Breed Differences in Boar Taint: Relationship Between Tissue Levels of Boar Taint Compounds and Sensory Analysis of Taint

JinLiang Xue*,2, Gary D. Dial*, Elizabeth E. Holton†, Zata Vickers‡, E. James Squires§, Yanping Lou§, Daniel Godbout§, and Nathalie Morel§

Departments of *Clinical and Population Sciences and †Food Science and Nutrition, University of Minnesota, St. Paul 55108; ‡Department of Animal and Poultry Science, University of Guelph, Guelph, Ontario, Canada; and §GenetiPorc, St-Bernard, Beauce, Quebec, Canada

ABSTRACT: A total of 228 intact male pigs from Duroc, Hampshire, Landrace, and Yorkshire breeds were used in the experiment. Samples of salivary gland and backfat were collected at slaughter for colorimetric assay of salivary and fat 16-androstene levels and fat skatole levels. Fat samples also were tested by a sensory panel using an R-index technique for detecting the presence of boar taint. The proportion of tainted carcasses determined by the sensory panel was 5.0% for androstenone and 11.4% for skatole, with a combined total of 15.0% tainted from either source. Sensory analysis of taint showed a lower proportion (P < .05) of tainted carcasses in Hampshire, with no difference in taint across the other three breeds. Analysis of taint compounds indicated that overall 14.5% of pigs had salivary gland 16-androstene levels and 20.9% had fat 16-androstene levels above acceptable limits. There was a higher (P < .05) proportion of Duroc pigs above the threshold levels for 16-androstenes in both salivary gland and fat. Landrace pigs had the lowest (P < .05) average tissue concentrations of steroids and skatole. Across breeds, only 1.8% of pigs had fat skatole concentrations above .25 ppm, which has been suggested as threshold levels of skatole for taint. The canonical correlation coefficient between fat compound levels and the R-indices of fat 16-androstenes and skatole was .40 (P < .001). Our results indicate breed differences in tissue levels of taint compounds and in taint assessed by a sensory panel. Levels of 16-androsterone steroids were highly associated with taint, but more pigs had measured levels above the threshold than those identified as tainted by sensory analysis. Levels of fat skatole were low overall and did not account for all the pigs judged as tainted from skatole by sensory analysis.

Key Words: Boar Taint, Breeds, Androstenone, Skatole, 16-Androstenes, Sensory Evaluation

Introduction

Raising intact male pigs for market rather than castrating them neonatally is potentially one of the simplest methods of improving carcass lean percentage (Xue et al., 1995). Despite the economic advantages, the rearing of intact males for meat, however, is not without commercial concern. The main problem with market boar production is the occurrence of "boar taint," an unpleasant odor in the meat from some male pigs (Patterson, 1968). The 16-androsterone steroids (mainly 5α-androstenone) and skatole are considered to be the two primary sources of boar taint (Patterson, 1968; Vold, 1970). Because tainted pork potentially will offend consumers, carcasses contaminated with taint need to be identified and prevented from entering the fresh meat market. Thus, chemical tests have been developed for use in the detection of boar taint.

Threshold values above which carcasses are considered tainted have been proposed, 1.0 ppm for fat 5α-androstenone measured by immunoassay, 50 ppm for 16-androsterone steroids in salivary gland as measured by a colorimetric assay, and .20 to .25 ppm for fat skatole (Desmoulin and Bonneau, 1982; Mortensen et al., 1986; Babol et al., 1996). For these threshold values to be commercially useful in identifying tainted carcasses, they must accurately distinguish tainted from untainted carcasses while minimizing the proportion of untainted carcasses incorrectly identified as being tainted.

Piemâtre boars have higher concentrations of 5α-androstenone than Belgian Landrace boars (Bon-
neau et al., 1979). Androstenone concentrations in German Edelschwein males (a Large White-type breed) are higher than those of German Landrace males (Falkenberg and Blödow, 1981). These findings suggest genetic differences in the tissue levels of the compounds associated with boar taint. Genetic influences on fat content of skatole have also been proposed, but they have not yet been defined (Lundström et al., 1994). Thus, the reliability of using 16-androstenes or 5α-androstenone alone to identify tainted carcasses is to be determined.

This study was designed to determine genetic differences in tissue concentrations of 16-androstenes and skatole in breeds used commonly in North America, and the relative frequencies of boar taint as determined by a sensory panel and chemical analyses.

Materials and Methods

Animals and Samples

Two hundred twenty-eight male pigs from four breeds of Duroc (D), Hampshire (H), Landrace (L), and Yorkshire (Y) were used in the experiment. The pigs were reared on four farms by the same genetic company. The facilities, diets, and management of the four farms were similar. Animals were transported to a slaughterhouse upon reaching 100.4 ± .4 kg body weight. Individual live and carcass weights were obtained at slaughter. Backfat and loin depth at the 10th rib, 6 cm from the midline of the back, were measured with the Hennessey grading probe model GP2 (Hennessey Grading Systems Ltd, Auckland, New Zealand). The percentage of yield was calculated from live weight and carcass weight. The percentage of lean was based on the equation % Lean = 58.7716 − .6676 fat depth (mm) + .0735 loin depth (mm) + .0069 fat depth² (mm). The bulbourethral (Cowper) gland was excised and trimmed of non-glandular tissue before weights were obtained. The lengths of glands were measured using a caliper. Samples of submaxillary salivary gland and backfat at the area of the shoulder were collected, placed individually into plastic bags, and frozen at −20°C for subsequent analyses.

Colorimetric Assay of Steroids and Skatole

Salivary glands and backfat were assayed for concentrations of 16-androstene steroids using a colorimetric method described previously (Xue et al., 1994). All samples were extracted and assayed in duplicate. Tissue samples (3 g of fat or 1 g of salivary gland) were extracted with methanol before the 16-androstene steroids were concentrated on C18 cartridges. Cholesterol was removed from the fat extracts, but not the salivary gland extracts, using a digitonin column. This assay measures total 16-androstenes and steroids in tissue samples. Results are expressed as 16-androstene steroid equivalents, using 5α-androstenedione as a standard for salivary gland and 5α-androstenone as a standard for fat. Concentrations of skatole in fat were analyzed in duplicate using the Danish colorimetric method (Mortensen and Sørensen, 1984). This method is not entirely specific for skatole, so results are expressed as skatole equivalents.

Sensory Evaluation of Pork Fat Taint

Fat samples were tested for the presence of boar taint by a sensory panel. Ten judges participated in the sensory test. Before the onset, 25 subjects were screened for their ability to identify 5α-androstenone. They were supplied with 10 bottles: 5 contained androstenone and 5 contained no androstenone. To be a qualified judge, subjects had to correctly identify at least 4 of the 5 bottles containing androstenone. Bottles with androstenone contained a cotton ball with 1.2 mL of .7 ppm androstenone in deodorized mineral oil; those without androstenone contained 1 mL of deodorized mineral oil. Thirteen of the 25 subjects were qualified, and 10 of those 13 participated in the test. Before testing, the judges also were familiarized with the odor of skatole by smelling bottles that contained a cotton ball with .2 mL of 5 ppm skatole. They were not screened for an inability to smell skatole.

Frozen fat samples were cut into approximately 2-g pieces and placed onto a coded 35 × 10-mm plastic Petri dish. Samples were kept frozen until immediately before serving. Before serving, a sample was removed from the freezer, placed in the center of a 700-W commercial microwave oven, and heated on high power for 40 s. Two grams of pork fat obtained from center cut loin chops purchased at a local grocery store were used as controls. Judges evaluated the heated fat samples in tasting booths. They evaluated the freshly cooked fat samples by opening the Petri dish and sniffing as soon as possible after the samples had been taken out of the microwave oven. Based on that sniff, the judge indicated the presence or absence of an androstenone odor using an R-index technique (O’Mahony, 1988). The judges could make one of four responses for androstenone: P (the odor was definitely present), P? (the odor was present but they were not sure), N? (the odor was not present but they were not sure), or N (the odor was definitely not present). The judges also made one of the four responses for skatole. The judges had access to reference bottles containing skatole and androstenone during the testing.

The judges evaluated about 20 fat samples during a test session. The order in which the fat samples were served was randomized. The judges evaluated the presence/absence of both skatole and androstenone from the single sniff. They waited for 30 to 60 s
between samples. One control fat sample was presented to each judge during each session. Neither judges nor experimenters were aware of the concentrations of 16-androstenes or skatole in the samples during the sensory tests. Testing sessions were separated by at least 4 h and no judge participated in more than two sessions during a single day.

**Statistical Analysis**

The general linear model (GLM) procedure was used to analyze carcass-related traits (SAS, 1988). Farm and breed were considered as main effects in statistical models. Age was initially considered a covariate in statistical models for body weight, carcass weight, yield, fat thickness, loin depth, and percentage of lean. Because it was found to be not significant (from P > .07 to P > .99) in all models, age subsequently was eliminated from models. Body weight was included in models to adjust for its effects on yield. Carcass weight was included in models to adjust for its effect on fat thickness and loin depth. Neither body weight (P > .21) nor carcass weight (P > .06) influenced percentage of lean; therefore, weights were excluded from models estimating percentage of lean.

Salivary and fat concentrations of 16-androstenes and fat levels of skatole in fat were analyzed using the GLM procedure (SAS, 1988). Farm and breed were set as categorical variables. Tissue concentrations of steroids and skatole were not influenced by age (P > .64), live weight at slaughter (P > .34), or carcass weight (P > .39). Therefore, the models ignored these variables.

R-indices of androstenone and skatole were calculated from the responses of P, P?, N?, and N over all judges for each sample (O’Mahony, 1988). The R-index computation requires an estimation of the noise level, that is, the responses of judges when a sample of fat not contaminated with taint was evaluated. Commercially purchased pork fat served within each test session was used as the noise level. Thus, the R-index value gives the probability of an experimental sample of pork fat rated as having more of a detectable odor like either androstenone or skatole than the control. Statistical treatment of the R-index values was conducted with a Rank Sums Test (O’Mahony, 1988), which produces a Z value. Z values greater than 1.645 are significant at a level of P < .05.

Canonical correlation analysis using the CANCORR procedure was used to determine the relationships between carcass-related traits and tissue concentrations of skatole and steroids (SAS, 1988). The analysis is a multivariate statistical method and is used to identify the associations between two groups of variables. The first set of variables used in correlations, called the first canonical variate, was the carcass-related traits: age at slaughter, carcass weight, length and weight of bulbourethral gland. The second set of variables, called the second canonical variate, was salivary gland concentrations of 16-androstenes and fat concentrations of 16-androstenes and skatole. Prior to conducting the CANCORR procedure, multivariate normal distributions were examined using Q-Q plots for marginal distributions of salivary gland 16-androstenes, fat 16-androstenes, and skatole concentrations (Johnson and Wichern, 1992). Pairs of points of sample quantiles vs the quantiles for 16-androstenes in salivary gland and fat were found to lie very nearly along a straight line, indicating that the normality assumption was tenable. A few observations of fat skatole concentrations, which either were equal to 0 or greater than .36 ppm, did not fall on a straight line. The 0 ppm problem was corrected using the average of the quantiles of the observations, because the observations had the same value. The three observations of skatole concentrations above .36 ppm were omitted in the correlation analysis because they seemed to be outliers (lower quartile = .069, median = .096, upper quartile = .117 ppm for skatole concentrations). The CANCORR procedure also was used to estimate the relationships between adipose concentrations of 16-androstenes and skatole, and R-indices of androstenone and skatole (SAS, 1988). The two sets of variables used in the correlations were fat concentrations of 16-androstenes and skatole (the first canonical variate) and R-indices of androstenone and skatole (the second canonical variate). Multiple regression analyses (ALL and VREG) were requested following the CANCORR statement.

The proportions of pigs with concentrations of 16-androstenes and skatole above threshold levels (Desmoulin and Bonneau, 1982; Mortensen et al., 1986; Babol et al., 1996) were calculated. The cutoff level for 16-androstone steroids was estimated from the correlation between levels of 16-androstone steroids in fat and salivary gland and checked by comparison with the sensory data. The proportions of the R-indices of androstenone and skatole above the P < .05 significance level were also calculated. Logistic regression was applied by the categorical data modeling (CATMOD) procedure for both tissue concentrations and R-indices of androstenone and skatole above (set as 1) or below (set as 0) cutoff levels (SAS, 1988). Farm and breed were included in the models. The CONTRAST statement was conducted to request comparisons among the breeds.

**Results**

There were no differences (P > .05) in age and live weight at slaughter, backfat, loin depth, and percentage of lean among the D, H, L, and Y breeds, but carcass weight, and thus yield, varied (P < .05) among the four breeds (Table 1). Lengths and weights of bulbourethral glands differed among the
CHEMICAL AND SENSORY TESTS OF BOAR T A I N T 2173

Table 1. Carcass-related traits by breed of boars (least squares means ± SE)

<table>
<thead>
<tr>
<th>Breed</th>
<th>Duroc</th>
<th>Hampshire</th>
<th>Landrace</th>
<th>Yorkshire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, d</td>
<td>72</td>
<td>8</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>Body wt, kg</td>
<td>172.5 ± 2.8</td>
<td>181.9 ± 5.3</td>
<td>168.7 ± 2.9</td>
<td>169.5 ± 2.4</td>
</tr>
<tr>
<td>Carcass wt, kg</td>
<td>100.8 ± 1.3</td>
<td>104.6 ± 2.4</td>
<td>98.0 ± 1.3</td>
<td>102.0 ± 1.1</td>
</tr>
<tr>
<td>Yield, %</td>
<td>77.9 ± .4</td>
<td>77.1 ± 1.0</td>
<td>75.8 ± .7</td>
<td>77.9 ± .5</td>
</tr>
<tr>
<td>Backfat, mm</td>
<td>14.0 ± .4</td>
<td>13.5 ± .9</td>
<td>14.1 ± .7</td>
<td>14.2 ± .5</td>
</tr>
<tr>
<td>Loin depth, mm</td>
<td>50.8 ± 1.3</td>
<td>49.1 ± 2.8</td>
<td>52.4 ± 2.1</td>
<td>51.0 ± 1.6</td>
</tr>
<tr>
<td>Lean, %</td>
<td>54.6 ± .2</td>
<td>54.6 ± .5</td>
<td>54.6 ± .4</td>
<td>54.5 ± .3</td>
</tr>
<tr>
<td>Bulbourethral gland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length, cm</td>
<td>11.0 ± .4</td>
<td>13.2 ± .8</td>
<td>10.6 ± .4</td>
<td>12.6 ± .3</td>
</tr>
<tr>
<td>Weight, g</td>
<td>95.0 ± 11.0</td>
<td>159.3 ± 21.2</td>
<td>110.0 ± 10.7</td>
<td>148.5 ± 9.6</td>
</tr>
</tbody>
</table>

Breed differences in concentrations of salivary gland (S.G.) 16-androstenes (1a), adipose 16-androstenes (1b), and adipose skatole (1c) (bars with different letters differ by at least P < .05. Lines represent SE).

Breeds (P < .001); H pigs had the largest glands. No farm effect was detected (P > .05) for any carcass-related trait except for age at slaughter.

Both breed and farm influenced (P < .05) concentrations of salivary and fat 16-androstenes and skatole. The L pigs had the lowest (P < .05) average tissue concentrations of steroids and skatole among the breeds (Figure 1). The H and D pigs had higher (P < .05) average concentrations of steroids than either Y or L pigs. The H and Y pigs had higher (P < .01) skatole levels than L pigs. Skatole levels of H pigs were greater (P < .05) than those of D pigs.

Three canonical correlation coefficients were obtained for carcass-related traits and tissue levels of compounds. The first canonical correlation between the carcass-related traits and the tissue concentrations of steroids and skatole was .41 (P < .001). The remaining two correlations were not significant (P > .50). Canonical variate coefficients for the first canonical correlation were as follows: the first estimated canonical variate = .18 age + .27 carcass weight + .35 bulbourethral gland length + .58 bulbourethral gland weight; the second estimated canonical variate = .54 salivary 16-androstenes + .56 fat 16-androstenes + .18 skatole. Correlations between original variables and the two canonical variates are shown in Table 2.

Of the carcass-related traits, weight of bulbourethral gland had the highest canonical coefficient (.58). Also, gland weight had the highest correlations to the two canonical variates (.93 and .39). Of the tissue concentrations of taint compounds, fat 16-androstenes had the largest canonical coefficient (.56) and the highest correlations to the two canonical variates (.36 and .86).

The R-index of .72 was determined as a cutoff value for both fat 16-androstenes and skatole, based on their

Table 2. Correlations between original variables and canonical variables

<table>
<thead>
<tr>
<th>Original variables</th>
<th>Canonical variates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Age</td>
<td>.30</td>
</tr>
<tr>
<td>Carcass wt</td>
<td>.35</td>
</tr>
<tr>
<td>Bulbourethral gland length</td>
<td>.88</td>
</tr>
<tr>
<td>Bulbourethral gland wt</td>
<td>.93</td>
</tr>
<tr>
<td>Salivary 16-androstenes</td>
<td>.35</td>
</tr>
<tr>
<td>Fat 16-androstenes</td>
<td>.36</td>
</tr>
<tr>
<td>Skatole</td>
<td>.12</td>
</tr>
</tbody>
</table>
Table 3. Proportions of pigs having tissue concentrations and R-indices of androstenone and skatole above cutoff values

<table>
<thead>
<tr>
<th>Breed</th>
<th>Salivary gland 16-androstenes</th>
<th>Fat 16-androstenes</th>
<th>Skatole</th>
<th>Total</th>
<th>Androstenone</th>
<th>Skatole</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n %</td>
<td>n %</td>
<td>n %</td>
<td>n %</td>
<td>n %</td>
<td>n %</td>
<td>n %</td>
</tr>
<tr>
<td>Duroc</td>
<td>64 15 23.4d</td>
<td>23 35.9d</td>
<td>1 1.6d</td>
<td>26 40.6d</td>
<td>7 10.9d</td>
<td>7 10.9d</td>
<td>13 20.3d</td>
</tr>
<tr>
<td>Hampshire</td>
<td>8 2 25.0d</td>
<td>5 62.5d</td>
<td>1 12.5d</td>
<td>5 62.5d</td>
<td>0 .0d</td>
<td>0 .0e</td>
<td>0 .0e</td>
</tr>
<tr>
<td>Landrace</td>
<td>74 5 5.4e</td>
<td>9 12.2e</td>
<td>0 .0e</td>
<td>10 13.5e</td>
<td>1 1.4e</td>
<td>7 9.5d</td>
<td>8 10.8d</td>
</tr>
<tr>
<td>Yorkshire</td>
<td>74 11 14.9de</td>
<td>9 12.2e</td>
<td>2 2.7d</td>
<td>17 23.0e</td>
<td>3 4.1de</td>
<td>11 14.9d</td>
<td>12 16.2d</td>
</tr>
<tr>
<td>Total</td>
<td>220 32 14.5</td>
<td>46 20.9</td>
<td>4 1.8</td>
<td>58 26.4</td>
<td>11 5.0</td>
<td>25 11.4</td>
<td>33 15.0</td>
</tr>
</tbody>
</table>

Z values of 1.645 (P < .05). That is, an R-index greater than .72 indicates that pork fat samples were judged as tainted. Eleven pigs had an R-index above .72 for androstenone and 25 pigs had an R-index above .72 for skatole. Based on a suggested cutoff value of 50 ppm of 16-androstenes in salivary gland, a cutoff value of 1.5 ppm for 16-androstenes in fat was calculated by regression analysis. The R-index values for skatole and androstenone obtained for the individual animals are plotted against the tissue levels of these compounds in Figure 2. Nine of the 11 pigs with an R-index of androstenone above .72 had levels of 16-androstenes in fat above 1.5 ppm. On the other hand, of the 25 pigs having the R-index of skatole above .72, only two had fat skatole levels above .25 ppm and only 3 had fat skatole levels above .20 ppm, suggesting that the tissue levels of skatole do not accurately reflect the incidence of skatole taint detected by the sensory panel. However, of the 25 pigs with an R-index of skatole above .72, 12 had fat 16-androstenes levels above 1.5 ppm and 5 had 16-androstenes in salivary gland above 50 ppm.

Table 3 gives the proportions of samples having R-indices of androstenone and skatole above .72, levels of salivary 16-androstenes above 50 ppm, levels of fat 16-androstenes above 1.5 ppm, and levels of skatole above .25 ppm. No farm effect on the proportion of samples having tissue concentrations of taint compounds and R-indices above the cutoff values was detected (P > .3). Across breeds, 20.9% of pigs had fat 16-androstenes concentrations above 1.5 ppm and 14.5% had salivary gland 16-androstenes above 50 ppm. The H and D breeds had higher (P < .05) proportions of pigs exceeding the cutoff levels for 16-androstenes in fat and salivary glands than L and Y breeds. However, the proportion of pigs with R-index for androstenone above the cutoff was lower than the...
percentage of pigs that had 16-androstenes in fat or salivary gland above threshold levels. On the other hand, more pigs were found to be tainted using the R-index of skatole than by analysis of fat skatole concentrations. In total, 11.4% of pigs were judged by the sensory panel as tainted from skatole whereas only 1.8% of pigs had skatole concentrations above .25 ppm and 3.2% had skatole levels above .20 ppm. The overall proportion of pigs tainted from either skatole or androstenone were 15.0% by sensory analysis and 26.4% by analysis of tissue levels of these taint compounds.

Two canonical correlation coefficients were obtained for tissue concentrations and R-indices of androstenone and skatole. The first canonical correlation between fat concentrations of 16-androstenes and skatole and R-indices of androstenone and skatole was .40 (P < .001). The second canonical correlation was not significant (P > .05). Canonical variate coefficients for the first canonical correlation were as follows: the first estimated canonical variate = .85 fat 16-androstene + .39 fat skatole; the second estimated canonical variate = .53 R-index of androstenone + .62 R-index of skatole. Correlations between original variables and the two canonical variates are presented in Table 4. Fat concentrations of 16-androstenes had a higher canonical variate coefficient (.85) and higher correlations to the canonical variates (.92 and .37) than skatole. However, the R-index of skatole had a higher canonical coefficient (.62) and higher correlations to the two canonical variates (.36 and .89) than androstenone. In regression analysis using the CANCORR procedure, the R-indices of both androstenone and skatole were affected (P < .001) by adipose concentrations of 16-androstenes. Fat concentrations of skatole affected (P < .008) the R-index of skatole but did not influence (P > .3) the R-index of androstenone. No interaction was detected between fat concentrations of 16-androstenes and skatole when data were further analyzed by GLM with farm and breed as categorical variables and with the R-indices of androstenone (P > .07) and skatole (P > .37) as response variables in the model. No farm effect was found for the R-indices of androstenone (P > .16) and skatole (P > .85). Breed influenced the R-index of androstenone (P < .05), but not that of skatole (P > .33).

Discussion

Differences in tissue concentrations of 16-androstenes were detected among the different breeds used in this study. The D and H breeds had higher concentrations of taint steroids in both the salivary glands and fat tissue and higher proportions of these breeds had steroid levels above the cutoff for taint than Y and L breeds. These findings are similar to those observed in an earlier Canadian study using the same genetic lines (Squires, 1992). They also support earlier observations of genetic differences in fat levels of androstenone between two European breeds (Bonneau et al., 1979). The absence of age, live weight, or carcass weight influences on tissue levels of taint steroids suggests that the genetic differences in tissue steroid content may be due to differing rates of sexual maturation. Genetic differences in age at puberty have been previously reported for D, H, L, Large White, and Y breeds (Christenson and Ford, 1979). Fat concentrations of androstenone were greater in Meishan boars from 6 to 33 kg BW than those of Large White boars from 100 to 116 kg BW (Prunier et al., 1987). The former breed reaches sexual maturity much earlier than the latter one (Xue, 1991). It is interesting, however, that in our study the bulbourethral glands were smallest in the Duroc pigs but the steroid levels were high in this breed.

The weight or length of bulbourethral glands was highly related to tissue levels of steroids, in particular fat concentrations of 16-androstenes. This suggests that measurements of bulbourethral glands may be a useful indicator of fat 16-androstenone content. In previous studies, correlation coefficients between bulbourethral gland length and fat androstenone content have been determined from .39 to .75 (Førland et al., 1980; Bonneau and Russell, 1985; Booth et al., 1986; Deng et al., 1992), which is consistent with our findings.

Fat concentrations of skatole were lower in L than in D, Y, and H pigs. These findings may contrast with those of Squires (1992), who observed that L pigs (.11 μg/g fat) had numerically, but not significantly, greater fat concentrations of skatole than D (.08 μg/g fat), H (.08 μg/g fat), and Y pigs (.10 μg/g fat). Workers in Denmark (Palmo and Pedersen, 1995) have also reported higher levels of skatole in Landrace pigs. Chen and coworkers (1993) found no differences in skatole concentrations between D and Y pigs. Skatole is produced in the large intestine by bacteria and levels of skatole in fat are influenced by environmental conditions (Wilkins, 1990) as well as genetic factors (Lundström et al., 1994). Therefore, skatole concentrations can vary between different studies. Fat skatole levels were low in the present study; only about 2.0% of pigs had skatole levels above .25 ppm.

| Table 4. Correlations between original variables and canonical variables |
|---------------------------|-----------------|
| Original variables        | Canonical variates |
|                          | 1               | 2               |
| Fat 16-androstenes        | .92             | .37             |
| Fat skatole               | .54             | .22             |
| R-index: androstenone     | .34             | .85             |
| R-index: skatole          | .36             | .89             |

Differences in tissue concentrations of 16-androstenes were detected among the different breeds used in this study. The D and H breeds had higher concentrations of taint steroids in both the salivary glands and fat tissue and higher proportions of these breeds had steroid levels above the cutoff for taint than Y and L breeds. These findings are similar to those observed in an earlier Canadian study using the same genetic lines (Squires, 1992). They also support earlier observations of genetic differences in fat levels of androstenone between two European breeds (Bonneau et al., 1979). The absence of age, live weight, or carcass weight influences on tissue levels of taint steroids suggests that the genetic differences in tissue steroid content may be due to differing rates of sexual maturation. Genetic differences in age at puberty have been previously reported for D, H, L, Large White, and Y breeds (Christenson and Ford, 1979). Fat concentrations of androstenone were greater in Meishan boars from 6 to 33 kg BW than those of Large White boars from 100 to 116 kg BW (Prunier et al., 1987). The former breed reaches sexual maturity much earlier than the latter one (Xue, 1991). It is interesting, however, that in our study the bulbourethral glands were smallest in the Duroc pigs but the steroid levels were high in this breed.

The weight or length of bulbourethral glands was highly related to tissue levels of steroids, in particular fat concentrations of 16-androstenes. This suggests that measurements of bulbourethral glands may be a useful indicator of fat 16-androstenone content. In previous studies, correlation coefficients between bulbourethral gland length and fat androstenone content have been determined from .39 to .75 (Førland et al., 1980; Bonneau and Russell, 1985; Booth et al., 1986; Deng et al., 1992), which is consistent with our findings.

Fat concentrations of skatole were lower in L than in D, Y, and H pigs. These findings may contrast with those of Squires (1992), who observed that L pigs (.11 μg/g fat) had numerically, but not significantly, greater fat concentrations of skatole than D (.08 μg/g fat), H (.08 μg/g fat), and Y pigs (.10 μg/g fat). Workers in Denmark (Palmo and Pedersen, 1995) have also reported higher levels of skatole in Landrace pigs. Chen and coworkers (1993) found no differences in skatole concentrations between D and Y pigs. Skatole is produced in the large intestine by bacteria and levels of skatole in fat are influenced by environmental conditions (Wilkins, 1990) as well as genetic factors (Lundström et al., 1994). Therefore, skatole concentrations can vary between different studies. Fat skatole levels were low in the present study; only about 2.0% of pigs had skatole levels above .25 ppm.
In a Canadian study (Squires, 1992), no pig was detected as having fat skatole level above the .25 ppm cutoff.

Approximately 26% of the pigs in the present study had at least one of the taint compounds above the cutoff levels. The proportion of pigs having salivary gland levels of 16-androstanes above the cutoff level was 14.5%. Squires (1992) observed 7% of pigs from the same breeds used in this study having salivary 16-androstene sterol levels above the cutoff. A similar proportion (20.9%) of the pigs in this study had fat 16-androstanes above the cutoff. High correlations between concentrations of salivary gland 16-androstanes and adipose 16-androstanes were observed in both the present and previous studies (Booth et al., 1986; Xue et al., 1994, 1995).

There was a notable lack of agreement between the proportion of carcasses having detectable skatole or androstenone as determined by the test panel and the proportion found to be above threshold levels for skatole or 16-androstenone steroids. In particular, a higher incidence of taint from skatole was found by sensory analysis than could be accounted for by tissue levels of skatole. It may be that high levels of 16-androstene steroids in some pigs influenced the assessment of skatole taint by the sensory panel. On the other hand, the incidence of taint by sensory analysis of androstenone was lower than what could be expected from analysis of tissue levels of 16-androstene steroids. The reason for the disagreement between panel and chemical tests is not known. Adjusting the cutoff levels for taint compounds or adjusting R-indices did not eliminate the disagreement in either our study or a previous investigation (Walstra et al., 1986). Other compounds may contribute to taint. There is evidence that 5β-androstenone, 5α- and 5β-androstenols, and indole also are associated with taint (Thompson et al., 1972; Hansson et al., 1980). This may partly explain why only 9 of 46 carcasses having fat 16-androstanes above 1.5 ppm were found to be tainted by the androstenone R-index, whereas 23 of 25 tainted carcasses determined by the skatole R-index had skatole levels below .25 ppm. Among the 25 skatole-related carcasses, 12 of them had fat 16-androstanes above 1.5 ppm. This indicates that 16-androstanes may play a role in the sensory determination of skatole taint. In correlation analyses (Table 4), the correlations between fat 16-androstanes and the two canonical variates were 1.7 times the correlations between fat skatole and the two variates, while the relationships between R-index of skatole and the two variates were only 1.1 times of the relationships between R-index of androstenone and the two variates. Nine of the 12 samples having fat 16-androstanes above 1.5 ppm, however, had an R-index of androstenone below the cutoff value, indirectly suggesting that compounds other than androstenone per se may be involved in taint detection.

The accuracy of the sensory judges may also contribute to the disagreement between sensory and chemical tests. It has been reported previously that panelists were unable to distinguish between the odors of 5α-androstenone and 4,16-androstadienone, and between 5α- and 5β-androstenols (Brooks and Pearson, 1989). In our study, the judges could only report either taint due to androstenone or taint due to skatole. Some judges, in fact, complained during the evaluation procedure that odors were strong and unpleasant but neither androstenone-like nor skatole-like. Such other odors could mask androstenone and(or) skatole, making them less likely to be identified. On the other hand, they could be confused with androstenone or skatole, creating false positives. In retrospect, training the panel to minimize both such effects would have been helpful. Alternatively, we could have asked them to measure the more general attribute “taint,” although that would not have allowed separately distinguishing the two compounds.

The inconsistency between sensory and chemical analysis of taint has been reported previously. Bonneau et al. (1992) and Stamer et al. (1993) found poor relationships between sensory scores and either fat androstenone or skatole. Berg et al. (1993) reported that 8% of boar carcasses detected by a panel as tainted were below the cutoff levels of taint compounds. García-Reguiero and Diaz (1989) observed that 8 out of 15 tainted samples judged by a panel had fat androstenone below the cutoff level, and all 15 tainted samples had fat skatole below the cutoff level.

Implications

Differences in tissue concentrations of taint compounds were detected among intact males of Duroc, Hampshire, Landrace, and Yorkshire breeds. Weight or length of bulbourethral gland was correlated to concentrations of 16-androstanes. 16-Androstenone steroids in fat and salivary gland were highly associated with taint detected by sensory tests, but not fat skatole.

Literature Cited


