The risks and benefits of feeding intact male swine in the United States and Canada

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Summary: *Raising intact males is a promising possibility in the ongoing quest for leaner hogs. This paper reviews the advantages and problems of rearing intact males, including an overview of boar taint, and outlines a practical feeding approach for split-sex feeding in operations that choose to rear intact males.*

This decade will be known as the decade of lean growth in the swine industry, as both carcasses and economic returns become more lean. The United States swine industry now realizes the importance of leaner carcasses. In Canada, where we rarely dispute the benefits of our 20-year-old national hog grading system, we are reevaluating whether this system has provided enough of an incentive for a fat- instead of a lean-genotype hog.

In our trend towards the lean carcass, our options are limited. We can:

- restrict feed;
- genetically select for leanness, a slow process;
- buy lean pork from overseas;
- use porcine somatotropin (PST) injections to achieve a leaner hog; or
- raise intact males.

PST is probably the most cost-effective way to increase lean yield, but it may not be launched onto the market. With or without PST, the North American swine industry is losing feed efficiency and average daily gain (ADG) by failing to rear intact males.

Boar taint

The most serious disadvantage of rearing intact males (especially to the slaughter weights typical in North America) is boar taint. Boar taint is caused primarily by the compounds androstenone[1] and skatole;[2] however, sensory studies carried out by Bonneau[3] suggest that there are other contributing compounds. These compounds are probably testicular in origin and are more likely to contribute to boar taint in the sexually mature male than in younger, lighter, or later-maturing boars.

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Androstenone

Androstenone is a testicular steroid which imparts a urine-like smell to carcass fat. Unfortunately, the tests for androstenone concentrations are expensive and complicated. At this time, there is no practical test for measuring androstenone concentrations on the slaughter line.

Testicular synthesis of androstenone depends on the animal's age, sexual maturity, weight, genotype, and environment.[3] Plasma androstenone concentrations increase slowly from 70 to 170 days;[4] concentrations vary greatly among individuals, however. Steroid concentrations rise markedly after 200 days of age, following sexual stimulation, or after any excitement such as fighting.[3] Because androstenone levels are dependent on both age and liveweight, and because their relative importance is unclear, it is difficult to predict the ideal slaughter weight and age for intact males to eliminate boar taint.

Skatole

Skatole is produced as gut bacteria metabolize tryptophan, an amino acid found in the large intestine and cecum.[5,6] It imparts an intense fecal odor to the carcass fat, but, unlike androstenone, skatole can be measured inexpensively on the slaughter line using a rapid colorimetric test.[7] Environmental factors, such as the health status of the herd, may influence skatole levels in the subcutaneous fat more than gender, castration, or genetics.[8] Recent work has confirmed that dietary fiber can significantly reduce concentrations of skatole in the feces, but will not reduce skatole concentrations in the subcutaneous fat.[9] Compared to pigs fed dietary fiber, fecal concentrations of skatole were higher in pigs fed dietary lactose or tylosine phosphate supplements.

Although these studies do not solve the problem of boar taint, they do show the industry's commitment to controlling the problem. The influence of the less-understood compounds that also contribute to boar taint unfortunately at present limit the accuracy of on-line slaughter detection. Once we determine a practical, economical way to prevent boar taint, however, feeding intact males should be the industry standard.

Physiologic and performance differences

To assess the relative economic merits of raising intact male swine, it is necessary to understand their physiologic and performance benefits.

In the late 1980s, the British Meat and Livestock Commission initiated performance trials at Stotfold[10] to compare genotypes of the following breeding companies: National Pig Development Company, the Pig Improvement Company, Masterbreeders, and Cotswold. These trials were designed to:

- compare production efficiency of meat-type sires with conventional sires;
- examine the influence of genotype, gender, feeding regimen, and slaughter weight on carcass and meat quality; and
- estimate a genetic baseline for assessing changes in meat production and quality generated by future breeding policies.

Results from Stotfold and other studies indicate that intact boars have:

- 4% greater lean yield;[10,11]
- 1%–3.5% greater slaughter yield;[11,12]
- liveweight feed conversion improvement of 6%–33%;[10-16]
- 6%–17% greater average daily feed intake;[10-14] and
- ADG increased 0%–17%.[10-14]

Up to 45 kg liveweight, the differences in liveweight gain among the genders are almost negligible.[11] After they reach 45 kg, however, intact boars gain substantially more weight per day than gilts. Barrows gain less weight per day than gilts if given equivalent daily nutrients (Table 1);[10,13] however, in the field, barrows often have higher ADG than gilts because they eat more on ad libitum feeding programs. Barrows eat more than gilts and boars because sex hormones suppress the appetite.[10,13] This added weight, however, is mostly fat.

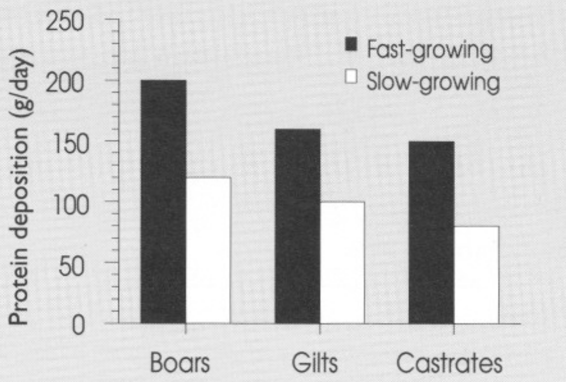

Fig 1.— Rates of protein deposition by gender and genotype.
Note: protein deposition rates are reduced 0–30 g/day if feed is restricted to 90% of ad-libitum intake.[17]

Lean growth

Within similar genotypes and with similar daily nutrient intakes, boars have the highest protein deposition rate (g of protein accrued per day), while barrows have the lowest protein deposition rate (Fig 1).[11,17] Lean tissue growth rate (g of muscle tissue [protein + water + intramuscular fat - lean organ tissue] accrued per day) also is highest in boars and lowest in barrows.[10,11] Lean tissue has a higher metabolism that produces more metabolic heat than does adipose tissue.[11] Therefore, because of their higher lean content, boars require more calories to maintain their weight than do gilts or barrows.

Fat deposition

The fat deposition rate (g of adipose tissue accrued per day) is highest for barrows and lowest for boars of the same genotype. In barrows fed ad libitum, the higher fat deposition rate is compounded by the higher daily feed and energy intake, which intensifies the difference in fat deposition among genders.

The fat of intact males is less saturated and softer than that of gilts and barrows.[10,12,14,18,19] In barrows, fat softness at slaughter depends at least in part on the age at which the animal was castrated. Males castrated before 16 weeks of age have harder fat than gilts, while the fat of those castrated between 16-20 weeks of age is softer than that of gilts.[20] Also, carcass fat is softer in animals whose feed was restricted compared to animals fed ad libitum; however, considerable variation exists among the genetic sources.[10] The less-saturated fat of intact males may be a consumer health benefit. Extremely soft fat, however, can separate or be-

Table 1.— Stotfold trial results:[10] Growth and carcass characteristics among genders (ad-libitum feeding, 27 kg liveweight to 75 kg carcass weight).

	Boars	Gilts	Barrows
Average daily feed intake	2.08 kg	2.11 kg	2.28 kg
Daily liveweight gain	862 g	796 g	823 g
Daily energy intake	7110 kcal 29900 kJ	7210 kcal 30300 kJ	7790 kcal 32700 kJ
Slaughter yield (%)	75.4	76.9	76.3
Carcass feed conversion	3.11	3.32	3.50
Hot P2 backfat*	11.6 mm	12.1 mm	14.6 mm
Loineye depth	57.8 mm	59.2 mm	56.0 mm
Lean yield	57.2%	56.4%	53.0%
Lean tissue growth rate	388 g/day	360 g/day	343 g/day
Lean tissue feed conversion	5.42	6.01	6.89

*P2 backfat is a measurement of subcutaneous fat 6.5 cm from the dorsal midline at the last rib.

come rancid during processing. Fat quality may not significantly vary among most modern genotypes: Sather found only a low percentage of boars and gilts to have extremely soft fat.[21]

Economic advantage of feeding intact males

Because of their superior feed efficiency, lean yield, and perhaps, average daily gain, raising intact boars can provide economic advantages (Calculation 1). Gender differences in the weight of the bones and nonreproductive organs are relatively small, but because of their heavier reproductive tracts, boars have a slightly lower lean carcass yield than gilts or barrows.[11,29] Their carcass is more valuable, however, because it contains more lean meat. In Canada, the present index system does not allow the producer to fully realize the benefits of this additional lean yield. This is not the case in the United States, where packers pay more substantial premiums for lean content.

Feed costs per hog

On a liveweight basis, boars convert feed more efficiently than gilts and barrows. All controlled studies have demonstrated a marked superiority in the feed efficiency of boars. In the future, most intensive hog operations will practice split-sex feeding, so that the diet can be manipulated to reduce skatole concentrations in the fat of entire males. Under split-sex feeding programs, the differences in feed conversion and, therefore, feed cost per kg gain between males and barrows will vary from farm to farm depending on the energy density and amino acid profile of the diet.

Turnover ratio

Although increases in liveweight gain have not been a consistent finding among laboratories, some evidence suggests that the average daily gain of intact males is superior to that of gilts and barrows. This inconsistency of results could be due to inadequate nutrient intake, which would inhibit the full expression of the genetic capability of the male.

Producers must increase turnover, maximizing throughput, to take economic advantage of these faster growth rates. Reducing animal density could provide further improvement in growth rates in overcrowded barns. Alternately, when constructing a new facility, less space per pig would be needed.

A practical approach to feeding

To formulate the optimal ration for each age and gender of pigs, you must:

- understand the gender's biological capacity to deposit muscle protein;
- determine the nutrients and amount of energy that each gender needs daily to allow it to fully express this capacity;
- assess average daily feed intake on the farm; and then
- formulate the optimal ration for each age and gender of pig to ensure they achieve their biological capacity for lean growth.

ALthough gender differences in lean protein accretion begin to occur at 45 kg, 50 kg is a more practical breaking point when using a two-diet system as in our model.

Pigs weighing 20–50 kg

For this weight group, average daily gain within a genotype is largely dependent on the animal's daily energy consumption. Gender differences do exist, but they are often small and confounded by energy restrictions or environmental compromises. At this age, feed consumption is limited to the volume of the digestive tract, and even animals fed ad libitum may not realize their full potential.[22]

In an Australian study, Campbell and Taverner[23] fed growing pigs increasing concentrations of energy in protein-adequate diets until they reached 7400 kcal DE (31080 kJ DE) per day. With each incremental increase, the protein deposition rates of all genders increased. A daily digestible energy intake of 7400 kcal (31080 kJ) was the maximum daily intake of energy investigated, and it was surmised that all genders probably would have responded positively to higher daily energy intakes if they had been offered.

At this age, all genders should be fed diets as high in energy as economically possible. Housing conditions and ambient temperature should be geared to encourage average daily feed intake. Campbell[23] suggests that for this age group, the maximum ingestive capacity lies between 2.0–2.2 kg per day, and that diets of 3350–3465 kcal DE (14070–14550 kJ) are required to maximize protein and fat growth. On a typical western-Canadian diet which lacks corn but is based on wheat, barley, and soybean meal as the grain sources, average daily feed intake during this period must be 2.25 kg per day to achieve the 7400 kcal DE (31080 kJ) intake per day.

Many researchers have investigated the protein and amino acid requirements of the pig for maintenance and protein accretion,[12,19,24,25] however few have examined the gender differences of modern genotypes. Although not at the daily energy intakes used by Campbell and Taverner,[13] Yen and others[15] found that the growth rates varied among genders in response to increasing increments of total dietary lysine.

Peak liveweight gains corresponded with:

- 18.3 g total lysine intake per day for boars (4.1 total dietary lysine to digestible energy ratio);
- 17.8 g for gilts (3.8 total dietary lysine to digestible energy ratio); and

Example:	Boar	Barrow
Live animal weight	108 kg	106 kg
× Slaughter yield	77%	78%
= Carcass weight	83.2 kg	82.7
× Slaughter price (dressed)	$1.32 per kg	$1.32 per kg
× Carcass index* / 100	1.14	1.07
Income per hog†	**$125.14**	**$116.78**

	Boar	Barrow
Live weight gain	30 kg	30 kg
× Feed conversion ratio	2.14	2.25
× Diet cost per kg	$0.186	$0.186
Grower feed costs	**$11.94**	**$12.55**

	Boar	Barrow
Live weight gain	58 kg	56 kg
× Feed conversion ratio	2.55	3.05
× Diet cost per kg	$0.136	$0.128
Finisher feed costs	**$20.11**	**$21.86**

Example:	Boar	Barrow
Income per hog	$125.14	$116.78
– Grower feed cost	$11.94	$12.55
– Finisher feed cost	$20.11	$21.86
Margin over feed cost per male hog	**$93.09**	**$82.37**

Diet formulations and nutrient specifications:

Live weight (kg):	20–50	50–100	50–100
Gender:	All genders	Boar	Barrow
Ingredient (% of ration)			
Barley	8.0	20.0	45.0
Wheat	70.0	64.4	42.5
47% Soybean meal	12.0	11.0	8.0
Canola oil	3.0	1.0	1.0
Threonine	0.15	0	0
Lysine	0.30	0.1	0
Methionine	0.05	0	0
Tallow	2.5	0	0
Custom premix	4.0	3.5	3.5

Live weight (kg):	20–50	50–100	50–100
Gender:	All genders	Boar	Barrow
Nutrient analysis			
Digestible energy (kcal/kg)	3468	3262	3197
(kJ/kg)	14560	13700	13430
Crude protein (%)	16.4	16.3	14.9
Crude fat (%)	6.8	2.5	2.5
Crude fiber (%)	2.6	3.0	3.6
Total lysine (%)	1.02	0.8	0.65
Total meth + cystine (%)	0.61	0.56	0.50
Total tryptophan (%)	0.21	0.22	0.20
Diet cost per kg	**$0.186**	**$0.136**	**$0.128**

*assumes carcass lean is 53.5% in boar and 49.5% in barrow, and is used to calculate the premium above per kg slaughter price; based on the Canadian Grading Grid. Carcass index is relative to a standard value of 100, so here we divide the index values 114 and 107 by 100 to get the values 1.14 and 1.07 by which we can multiply the slaughter price per kg..

†in the United States, income per hog is calculated as: Live animal weight × Slaughter price (live) + Lean yield premium.

Note: All dollar values are Canadian except where US dollars are calculated based on an exchange rate of $US 1.00 = $CAN 1.25.

Example:	Boar	Barrow
Live weight gain	30 kg	30 kg
÷ Average daily gain	0.88 kg	0.84 kg
Days from 20–50 kg	**34 days**	**36 days**

Live weight gain	58 kg	56 kg
÷ Average daily gain	1.1 kg	1.0 kg
Days from 50 kg to slaughter	**53 days**	**56 days**

Days from 20–50 kg	34 days	36 days
÷ Days from 50 kg to slaughter	53 days	56 days
Days from 20 kg to slaughter	**87 days**	**92 days**

Example:	Boar	Barrow
Days per year	365 days	365 days
÷ Days from 20 kg to slaughter	87 days	92 days
× Estimate of feeder barn efficiency	95%	95%
Feeder barn turnover ratio	**4.0**	**3.8**

Example:	Boar	Barrow	Economic advantage of feeding intact males:
Margin over feed cost per male hog	$93.09	$82.37	**$10.72 ($8.58 US)**
Feeder barn turnover ratio	4.0	3.8	
Margin over feed cost per pig space housing male hogs	**$372.38**	**$313.01**	**$59.35 ($47.48 US)**

Calculation 1.— Calculating the economic benefits of rearing intact boars compared to castrates using a two-diet system.

- 16.5 g for barrows (3.8 total dietary lysine to digestible energy ratio).

Dietary energy intakes in this study were held constant at 5700 kcal DE (23940 kJ DE) per day.[15] Feed efficiency responded in a similar fashion to incremental increases in dietary lysine.

Because protein is deposited at a similar rate across all genders at this age, the daily lysine requirements are probably similar. However, when you extrapolate lysine requirements from field work, you should use available lysine rather than total dietary lysine levels in your calculations, since the availability of the amino acids will vary according to the diet's formulation (Calculation 1).

Pigs weighing 50–90 kg

In this weight group, gender differences in protein accretion rates are pronounced enough to warrant split-sex feeding. Because considerable genotypic, phenotypic, and seasonal variation exists in average daily feed intake, it is essential to know daily feed intake when comparing diet formulations among farms.

The daily dietary lysine requirement of the growing pig depends largely on the genotypic potential for lean tissue growth, the energy intake, and the bioavailability of lysine in the diet. Assuming that meat or carcass protein is 6.5% lysine, daily requirements of available lysine can be crudely estimated. Using our knowledge of on-farm feed consumption, the apparent ileal lysine availability[26,27] (Table 2) and the protein deposition rate, we can calculate the lysine content of the diet. However, amino acid may be recycled in the gastrointestinal tract, a concept which is currently being researched.[28]

Campbell has shown that in 50- to 90-kg boars fed 7650 kcal DE (32130 kJ DE) per day, liveweight gain and protein deposition rates level off at 130 g per day and these rates in 50- to 90-kg gilts level off at 102 g per day.[29] If the high-lean genotypes used at Stotfold respond in a similar fashion, boars and gilts could be fed ad libitum until slaughter at 105 kg, whereas barrows should be restricted in energy at or before the 7650 kcal DE (32130 kJ DE) per day level (Calculation 1).

Animal welfare considerations

Raising intact males will obviate the need to castrate piglets, a painful procedure that under nonsterile conditions can result in ascending and/or systemic infections. It would also avoid late castration of market-aged hogs. Unfortunately, this occurs occasionally on most farms and in breeding stock supplier herds where poor-performance males are castrated after the growth testing period (at around 18 weeks of age).

However, raising intact males is not without welfare implications. If producers mix boars in pens or on the trucks preceding slaughter, it may exacerbate fighting among penmates. In addition, intact males housed next to cycling females often become aggressive or redirect sexual activities to penmates, especially lower peck-order animals. It is essential to separate females and boars in the grower herd.

Markets

Researchers have determined that consumers would be likely to detect concentrations of androstenone that exceed 0.5-1.0 ppm and of skatole that exceed 0.25 ppm.[6] Certain consumers and ethnic groups are less able to perceive boar taint, an ability which is controlled by genetics.

At the moment, United States Department of Agriculture (USDA) regulations do not prohibit the sale of meat from intact boars. Federal regulations, however, do require that boar meat with a pronounced sexual odor be condemned for human consumption. Boar meat with a slight sexual odor must be used only for rendering or comminuted products, like sausage.[30] In cases on the slaughter line where federal inspectors detect sexual odor, the carcass is retained and a veterinary medical officer makes the final assessment of the carcass.

In Canada, Agriculture Canada allows the sale of intact boar meat with no taint, but it must be marked as "B Grade." If there is absence of a strong urine or sexual odor, the boar carcass is passed for food purposes and the letter "B" is stamped on the hams, bellies, loins, and shoulders. Meat from boars weighing over 90 kg will not be used except to make spiced, cooked, or dried sausages. The retail sale of fresh meat

Table 2.— Apparent ileal digestibility (%) of lysine and threonine in selected feedstuffs.

Feedstuff	Lysine	Threonine	Source
Soybean meal	86	79	Knabe, Lenis
Corn	72	71	Knabe
Maize	56	62	Lenis
Barley	70	66	Lenis
Wheat	76	73	Knabe
Wheat middlings	71	63	Lenis
Peas	83	69	Lenis
Skim milk powder	94	85	Lenis
Fish meal	84	79	Knabe
Meat meal	68	61	Knabe
Meat meal*	75-83	72-78	Lenis

* digestibility dependent on quality of meal
Sources: Knabe,[26] Lenis.[27]

Table 3.— Suggested daily available amino requirements (g/day)

	35 kg	50 kg	65 kg	80 kg
Fast-growing boars				
Lysine	15.5	17.2	18.5	19.6
Met + cyst	5.9	7.6	8.1	8.5
Tryptophan	2.3	2.5	2.8	3.0
Threonine	7.7	8.9	9.4	9.6
Slow-growing boars				
Lysine	13.3	14.6	14.4	14.0
Met + cyst	5.9	6.3	6.3	6.0
Tryptophan	1.9	2.3	2.2	2.0
Threonine	6.8	7.6	7.2	7.0

Derived from "Feeding standards for Australian livestock," 1986; dietary energy density 12 MJ DE/kg.[33]

from such boars is prohibited. Most Canadian pork that is exported is sold to the United States.[31] Intact boar meat may be exported to the United States.

The North American swine industry will undoubtedly continue to weigh the risks and benefits of rearing intact male swine. It is unlikely, however, that the North American swine industry will rear intact males on a widespread basis until we can produce an 85-kg carcass free of boar taint.

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