Quantitative genetic opportunities to ban castration

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Introduction

Male pigs are castrated in most parts of the world to prevent the production of pork with an unpleasant odour called 'boar taint'. However, there is a growing welfare concern in the European society against this practice mainly because of the pain, and suffering of the young piglets. The practice is also undesirable from pig production perspective. The pig farmers also have great dislike for castration not only because of welfare concerns and uncomfortable labour but also because it is a threat to the health of piglets. Furthermore, the practice is also not desirable from economic point of view as pork production from castrated males is 5-12% less efficient than from entire males. However, if castration is stopped pork from some entire males could have boar taint. Hence pork from any entire male is considered full of risk and is completely unacceptable by most pork processors.

Boar taint is a penetrating unpleasant odour (and taste) often described as 'animal', 'urine', 'faecal' and/or 'sweat' like odour. It is especially prominent after the meat is heated. Boar taint can be largely (> 60%) attributed to three compounds, namely androstenone, skatole and indole (Bonneau et al., 2000; Inghild et al., 2005, Zamaratskaia and Squires, 2009). Androstenone is a male sex pheromone which promotes sexual behaviour in female pigs. Levels of androstenone increase at puberty along with other testicular steroids (Zamaratskaia et al., 2004). It is associated with a urine and perspiration odour. Skatole is produced by microbial degradation of the amino acid tryptophan in the lower gut. It is associated with naphthalene and faecal odour (Vold, 1970; Walstra and Maarse, 1970). Indole is also synthesized in the large intestine from the same precursor tryptophan and is therefore considered to be related to skatole (Jensen and Jensen, 1998). Indole has been implicated in the development of boar taint, although to a much lesser degree than androstenone and skatole (Moss and Trimble, 1988). A higher concentration of androstenone results in reduced breakdown of skatole. It is therefore necessary to reduce the levels of both these compounds to eliminate boar taint from pork in commercial pig production.

There are significant genetic differences between existing breeds or lines and heritabilities boar taint compounds are relatively high ranging from 0.25 to 0.87 with an average of 0.56 (Sellier,1998). However, previous attempts of traditional selection against the major boar taint compounds such as androstenone have raised concerns with respect to male fertility and reproductive performance of sows due to the lower production of androgens and estrogens (Willeke et al., 1987; Sellier et al., 2000; Zamaratskaia and Squires, 2009). This study evaluates if genetic selection against the boar taint compounds will favourably or adversely affect a) finishing and meat quality traits b) male fertility in terms of semen quality and quantity and c) female reproduction or sow productivity. In addition the study also examines if the quantitative selection against boar taint compounds will actually have a significant effect on the reduction or boar taint from entire males in the slaughter houses or the kitchen tables of the pork consumers. An attempt is made to respond to these important questions through estimates of genetic correlations and expected effects of quantitative selection against the boar taint compounds.

Material and Methods

Boar taint compounds

Fat samples from the neck region at slaughter were collected from 2,139 purebred entire males of 3 purebred boar lines and males of crosses of these boar lines with F1 sows (TOPIGS breeding company, Vught, The Netherlands). The samples were then analysed by HLPC for androstenone, skatole and indole. For androstenone, a fat extraction was done on the fat samples as described by Tombola et al. (1997). Thereafter, androstenone concentrations in liquid fat were estimated by time-resolved fluoroimmunoassay. Skatole and indole were extracted from the fat sample using a mixture of methanol and hexane at 40°C in an ultrasonic bath. Skatole and indole were separated by HPLC on a reversed phase column. Fluorescence was measured at 285 nm and 340 nm at CCL B.V., Veghel, The Netherlands.

Androstenone and skatole were log-transformed (ln-androstenone, ln-skatole) as they were not normally distributed. Heritabilities, genetic correlations and breeding values were estimated using ASReml (version 2.0, Gilmour et al., 2006).

Finishing and meat quality traits

The finishing data from 31,964 pigs were used. These pigs belonged to 4 purebred boar lines (Pietrain, Large White and Duroc background) and to 5 different crosses of these boar lines with F1 sows. Pedigree information was available on about five generations of parents.

During the performance test, animals were weighed individually at the start of the testing period at about 25kg. The performance test ended after 16 weeks at about 175 days of age and individual live weight as well as ultrasonic backfat thickness was recorded. Culls were slaughtered one or two days after the end of the performance test. About 50% of the 20% selected animals were still culled as a result of negative AI ability scores, 45 days after the end of the performance test. These animals were also included in the dataset.

The pigs were slaughtered at an average live weight of about 120 kg. At slaughter, hot carcass weight (HCW) was recorded along with fat depth and muscle depth using the Hennessy Grading Probe. Meat quality measurements were taken on loin samples 24 hours after slaughter.

Genetic correlations between finishing traits and boar taint compounds were estimated through bi-variate analyses using ASREML 2.0 (Gilmour et al., 2006).

Male fertility

Semen characteristics were measured on boars from three sire lines (N=207 sires) and one dam line (N=112 sires). These characteristics included measurements on semen quality and quantity.

The relationship between the phenotypic measurements on semen characteristics and EBVs for boar taint compounds was evaluated with Pearson correlation coefficients and standard errors, using SAS (Version 8).

Sow productivity

Estimated breeding values of pigs from three sire and three dam lines were used, in total >200,000 litter records. The EBVs were available for sow productivity traits as well as boar taint compounds. At first, simple correlations between breeding values were calculated. The correlations were then adjusted using accuracies of the EBVs to calculate approximate genetic correlations closer to the true genetic correlations, according to the method of Calo et al., (1973).

Results and discussion

Prevention of castration will require a significant reduction in androstenone and skatole to such levels that there is no boar taint in the pork from entire males or better the pork is acceptable by processors and consumers. At the same time, it is also very important for the pork producers to keep up the genetic progress in other economically important traits as much as possible and relevant. Genetic selection against boar taint that will adversely affect feed efficiency, meat quality, male fertility and/or sow productivity is only acceptable if this can be balanced in a economical and sustainable way. Therefore relationships between the boar taint compounds with these traits were evaluated.

Genetic correlations

The genetic correlations between boar taint compounds and finishing traits are given in Table 1. The correlation of daily gain with androstenone was smaller but positive while that with skatole was slightly higher and negative, suggesting a possibility of some reduction in daily gain through selection against androstenone while improvement through selection against skatole. All other correlations except the one between skatole and meat colour were small and non-significant (P>0.01).

Table 1: Genetic correlations between boar taint compounds and finishing traits

	Androstenone	Skatole
Daily gain	0.19	**-0.33**
Backfat (HGP grading probe)	0.26	-0.01
Japanese Colour scale	-0.05	**0.42**
Drip loss %	0.09	0.11
Loin Marbling score	0.04	0.15

Correlations in bold are significantly (P<0.01) different from zero

The relationship between boar taint compounds and male fertility was evaluated through correlations between the EBVs for boar taint compounds and phenotypic measurements of semen quality and quantity (Table 2). Most of the correlations were non significant (P>0.01) except for the one between skatole and motility after one day. The results indicate no negative effects of reducing the levels of boar taint compounds, rather some possible improvement in motility after one day. In earlier studies, Sellier and Bonneau (1988) and Willeke and Pirchner (1989) reported negative effects of selection against androstenone on growth performance and onset of puberty. Those results could not be confirmed in this investigation.

There is a growing concern about any possible negative effects on sow productivity associated with reduction in the levels of androstenone and skatole. The relationships with sow productivity traits were evaluated through correlations between EBVs adjusted for different levels of accuracies. The estimates given in Table 3, show large differences between the lines with respect to the magnitudes and signs of the correlations, so much so, that it is hard to derive reasonable conclusions from these estimates.

Table 2: Correlations between EBVs for boar taint compounds and semen characteristics

Phenotype	N	EBV Androstenone	EBV Skatole
Volume	271	-0.04	0.09
Concentration	271	-0.02	-0.08
Av. sperm cells in ejaculate	271	-0.08	0.03
Primary defects	269	0.06	-0.09
Secondary defects	269	-0.08	-0.07
Motility in first 24 hours	201	0.03	-0.13
Motility after 1 day	192	-0.04	**-0.18**

Correlation in bold is significantly (P<0.01) different from zero.

Table 3: Approximate genetic correlations between boar taint compounds and reproduction traits derived from correlations between EBVs

EBV	Line	EBV Androstenone	EBV Skatole
Number total born	1	-0.35	0.28
	2	0.10	-0.03
	3	-0.03	-0.07
	4	-0.05	-0.15
	5	0.22	0.41
	6	-0.16	-0.02
Piglet vitality	1	-0.01	-0.06
	2	0.01	0.04
	3	0.22	0.14
	4	-0.14	-0.24
	5	-0.27	0.59
	6	0.22	-0.11

Quantitative selection against boar taint compounds

A simple quantitative selection index considering the two main boar taint compounds, androstenone and skatole, and correlations between them was used to evaluate practical effects of selection on finishing, male fertility and sow productivity traits. The index combined the EBVs for androstenone and skatole as follows:

BTT = 5.3 x EBV_Androstenone + 8.7 x EBV_Skatole

Boars were then divided into groups with high, low and medium values for boar taint index considering 10% selection intensity. Comparison of least-squares means (Table 4) suggest that selection using such an index will be very effective leading significant differences between low, medium and high groups with respect to both androstenone and skatole.

As indicated earlier by the genetic correlations (Table 1), there were significant differences among the three groups with respect to daily gain, feed intake and feed conversion ratio. Further, the feed conversion ratio for the High BTT group was poorest suggesting that culling of the top 10% boars with the highest values for boar taint index will actually affect the feed conversion ratio favourably. It is well known to pork producers that entire males have a better feed conversion and are therefore more desirable for efficiency of production.

Feed conversion and lean meat production of entire males is 5-12% higher than in castrates. Therefore, above results are in agreement with most of the earlier studies.

Table 4: Effect of selection using boar taint index on finishing traits in the sire lines

EBVs (LSMEANS)	Low BTT (N=24)	Med BTT (N=162)	High BTT (N=21)	Prob.
Boar taint index	-10.22	2.21	17.29	0.00
Androstenone	-0.44	0.11	0.75	0.00
Skatole	-0.10	-0.01	0.15	0.00
Test daily gain	12.37	46.80	51.73	0.00
Average backfat US	-0.29	-0.39	-0.38	0.83
Daily Feed intake	-22.05	68.15	134.88	0.00
Feed conversion ratio	-0.06	-0.02	0.05	0.00
Intra Muscular Fat %	0.09	0.05	0.15	0.17
Drip loss %	-0.11	-0.15	-0.15	0.77

In case of the traits of male fertility, there were no significant differences between the low, medium and high BTT index groups (Table 5). Therefore, selection against boar taint compounds is not expected to have any adverse effects on male fertility.

Table 5: Effect of selection using boar taint index on semen characteristics in the sire lines

EBVs (LSMEANS)	Low BTT (N=24)	Med BTT (N=162)	High BTT (N=21)	Prob.
Volume	315.10	295.08	30.08	0.57
Concentration	256.69	269.43	268.32	0.77
Av. sperm cells in ejaculate	79638	75437	77078	0.63
Primary defects	4.90	6.27	5.36	0.33
Secondary defects	8.23	8.57	9.19	0.82
Motility in first 24 hours	77.78	78.71	76.24	0.42
Motility after 1 day	7.61	71.42	68.91	0.52

The effect of selection on sow productivity traits was examined using the data on dam line boars (Table 6). The number of observations within the low, medium and high BTT index groups was lower than the sire lines and especially low in the high/low groups. In spite of this, the least-squares mean were still significantly different with respect to androstenone, skatole and the boar taint index. There were no significant differences between the groups with respect to age at first mating, total number of piglets born, weaning to conception interval and gestation length. The results show slightly higher mortality through selection against the high group. Partly, this could be due to small size of the high and low groups. They should be verified with a larger dataset.

Table 6: Effect of selection using boar taint index on sow productivity traits in the dam line

EBVs (LSMEANS)	Low BTT (N=11)	Med BTT (N=90)	High BTT (N=11)	Prob.
Boar taint index	-9.53	-0.66	9.17	0.00
Androstenone	-0.42	-0.04	0.37	0.00
Skatole	-0.06	0.01	0.15	0.00
Age at first mating	6.70	2.28	1.42	0.07
Number Total Born	-0.39	-0.44	-0.68	0.74
Litter mortality	0.08	0.05	-2.65	0.00
Weaning to oestrus interval	3.87	0.55	0.61	0.23
Gestation length	0.21	0.09	0.02	0.77

The real/perceived effect for pork processors and pork consumers

The above results show strong possibilities of reducing the levels of boar taint compounds through genetic selection and associated effects. However, one of the important questions remains if the reduction in the boar taint compounds will also lead to an actual reduction in boar taint such that the pork from entire males is accepted by the processors and consumers. The pork processors typically rely on a hot wire test in the slaughter plants to differentiate carcasses with and without boar taint. Genetic correlation between the levels of the boar taint compounds in fat samples of the neck region and the results of the hotwire test in pork samples was 0.67 (Knol et. al 2010). This correlation is reasonably high suggesting good opportunities for effective selection on results of the hotwire test. However, the boar taint odour is particularly prominent when the pork is heated for cooking (Vestergaard, et al. 2006). Therefore it is not surprising that in a consumer test where the pork prepared by a professional cook and after that presented to consumers, the correlation between the hot wire test results and the boar taint evaluation by consumers was only 0.10 (Knol et al. 2010). In fact, there is no clear relation between boar taint and consumer perception if we compare fat and meat samples.

Conclusions

Recent studies have already revealed possibilities of strong selection against androstenone and skatole to reduce the concentrations of compounds below the thresholds for boar taint in about four generations (Merks et al., 2009). This study further investigated the possible associated effects of such a selection on traits of importance for pork production.
The selection index considered in this study included the boar taint compounds only. This can be refined further by including other economically important traits, commonly used in selection of sire and dam lines. The results show that quantitative selection on an appropriately designed index may reduce feed intake and daily gain and thereby improve feed conversion. Selection against boar taint is not expected to have any adverse effect on male fertility as evaluated by the traits of semen quality and quantity. However, for female fertility there are large differences between different lines with respect to correlations between traits of female fertility and boar taint compounds. Probably, selection in commercial dam lines for improved female fertility indirectly affected the pathways along which boar taint is developed differently per line/breed dependent on breeding goal and selection intensity on different traits.
These results suggest that quantitative selection against the boar taint compounds can be a real possibility such that the need for castration can be eliminated without compromising too much in the efficiency of pork production.

Acknowledgements

We are grateful to TOPIGS for providing the data of non-castrated boars and tissue sampling. This research project has been co-financed by the European Commission, within the 6th Framework Programme, contract No. FOOD-CT-2006-016250 ("SABRE"). The text represents the authors' views and does not necessarily represent a position of the Commission who will not be liable for the use made of such information.

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