Evaluation of growth, carcass, and compound concentrations related to boar taint in boars and barrows

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Summary: *One hundred and sixty Large White × Landrace × Duroc crossbred pigs were assigned randomly to one of two treatments, boar or barrow, to determine gender differences in growth performance, carcass traits, and tissue levels of compounds associated with sex odor. The trial started when pigs reached an average body weight of 18.5±0.2 kg (40.8±0.4 lb). Animals were assigned by gender to four pens in the same room, with 40 animals in each pen. Body weight and backfat were measured approximately every 2 weeks. The feed consumption by each pen of pigs was recorded. Animals were allowed ad libitum access to feed and water. Pigs were slaughtered at approximately 95 kg (209 lb) body weight in four batches at weekly intervals. The first batch was killed 101 days after the onset of the experiment. Backfat and lean percent were measured by the Fat-O-Meter®. Samples of backfat and salivary gland were collected at slaughter and frozen at -20°C until subsequently analyzed using colorimetric methods for skatole and 16-androstene steroids. Barrows had greater (P < 0.001) average daily gain and consumed more feed daily (P < 0.05) than boars. Boars used less feed per unit of weight gain. Barrows had more backfat (P < 0.0001) and a lower proportion of lean tissues in the carcass than boars (P < 0.001) . Concentrations of 16-androstenes in salivary glands and 5α-androstenone in adipose tissue were higher (P < 0.001) in boars than in barrows. There was no difference (P > 0.5) in skatole concentrations in backfat between the two genders. Our data indicate that boars have better feed conversion, less backfat, higher lean percentage, and higher 5α-androstenone and 16-androstene concentrations than barrows. Skatole levels were not affected by gender.*

Previous studies demonstrate that boars, compared with barrows, have better growth performance, less backfat, and higher lean muscle content.[1–5] Raising boars for meat, however, is limited by the potential problem of boar taint.[6] For this reason, in the United States and many other countries, male piglets not destined for breeding are castrated for meat. In several countries, however, intact males are currently being raised for pork.[7] A new regulation (Number 64/433/EEC) of the European Economic Community (EEC), which became effective in 1993, allows rearing of boars up to 80 kg (176 lb) carcass weight without testing for carcass odor or taint.[8]

Boar taint is primarily associated with the 16-androstenes, a group of steroids produced in the testes. Among these compounds, 5α-androstenone is the main contributor to taint.[9,10] Another compound, skatole (3-methyl-indole) which is produced in the large intestine, also contributes to taint.[11,12] Equipment to test male pigs for the presence of boar taint due to skatole has been installed in Danish slaughterhouses.[13]

Despite worldwide interest in rearing boars for meat, research on raising boars for pork and on boar taint has been limited in the United States. The purpose of this study was to determine gender differences in growth performance, carcass characteristics, and tissue levels of compounds associated with boar taint in a genetic line commonly used in commercial swine herds of North America.

Materials and methods

Experimental design

One hundred and sixty Large White × Landrace × Duroc crossbred pigs were assigned randomly to one of two treatments: boar or barrow. Barrows were castrated between 6–7 weeks of age. The experiment started when pigs reached an average age of 60 days. The average bodyweight at the beginning of the experiment was 18.5±0.2 kg (40.8 ±0.4 lb). Animals were assigned by gender and bodyweight to four pens in the same room, with 40 animals in each pen (0.8 m^2 [8.6 sq ft] per pig). Two diets were used during the growth phase: one for body weights < 50 kg (110 lb) and one for body weights ≥50 kg (Table 1).

Growth data

Body weights were obtained and backfat was ultrasonically measured using a Renco Lean-Meater® (Renco Corporation, Minneapolis, Minnesota) at approximately 2-week intervals. Feed con-

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sumption was recorded by pen of pigs. Animals were allowed ad libitum access to feed and water. Pigs were slaughtered at approximately 95 kg (209 lb) bodyweight and killed in four batches at weekly intervals. The first batch of animals was killed 101 days after the experiment was initiated. Carcass backfat and loin depth at the 10th rib, 6 cm from the midline of the back, were measured using a Fat-O-Meter® (SFK, Denmark). Lean percentage was calculated by a formula developed and used by a packer (John Morrell & Co., Sioux City, Iowa):

Lean % = 58.86 - 0.61 backfat (mm) + 0.12 loin depth (mm)

Table 2

Growth, feed, and carcass data at slaughter

Trait	Boar	Barrow	P
Initial body weight (kg)	18.34 ±0.24	18.67 ±0.24	.3469
Final body weight (kg)	100.34 ±1.00	105.42 ±1.04	.0004
Average daily gain (g)	730.99 ±11.04	798.84 ±11.38	.0001
Average feed intake (kg/d)	1.82 ±0.14	2.06 ±0.14	.3603
Gain:feed ratio	2.48 ±0.09	2.62 ±0.09	.4349
Backfat (mm)	13.11 ±0.33	17.42 ±0.34	.0001
Lean tissue (%)	54.51 ±0.44	51.33 ±0.41	.0001

Least-squares means ±SE

Samples of backfat at the area of the shoulder and salivary glands were collected at slaughter and then frozen at -20°C until subsequently analyzed.

Boar taint compound analysis

The 16-androstene steroids in the salivary gland and 5α-androstenone and skatole in fat tissue were measured using a modified colorimetric method described previously.[14] Tissue samples (5 g of fat or 1 g of salivary gland) were minced and then extracted with methanol before the steroids were concentrated. Cholesterol was removed from the fat extracts using a digitonin column. All samples were extracted and assayed in duplicate for taint compounds. Results are expressed as 16-androstenes steroid equivalents, using 5α-androstenol as a standard for salivary gland and 5α-androstenone as a standard for fat tissue. Skatole was measured by a Danish colorimetric method[15] and, because the method is not specific for skatole, results are expressed as skatole equivalents.

Statistical analysis

Data were analyzed using the general linear model (GLM) procedure of SAS.[16] Data on bodyweight gain, feed consumption, and carcass characteristics measured at slaughter and tissue concentrations of steroids and skatole were analyzed by GLM with gender and litter identification in the model. Initial bodyweight was adjusted as a covariate for growth performance. Batch of slaughter ($P > 0.35$) and pen ($P > 0.13$) were examined and found not significant, so they were subsequently excluded in the statistical model for growth performance. The number of animals and slaughter weights of pigs in each batch at slaughter were not the same for boars and barrows. Thus, average daily gain (ADG), backfat, feed intake, and gain:feed ratio up to day 101 of the experiment were analyzed by GLM with repeated-measures analysis of variance to test between-animal effects, within-animal effects, and interactions between the two types of effects. Least-squares means were obtained using the GLM procedure and significant differences among the means were determined by the predicted difference statement (PDIFF). Pearson correlation coefficients between tissue concentrations of steroids and skatole were calculated using the correlation procedure (CORR) of SAS.

Table 1

Diet nutrients

Ingredient	Diet 1	Diet 2
Dry matter (%)	87.37	87.44
Protein (%)	19.11	16.40
Fat (%)	5.74	8.85
Fiber (%)	2.69	2.55
Calcium	0.70	0.60
Phosphorus (%)	0.60	0.50
Lysine (%)	1.10	0.95
ME (Kcal/kg)	3250	3420
Vit. A (IU/kg)	7160	6610
Vit. D (IU/kg)	1650	1810
Vit. E (IU/kg)	50	40

Diet 1 was used at body weights <50 kg (110 lb). Diet 2 was used at body weights > 50 kg (110 lb).

Results

Average daily gain

Although there was no difference in bodyweights between boars and barrows at the beginning of the experiment, the bodyweights of barrows were greater ($P < 0.001$) than those of boars at slaughter (Table 2). Barrows grew faster than boars through day 101 of the experiment (Figure 1). The heavier final body weights of barrows were consistent with their higher ADG. The ADG of barrows was greater ($P < 0.001$) than that of boars by 67 g (2.36 oz) per day (9.3%). The difference in ADG between boars and barrows was significant ($P < 0.05$) from day 56 of the experiment on.

Feed intake and feed efficiency

The feed consumption of barrows exceeded that of boars during the entire experimental period by 0.24 kg (0.53 lb) per day (13.2%), but the difference was not significant ($P > 0.35$) (Table 2). Boars consumed less feed per unit of weight gain than barrows. There were no differences ($P > 0.05$) either in the feed intake or the gain:feed ratios between the two genders before day 28 of the experiment (Figure 2 top). After that time, barrows ate more ($P < 0.05$) feed than boars (Figure 2a). Similarly, a larger difference between the genders in the gain:feed ratios was detected after day 28 (Figure 2 bottom).

Carcass composition

Barrows had more backfat ($P < 0.0001$) and a lower proportion of lean tissue in the carcass than boars ($P < 0.001$) (Table 2). Boars had less backfat than barrows from day 56 on (Figure 3). A dramatic increase ($P < 0.001$) in backfat of barrows occurred from day 71, when the animals were approximately 4 months old.

Boar taint compound concentrations

Concentrations of 16-androstenes in salivary glands and 5α-androstenone in adipose tissue were higher ($P < 0.001$) in boars than in barrows (Figure 4). Salivary 16-androstene concentrations were positively correlated to adipose 5α-androstenone concentrations ($r=0.414$, $P < 0.0001$). There was no difference ($P > 0.5$) in skatole concentrations in backfat between the two genders (Figure 4). Concentrations of steroids and skatole were weakly ($r < 0.16$, $P > 0.09$) correlated to either age or weight of animals at slaughter.

Discussion

The differences in feed intake, gain:feed ratio, backfat, and lean percentage between barrows and boars in our study are consistent with previously published reports.[1,5,17-21] There has been considerable difference among published studies in the growth rate between boars and barrows. Boars grew faster than barrows in some studies,[1,3] while in other investigations there was either no difference in growth rate between the two genders,[19,20,22] or barrows grew faster than boars.[3,23]

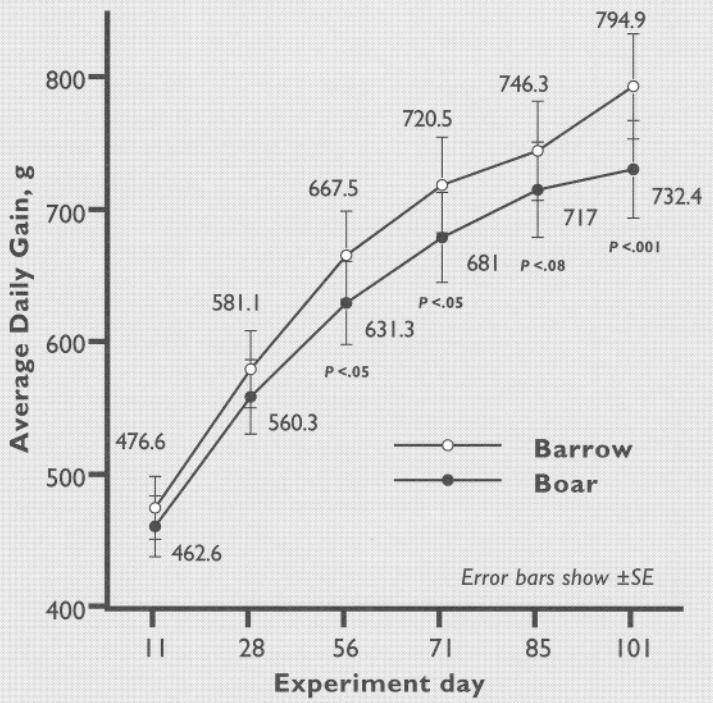
The greater feed intake observed in barrows relative to boars was similar to the results of other studies.[1,17,19,23] Pay and Davies[20] reported that barrows had a greater appetite than boars by the time they attained a weight of approximately 55 kg (121 lb), suggesting that they were already metabolically different at that time. The difference in metabolism appears to be mainly due to the anabolic effect of gonadal steroids since barrows treated with either testosterone or estradiol have reduced ad libitum feed intake.[24]

The improved feed efficiency of boars is apparently related to their carcass composition. A higher carcass content of lean muscle and proportionally less adipose tissue has been reported in boars relative to barrows.[4,19] In our study, difference in the accumulation of backfat between the two genders was observed at 56–71 days after the onset of the experiment, when the body weights of animals were 55–68 kg (121–150 lb). This early-age difference in carcass backfat content supports the earlier observation of an emerging difference in metabolism between intact males and castrates at 55 kg (121 lb) bodyweight.[20] Approximately 75% of lean tissue is water, while only about 25% of the fat in a pig carcass of 100 kg (220 lb) bodyweight is water.[25] Thus, lean tissue contains about three times more water than does fat tissue. Carcasses of boars slaughtered at 92 kg (203 lb) have 8% more moisture and those slaughtered at 105 kg (231 lb) have 16% more moisture than those of barrows.[4,26] This means that more feed is needed to produce the same unit of fat than lean tissue. Since boars have more lean and less fat tissue, they consequently have better feed efficiency than barrows.

Although in this study there was no significant difference in the feed intake and gain:feed ratio from the beginning of the experiment to slaughter between boars and barrows, the data may have been confounded by different ages at slaughter and the different proportions of boars and barrows in each slaughter group. When data from day 0–101 of the experiment were analyzed (Figure 2), significant differences in both feed intake and gain:feed ratio between the genders were detected at the later stage of the experiment. Although the replicates of feed traits were limited, which would have influenced the significance levels achieved in the data analysis, variations among pens within treatment groups were small.

The growth rate of boars relative to barrows, as cited in the published literature, is inconsistent. There are several factors that may have influenced the results in the literature and in this study. Likely explanations include differences in nitrogen retention and nutrient needs of boars and barrows. Boars are later-maturing and have less fat than barrows of a similar weight. Knudson, et al.,[22] reported that the growth rate of barrows was slightly greater than boars until 76 kg (167 lb) liveweight, when it plateaued. In that study, boars reached their maximum rate of gain at 87 kg

Figure 1



Average daily gain of boars and barrows from day 0–101 of the experiment. (*P* values denote significant differences between the two genders during the same time period.)

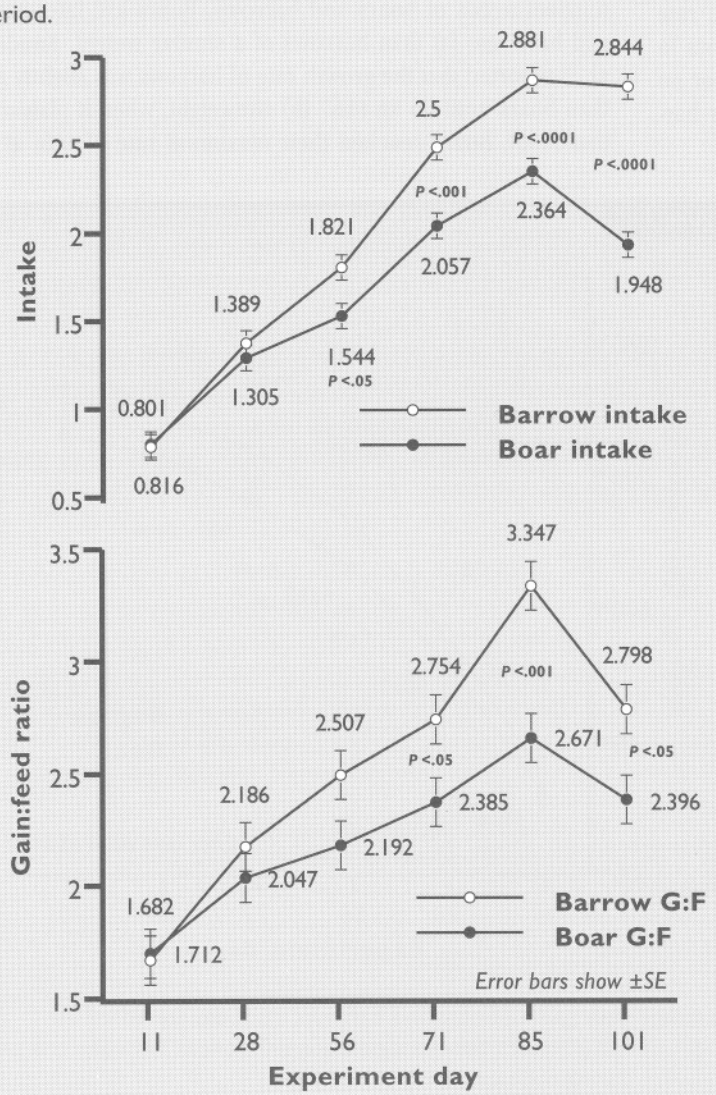
(191 lb). Similar results have been reported by Hansen and Lewis,[27] who found that rates of nitrogen retention were maximized at 60 kg (132 lb) in boars fed approximately 20% protein, whereas nitrogen retention was maximized at 55 kg (132 lb) in barrows fed only approximately 17% protein.

Another factor that may have contributed to the lower growth rate of boars relative to barrows is that boars may have been provided with inadequate levels of dietary protein or amino acids (especially lysine). Relative to castrates, intact males have a higher capacity for protein deposition and, thus, require more dietary protein to support maximum growth, particularly during the later stages of growth.[21,28] While initially we thought that the dietary protein and lysine contents in our study were adequate for boars, the relatively low daily feed intake of boars likely limited the amount of daily protein consumption, especially during the later stages of growth. This would have depressed bodyweight gain.

Growth rate is also influenced by floor space and group size. Daily weight gain was reported to decrease in groups of pigs allowed 0.34 m^2 (3.66 sq ft) per pig relative to groups provided with 0.68 or 1.01 m^2 (7.32 or 10.87 sq ft).[29] The floor space allowance (0.8 m^2 [8.6 sq ft] per pig) used in our study falls in the range of optimal performance determined by Meunier-Salaun et al.[29] However, information on the group size that optimizes the growth performance of boars has not been well documented. Furthermore, it is not clear whether either feed intake or growth rate were influenced by housing boars in the group sizes of 40 boars per pen used in our study. There is an increase in aggressive behavior when group sizes and stocking rates are increased.[30] Boars with high concentrations of salivary androstenone had more aggressive behavior than the control barrows,[31] indicating that boars may be more aggressive with each other than barrows. We presume that some of the dominant boars in the boar groups may have spent more time around feeders, which may have depressed the feed intake of subordinate boars, especially during the later phase of the experiment when boars were reaching puberty.

Figure 2

Average daily feed intake (top) and feed:gain ratios (bottom) of boars and barrows from day 0–101 of the experiment. *P* values denote significant differences between the two genders during the same time period.

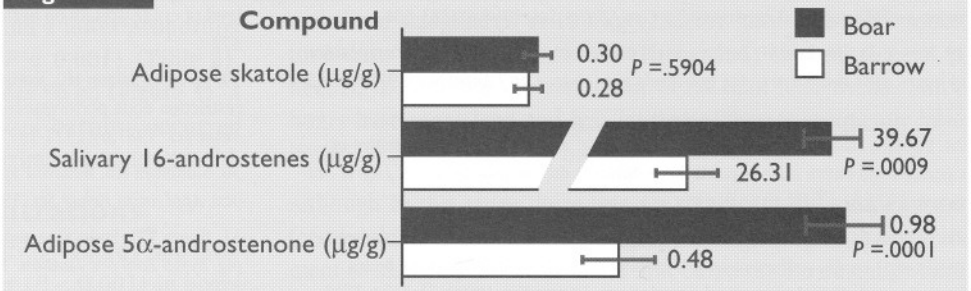


The higher concentrations of 5α-androstenone in adipose tissue, 16-androstenes in the salivary gland, and similar concentrations of skatole in boars relative to barrows that we observed were consistent with our previous study of mature boars.[14] Significant positive correlations between adipose 5α-androstenone and salivary 16-androstenes and low correlations between steroid compounds and skatole also were consistent with our previous study. High concentrations of adipose skatole (0.30 µg per g for boars and 0.28 µg per g for barrows) were detected in the present study, which is greater than our previous study, but lower than the results of 0.37 µg per g reported earlier by Judge et al.[32] Differences in skatole concentrations may be due, in part, to age of the animals or diets. The similar concentrations of skatole between boars and barrows indicate that skatole levels may not be an appropriate determinant for taint.

Carcasses with concentrations of 5α-androstenone above 1 µg per g[33] or skatole concentrations above 0.25 µg per g[34] are considered to be tainted in the EEC. However, an American study found that consumers rated fat samples with average concentrations of 1.51 µg per g 5α-androstenone and 0.37 µg per g skatole from boars weighing 102 kg (224 lb) as "quite low" in offensive odor.[32] No difference in boar taint between boars and barrows was reported in a Canadian study.[5] Consumers in Canada did not discriminate against pork because of boar taint.[35] In another Canadian study, approximately 15% and 33% of boars had skatole and 16-androstene levels, respectively, that exceeded acceptable limits.[36] A trained sensory panel indicated that 24% of boars had a potential problem with boar taint, but the taint problem

was not perceived by a consumer survey.[36] Based on the above observations, we speculate that consumers in North America have a relatively high tolerance for 5α-androstenone and skatole. Alternatively, boars reared in commercial production facilities in North America may have a low incidence of offensive odor.

Figure 4



Tissue concentrations of compounds related to boar taint. (Least-squares means ±SE.)

Implications

- Our study indicates that entire male pigs reared under United States commercial conditions had better feed efficiency, less backfat, and higher lean tissue than their contemporary castrates.
- More meat will be produced if male pigs are kept intact instead of castrated.
- More studies are necessary to establish the threshold concentrations above which North American consumers are likely to perceive taint in boar carcasses.

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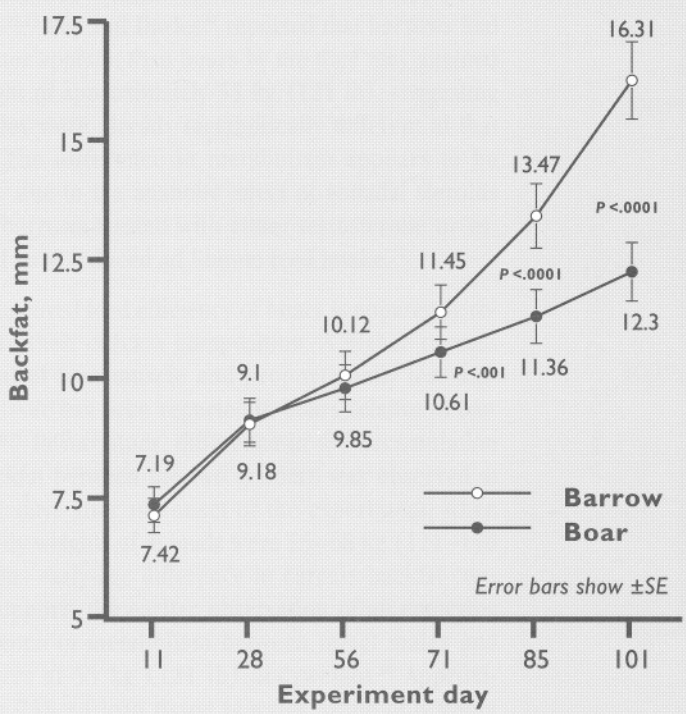
Figure 3



[Average? Least-sq. means?] backfat of boars and barrows from day 0–101 of the experiment. (*P* values denote significant differences between the two genders during the same time period.)

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