR TAINT IN ENTIRE MALE PIGS

In most countries, the production of meat from entire male pigs cannot be generalised unless the problem of boar taint is controlled. Provided that the incidence of boar taint in entire male pig populations is sufficiently low, tainted carcasses can be sorted out on the slaughter line to be used in processed products.

Possible ways of reducing the incidence of boar taint in entire male pig populations

In the present state of knowledge (see section on factors of variation of skatole and androstenone contents), there are several possible ways for reducing the incidence of boar taint in slaughter pigs. Skatole levels can be controlled by modulating rearing conditions and feeding, whereas selection is more efficient to deal with androstenone contents. Furthermore both compounds can be reduced by delaying or suppressing sexual development.

Reduction of skatole levels

Fat skatole levels can be limited by rearing pigs on slatted floors rather than on concrete, by using wet instead of dry feeding, by keeping pigs clean, by allowing them unlimited access to drinking water (Kjeldsen, 1993; Hansen et al., 1994). Wet feeding of boars on a low protein diet with virginiamycin as growth enhancer in fully slatted pens reduced the level of boar taint (Allen et al., 1997). Claus et al. (1994) demonstrated that feeding pigs a mixture of inuline and bicarbonate during a few days before slaughter results in a sharp reduction in fat skatole levels. A number of feedstuffs containing high amounts of fermentable carbohydrates can be incorporated in the diets, resulting in a decrease in skatole levels (Jensen et al., 1995, 1997; Andersson et al., 1997). The addition of zinc bacitracin (Hansen et al., 1997) or zeolite (Baltic et al., 1997) to the diet is effective in reducing fat skatole levels. Finally, withholding feed on the evening prior to slaughter has been shown to reduce fat skatole levels (Maribo, 1992; Kjeldsen, 1993).

Provided that the existence of a major gene controlling fat skatole levels (Lundström and Malmfors; 1993) is confirmed, it would be theoretically possible to select pigs against skatole. However, because this gene is not always expressed phenotypically, the possibility to select pigs directly on fat skatole levels may be not realistic.

Reduction of androstenone levels

The heritability of fat androstenone content is very high (see above). However, a selection against androstenone is likely to result in a decrease in the production of androgens and oestrogens and, thus, to have a negative effect on performance and sexual maturation. Indeed, Willeke et al. (1987) observed a delayed puberty in the gilts of a "low androstenone" line. Selecting against androstenone without any negative impact on sexual maturation is possible by using a selection index associating androstenone and either testis (Sellier and Bonneau, 1988) or bulbo-urethral gland (Sellier et al., 1997) development. However, although a selection against androstenone is biologically feasible, it is probably not realistic in practice if one were to use the selection criteria used in the above mentioned experiments. Taking into account the existence of a major gene controlling fat androstenone level (Fouilloux et al., 1997) and of a genetic linkage with markers on chromosome 7 (Bidanel et al., 1997), the development of a molecular probe for the gene and/or the possibility to use marker-assisted selection can now be envisaged.

A number of studies have investigated the possibility to immunise entire male pigs against androstenone (Shenoy et al., 1982; Williamson and Patterson, 1982; Williamson et al., 1985) or immediate precursors of androstenone (Brooks et al., 1986). If successful, the procedure would result in a reduction of androstenone without any negative effect on androgens and oestrogens. Unfortunately, the results have been quite inconsistent and, even in the best cases, the obtained reduction in fat androstenone was not sufficient.

Reduction of both compounds

Late castration of entire male pigs, at the end of the fattening period, would enable to get rid of androstenone and skatole and still benefit from the anabolic effects of androgens and oestrogens during most of the productive life of the animal. Indeed it has been demonstrated that castrating pigs two or three weeks before slaughter is sufficient for androstenone content in fat to decrease to levels similar to those observed in castrates and gilts (Claus, 1976; Bonneau et al., 1982). However, surgical castration cannot be used in practice. Active immunisation of entire male pigs against LHRH (Luteinising Hormone-Releasing Hormone, which regulates LH and steroid production ; LHRH is also named GnRH for Gonadotropin-Releasing Hormone) results in a sharp reduction in fat androstenone contents (Caraty and Bonneau, 1986; Meloen et al., 1994; Oonk et al., 1995; Manns and Robbins, 1997). The most recent studies have led to vaccines and vaccination schedules which can be envisaged in practice (Bonneau et al., 1994; Hennessy et al., 1995, 1997). They have also demonstrated that, as expected, immunocastration also results in a reduction of fat skatole contents (Hennessy et al., 1995, 1997).

In conclusion, a proper control of the environment and of feeding may reduce fat skatole levels substantially. Immunocastration can be used to control the levels of both skatole and androstenone and the most recent Australian studies (Hennessy et al., 1997) have demonstrated that it can be used efficiently in farm conditions. Whether or not the technique is commercially viable in EU economic conditions remains to be determined. However, the main problem might be the acceptability of the technique by the general public. One may have some day to choose between one of the three following solutions, none of them being fully satisfactory: i) accept to eat tainted meat, ii) accept castration as it is now, with the associated suffering for the animals, iii) accept immunocastration. On the long range, selection against skatole/androstenone may be a more readily acceptable way of dealing with the boar taint problem. However, there is still a long way to go before this can be achieved.

Assessment of boar taint on the slaughter line

The existence of quick, cheap and reliable methods for the assessment of boar taint on the slaughter line would enable to sort the carcasses according to boar taint.

A rapid spectrophotometric method for the measurement of skatole has been developed in Denmark (Mortensen and Sorensen, 1984). However it is quite expensive, it can deal with no more than 180 samples per hour, and it measures only one of the involved compounds. Although important improvements have been made, which make the measurement of androstenone (Claus et al., 1988, 1997) or total 16-androstenes (Squires, 1990) easier and quicker, there is still a long way to go before an industrial method can be available.

New technologies based on gas sensors (Van Dijk, 1995; Berdagué et al., 1995) or pyrolysis-mass spectrometry (Berdagué et al., 1996) are currently under investigation in a number of laboratories. According to recent results, artificial noses are well capable of simulating the response of a laboratory panel to boar taint (Annor-Frempong et al., 1997). Further studies are needed to develop quicker, more sensitive and more robust sensors and to assess the feasibility of the technique in industrial conditions.

Use of tainted meat in processed products

The beneficial effects of processing on the acceptability of tainted meat have been demonstrated in a number of studies (e.g. Williams et al., 1963; Pearson et al., 1971; Walstra, 1974; Bonneau et al., 1979). A proportion of the androstenone stored in fat disappears during processing (Bonneau et al., 1980) and the threshold for perception may be higher in processed products, especially for those which are consumed at room temperature (Moerman and Walstra, 1978; Desmoulin et al., 1982). Moreover, in such products as sausages, tainted meat can be mixed with untainted one, thus decreasing the final concentration of malodorous compounds. Lastly, in some products, unpleasant odours or flavours can be masked with spices. Tainted meat can therefore be used through processing. However, the exact conditions in which tainted meat can be used needs to be studied individually for each of the variety of products prepared from pork meat (McCauley et al., 1997).

CONCLUSIONS

Although there are numerous advantages to the use of entire males for pig meat production, there is still much reluctance in most EU countries to discontinue castration of young male piglets, mostly because of the boar taint problem. The most recent results from an international study involving 7 EU countries have shown that boar taint is a real issue since the proportion of consumers that are dissatisfied for odour or flavour is significantly higher with entire male than with gilt pork. However, it may be envisaged that the animal right issue can result someday in regulations prohibiting surgical castration of piglets unless it is performed by a veterinary surgeon under anaesthesia. For reasons of cost and feasibility, this would force to discontinue castration of males in pig production. The pig meat industry would then be in trouble unless a satisfactory solution is found to the boar taint problem.

There is no single solution to this problem that can be solved only with an integrated approach associating actions taken at all three levels of animal production, slaughter and processing. On the short range, immunocastration may offer a viable way for a drastic reduction of the incidence of boar taint in entire male pig populations. On the long range, selection may be cheaper and more readily acceptable. Artificial noses and related techniques offer interesting possibilities for the assessment of boar taint on the slaughter line, however further developments are needed in order to determine whether they can be used in industrial conditions. Tainted meat can be used through processing, however specific studies have to be conducted for each of the many products that can be processed from pig meat.

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