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The Effect of Gender of Finishing Pigs Slaughtered at 110 Kilograms on Performance, and Carcass and Meat Quality

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ABSTRACT: Twenty-four crossbred pigs (Large White x Landrace x Segher) were divided into three equal groups of boars, barrows and gilts. Prior to slaughter, they were raised from 30 kg to 110 kg. under controlled conditions. Gender had no significant effect concerning total weight gain, average daily gains, feed conversion ratio, and production costs. Backfat thickness of boars was lower ($p<0.05$) than that found in barrows and gilts (2.27 vs. 2.96 and 2.73 cm, respectively). In other carcass quality traits, such as dressing percentage, carcass length, loin eye area and lean percentage, there were no significant differences among groups. Lean meat percentage was lower ($p<0.05$) in barrows, than in boars and gilts. Applying Thai cutting style, there was a higher ($p<0.05$) lean meat percentage in boars than in barrows while fat percentage was lower ($p<0.05$) in boars compared to the barrows (8.2 vs. 11.0 %, respectively). Meat pH was found to not be significantly different across groups. However, boars tended to have a comparatively faster rate of pH decline. Therefore, their carcasses were more susceptible to PSE. Color (L*, a*, b*), drip loss and thawing loss differed among the three groups. Boiling loss of boar and gilt meat was larger ($p<0.001$) than that of barrow meat (22.1 and 23.1 vs. 16.2%, respectively). However, intramuscular fat content was higher ($p<0.05$) in the barrows than in boars and gilts, while the latter groups did not differ much. Although not obvious from flavor scores, boar meat showed the overall lowest sensory acceptance. This was mainly caused by reduced ($p<0.05$) tenderness scoring, which was partially confirmed by shear force measurements, the lower juiciness impression, and less obviously by the highest ($p<0.001$) plasma testosterone level (278 vs 0.09 and 0.02 pg/ml in boars vs. barrows and gilts), probably associated with high levels of androstenone, and backfat skatole concentrations. Backfat contents of unsaturated fatty acids, among them the dietetically undesired arachidonic acid, tended to be slightly higher in boars than in barrows and gilts, and this was associated with a clearly ($p<0.05$) softer fat and a higher inclination for oxidation as determined in the backfat. Overall, this suggests that boar meat has a slight advantage in carcass quality but is clearly inferior in quality compared to meat from barrows and gilts even in the absence of noticeable boar taint.

KEYWORDS: animal welfare, fattening, growth, slaughter, boar, swine.

INTRODUCTION

Nowadays, production of high quality meat is an important issue and becomes a necessity as consumers become more selective in their consumption habits. Therefore, not only growth characteristics, feed conversion ratio and high carcass quality are the primary goals of pig production, but also meat quality, including aspects of fat tissue quality.[1] Important determinants of meat quality are the result of changes in the muscle after the animal is slaughtered. Individual quality traits affect different aspects of consumer's satisfaction and its suitability for processing into various meat products.[1]

From an animal welfare perspective, fattening of boars meets community agriculture policy, as it helps to reduce the application of procedures, which cause or are likely to cause suffering or injury to any of the animals concerned. This is an important aspect with respect to expected demands on pork that is to be exported from Thailand, too. In terms of daily weight gain, feed conversion ratio and lean meat content, boars typically

perform better than gilts and barrows.[2-6] However, differences are not always very pronounced and the boars' high lean meat percentage is often associated with a reduced meat quality. Boars are more sensitive to stress than gilts and barrows. This higher stress susceptibility facilitates a more rapid post mortem muscle glycogen degradation with the result of a high concentration of lactic acid and hence a reduced meat pH. A low pH is associated with a poor water-holding capacity, resulting in high water losses during storage and cooking, and ultimately causing pale meat, a trend more obvious in boars than in barrows.[7-8] On the other hand, there might be gender effects on fatty acid deposition in the body, particularly due to the hormonally determined differing rates of fat deposition.[1] This might affect the dietetic value and shelf life of the meat and meat products. This aspect remains widely unexplored so far, and there are also few comprehensive studies over a wide range of performance and meat quality aspects concerning boar fattening so far.

The objective of this study was to compare various variables of growth performance, carcass and meat quality, as well as carcass fat characteristic traits in boars, barrows and gilts, in order to provide data for the detailed evaluation of the advantages and constraints of boar fattening. Measurements also included analyses on indicators of boar taint and sensory properties.

Materials and Methods

Feeding regimen was divided into two periods. The composition of the diets was calculated by linear-programming based least cost formula for both growing (30-60 kilogram) and finishing (60-110 kilogram) pigs, in a way that nutritional requirements were covered[9] (Table 1). Contents of metabolizable energy were calculated based on Pongpiachan.[10] The diets were relatively low in tryptophan compared to typical pig diets,[10] because of the use of low-tryptophan feeds (namely yellow corn).

Pigs were fattened at the experimental facility of the Department of Animal Science, Faculty of Agriculture, Chiang Mai University, in 24 individual pens (2 x 3 m). Before the start of the experiment, all pens were cleaned with water, prior to being sterilized with lime and antiseptic (an iodine compound). Then, they were washed with clean water again. The pens were left empty for 15 days before the experimental pigs were allowed to enter. Twenty-four (Large White x Landrace x Seghers) of an average initial weight of 30.6 kg were used in this experiment. The three gender groups, boars, barrows and gilts, consisted of eight pigs each, fattened from 30-60 kilograms (growing) and 60-110 kilograms (finishing). Spatial distribution of group members in the animal house was allocated by a completely randomized design.

Table 1. Composition of the experimental diets fed to growing pigs (30-60 kg.) and finishing pigs (60-110 kg.).

Diets	Growing stage	Finishing stage
Ingredients (%)		
Rice bran	7.00	11.0
Broken rice	28.0	32.0
Yellow corn	35.7	37.6
Soybean meal	23.6	14.4
Fish meal (62.3 % CP)	2.50	2.50
Limestone	0.50	0.50
Dicalcium phosphate (DCP)	1.00	0.54
Tallow	0.93	0.64
Vitamin-mineral premix	0.25	0.25
Salt	0.50	0.50
Total	100	100
Cost, baht/kg.*	8.26	7.83
Calculated composition (as fed)		
ME, kcal/kg.	3,265	3,265
Crude protein, %	18.0	15.0
Crude fat, %	4.00	4.30
Crude fiber, %	3.70	3.60
Phosphorus, total %	0.58	0.45
Calcium, %	0.65	0.51
Lysine, %	1.00	0.79
Methionine, %	0.32	0.28
Tryptophan, %	0.22	0.17
Threonine, %	0.68	0.56
Methionine & Cysteine, %	0.61	0.53
Analyzed composition (as fed)		
Dry matter, %	89.5	90.1
Crude protein, %	18.9	15.9
Ether extract, %	6.19	5.45
Crude fiber, %	2.32	2.47
Ash, %	5.04	5.76
N-free extract, %	56.3	60.5
Gross energy, kcal/kg.	4,457	4,405

* Computation based on the prices (baht/kg.) when the experiment was conducted during June-November, 2002.

Pigs of all groups were slaughtered and dissected according to the Thai style at the Chiang Mai Meat and Dairy Products Unit, Livestock Development Department, Chiang Mai.[11] The pH of two muscles (Semimembranosus, SM and Longissimus dorsi, LD) was evaluated 45 min. ($pH_{45\,min.}$) and 24 hr post mortem ($pH_{24\,hr}$) with a pH meter (model 191, Knick, D-Berlin), according to the method of Jaturasitha.[11] After chilling of the carcasses at 4 °C for 24 hr, the LD of the left side as well as the overlaying backfat were dissected from the 6th to the 15th rib. The LD section located between the 8th and the 9th rib was cut and put into vacuum polyethene bags to be chilled at 4 °C for 24 hr. Then, they were refrigerated at 4 °C without the bag for 1 hr before conducting color measurement with a Chroma Meter (Minolta, CR-300, Osaka, Japan) to record

lightness, redness and yellowness (L*, a* and b*, respectively).

In the laboratory, various other measurements were performed. For the determination of drip loss, the LD between the 7th and the 8th rib was cut and weighed, both before and after storage. The sample was at first hooked in the refrigerator for 24 hr at 4 °C in an absorption pad inside of a polyethene bag. Drip loss percentage was then calculated after a second weighing. For thawing and cooking loss, LD from the section between the 13th and the 14th rib was obtained. The samples were weighed and kept frozen at -20 °C in polyethene bags until the analysis was begun by thawing at 4 °C for 24 hr. Then, the sample was dried with soft paper, weighed and kept in vacuumed heat resistant plastic bags. Boiling was done at 80 °C for 15 min, at which point an internal temperature of 72 °C was expected. Finally, it was cooled down to room temperature and weighed again. LD muscle obtained between the 12th and the 13th rib without connective tissue and tendon was homogenized and analyzed for its contents of moisture, protein and fat (representing the intramuscular fat) according to the AOAC.[12] LD slices of each of the 24 pigs obtained from between the 11th and the 12th rib were grilled for 12 min at 180 °C, which was about the time when an internal temperature of 70 °C was reached. The slices were cut into 1.5 x 1.5 cm pieces and served to six trained panelists according to the method of Wiriyajaree.[13] Each panelist independently evaluated tenderness, flavor, juiciness and overall acceptance by grading on a scale of five. All selected panelists were tested in advance to be able to register boar taint, as only part of the population has this ability. Six 1.27 cm diameters cores per each boiled LD sample were evaluated for shear force values. A Warner Bratzler shear device attached to an Instron Model 5565 Universal test machine with 200 mm/min test speed and a 5 kN load cell was used.

Indicators of off-flavor components subsumized as boar taint were determined by analyzing testosterone (having the same biochemical pathway as androstenone) in blood plasma by the RIA method of Wasser *et al.*[14] and the concentration of skatole in backfat by HPLC (Model Shimadzu, Tokyo, Japan) according to Dehnhard *et al.*[15]. Fat firmness was determined as outlined by Jaturasitha *et al.*[16] in molten backfat of which 10 ml was filled into 15 ml glass vessels. Fat was allowed to congeal for 45 min at room temperature, and then was stored at 18 °C until analysis. Penetrating force was determined after storing samples for 30 min at 25 °C using a metal stick with a surface at the end of 19.6 mm^2 attached to an Instron universal testing machine (Model 5565, Instron Ltd., Buckinghamshire, UK), on which a 100 N load cell was applied. The fatty acid profile of backfat was analyzed by the method of Folch *et al.*[17]. Fat was extracted by chloroform and methanol (2:1 v/v). Methyl esters were prepared by the method of Morrison and Smith.[18] Fatty acids were analyzed by gas chromatography (model GC-14B, Shimadzu, Tokyo, Japan). Thiobarbituric acid (TBA) number was analyzed as malonaldehyde concentrations in backfat and intramuscular fat (LD). They were stored at 4 °C after keeping at -18 °C and being defrosted at refrigerator temperature for 12 hr.

All data were statistically treated by analysis of variance.[19] Multiple comparisons among group means were performed by the Least Significant Difference (LSD) method. Pearson correlation coefficients between various traits were calculated. All analyses were performed with the SPSS program for Windows.

Results and Discussion

Productive Performance

When comparing feed intake at the growing stage (30-60 kg.), gilts and barrows consumed more ($p<0.05$) feed in total than boars, while no significant group differences occurred in daily feed intake (Table 2). These results supported the findings of Kumar and Barsual.[4] For the finishing (60-100 kg.) and the total fattening period (30-110 kg.), daily feed intake was not significantly different among groups, although barrows showed a slight trend to higher intakes than boars and gilts, as previously reported by Phugphong.[20] In none of the experimental stages did significant differences in average daily gains among groups occur. However, boars showed a very weak trend to higher gains compared to barrows and gilts. This could be explained by the fact that only boars produced testosterone, which is known to increase metabolism and growth rate.[21-24] Estrogen, the female sex hormone, has only a slight effect to increase body metabolism.[25] The present results support the findings of Campbell and King[26], Kumar and Barsual[4], Sather *et al.*[27] and Johansen *et al.*[28]. Barrows had the best feed conversion ratio in the growing period (significantly different from gilts; $p<0.05$). Calculated over the finishing period and both stages, boars tended to have a better feed conversion ratio than gilts. This resulted from both trends of lower feed intakes and higher growth rates, and again can be explained by the effect of the male sex hormone stimulating body metabolism and growth. The results support the findings of Wood and Riley[2], Chadd *et al.*[29], Johansen *et al.*[28], Klindt *et al.*[30] and Henry *et al.*[31]. Fattening of barrows resulted in the lowest feeding costs per unit of gain in the growing stage (significant against gilts; $p<0.05$). As with the feed conversion ratio, boars tended to be the group with the most favourable cost efficiency in the finisher period and over the complete fattening period.

Table 2. Productive performance of pigs of different genders.

Criteria	Barrows	Boars	Gilts	Mean	S.E.	P-value
No. of animals	8	8	8	-	-	-
Initial weight (wt.), kg.	30.2	30.8	30.9	30.6	0.59	0.862
Final wt. (growing stage), kg.	60.6	60.6	60.5	60.5	0.02	0.696
Final wt. (finishing stage), kg.	111	111	110	110	0.4	0.879
No. of days on feed						
stage 30-60 kg.	54.6	55.4	59.6	56.5	2.20	0.623
stage 60-110 kg.	66.8	62.6	66.9	65.4	2.06	0.650
stage 30-110 kg.	121	118	126	122	2.8	0.485
Total feed intake, kg.						
stage 30-60 kg.	70.7^{b}	84.8^{ab}	85.6^{a}	81.4	3.56	0.092
stage 60-110 kg.	199	181	190	190	6.0	0.489
stage 30-110 kg.	257	248	272	259	6.2	0.284
Average daily feed intake, kg.						
stage 30-60 kg.	1.36	1.40	1.39	1.38	0.014	0.897
stage 60-110 kg.	2.98	2.89	2.87	2.91	0.172	0.846
stage 30-110 kg.	2.54	2.52	2.50	2.52	0.169	0.995
Total weight gain, kg.						
stage 30-60 kg.	30.4	29.8	29.6	29.9	0.59	0.852
stage 60-110 kg.	50.2	50.1	49.7	50.0	0.43	0.896
stage 30-110 kg.	80.6	79.9	79.3	79.9	0.89	0.848
Average daily gains, kg.						
stage 30-60 kg.	0.56	0.55	0.52	0.54	0.019	0.696
stage 60-110 kg.	0.76	0.82	0.76	0.78	0.028	0.640
stage 30-110 kg.	0.67	0.68	0.64	0.66	0.015	0.446
Feed conversion ratio, kg. feed/kg. gain						
stage 30-60 kg.	2.33^{b}	2.84^{ab}	3.02^{a}	2.73	0.128	0.062
stage 60-110 kg.	3.97	3.62	3.81	3.80	0.117	0.439
stage 30-110 kg.	3.19	3.11	3.44	3.25	0.083	0.237
Feed cost per gain, baht/kg.						
stage 30-60 kg.	16.5^{b}	20.2^{ab}	21.5^{a}	19.4	0.91	0.062
stage 60-110 kg.	26.9	24.5	25.8	25.7	0.79	0.479
stage 30-110 kg.	22.2	21.6	23.9	22.5	0.58	0.237

Means within rows showing different superscripts are significantly different ($p<0.05$).

Table 3. Carcass characteristics of pigs of different genders.

Traits	Barrows	Boars	Gilts	Mean	S.E.	P-value
No. of animal	8	8	8	-	-	-
Slaughter wt., kg	111	110	110	110	0.5	0.474
Hot carcass wt., kg	83.2	81.6	83.2	82.7	0.60	0.823
Chilled carcass wt., kg	80.9	78.2	80.5	80.0	0.62	0.502
Dressing percentage*, %	75.1	74.0	75.7	74.9	0.36	0.226
Carcass backfat thickness., cm	2.96^{a}	2.27^{b}	2.73^{a}	2.66	0.089	0.050
Carcass length, cm	79.3	80.6	79.6	79.8	0.44	0.284
Loin eye area, cm^2	47.2	48.5	52.7	49.5	1.42	0.536
Lean cut**, %	59.3^{b}	61.8^{a}	61.7^{a}	60.9	0.50	0.034
Loin chop composition, %						
Lean meat	61.8	63.9	66.6	64.6	1.35	0.324
Fat	20.0^{a}	15.4^{b}	16.0^{b}	16.6	0.94	0.031
Bone	12.9	15.8	12.7	13.8	0.79	0.269
Skin	5.27	4.93	4.72	4.97	0.227	0.668
Lean meat : fat, 1:	0.32^{a}	0.24^{b}	0.24^{a}	0.26	0.020	0.054
Lean meat : bone, 1:	0.21	0.25	0.19	0.21	0.016	0.508
Lean meat : skin, 1:	0.09	0.08	0.07	0.08	0.005	0.364

Means within rows showing different superscripts are significantly different ($p<0.05$).
* chilled carcass wt./slaughter wt.
** based on formula[28]

Carcass Quality

Both hot and chilled carcass weights, as well as dressing percentage, were numerically lower in boars than in barrows and gilts (Table 3). This can be explained from the higher proportion of remaining digestive tract content in the body of the boars compared with that of gilts and castrates.[5-6] Carcass backfat of gilts and barrows was thicker ($p<0.05$) than that of boars by 23 and 17 %, respectively. This also affected lean cut percentage, as also reported by Weatherup *et al.*[6]. However, the loin eye area of gilts was the largest at a simultaneously high content of intramuscular fat.[4] The percentage composition of the loin chops, was in line with backfat thickness. Boars had significantly less fat but more bone in loin chops than barrows and gilts ($p<0.05$), which correspondingly affected the meat-to–fat ratio, similar to the results reported by Nold *et al.*[5]. Testosterone is known to promote muscle growth, so that, when it is lacking as in barrows, energy is transferred to fat tissue at a higher rate.

When applying the Thai cutting style (boneless, except for spare ribs), there were no significant differences among groups concerning the proportions of loin, tenderloin, ham, belly and spare ribs (Table 4). However, shoulder and jowl percentages were higher ($p<0.05$) in boars than in barrows and gilts, probably as a result of the different sexual development. Furthermore, boars yielded more ($p<0.05$) total lean and less fat than barrows and gilts. These results are supported by findings of Ellis et al. [32], Weatherup et al.[6] and Blanchard et al.[8].

Meat Quality

The $pH_{45\ min.}$ values determined in SM and LD did not significantly differ among groups (Table 5). This was similar to the findings of Ellis *et al.*[32], Cisneros *et al.*[33], Henry *et al.* [31] and Nold *et al.*[5]. However, the pH of boar meat tended to be lower than that of gilt and barrow meat. This would be expected from the more

Table 4. Carcass composition of fishing pigs of different genders when dissected according to the Thai style cutting (% of chilled carcass weight).

Parameters	Barrows	Boars	Gilts	Mean	S.E.	P-value
Loin	7.28	7.32	7.59	7.40	0.184	0.770
Tenderloin	1.13	1.44	1.39	1.32	0.066	0.114
Belly	9.78	8.71	10.2	9.56	0.409	0.319
Spare rib	3.60	4.54	4.29	4.14	0.301	0.435
Ham	20.0	20.7	20.2	20.3	0.33	0.709
Shoulder	12.1^{b}	13.8^{a}	12.2^{b}	12.7	0.28	0.024
Jowl	5.73^{ab}	6.22^{a}	5.29^{b}	5.75	0.145	0.024
Overall carcass						
Meat	46.6^{b}	49.9^{a}	47.1^{ab}	47.9	0.53	0.015
Fat	11.0^{a}	8.18^{b}	8.07^{b}	9.08	0.572	0.056
Abdominal fat	1.44	1.24	1.34	1.34	0.092	0.705
Skin	7.10^{a}	6.98^{a}	5.30^{b}	6.46	0.324	0.033
Bone	8.35	7.94	6.63	7.64	0.450	0.278

Means within rows showing different superscripts are significantly different ($p<0.05$).

Table 5. pH values and color of meat from pigs of different genders.

Traits	Barrows	Boars	Gilts	Mean	S.E.	P-value
Mean muscle $pH_{45\ min.}$						
M. Semimembranosus	6.36	6.10	6.26	6.24	0.089	0.511
M. Longissimus dorsi	6.27	5.97	6.14	6.12	0.102	0.496
Proportion of $pH_{45\ min.}$ values below 5.8						
M. Semimembranosus	0.25	0.25	0.25			
M. Longissimus dorsi	0.12	0.38	0.25			
Mean muscle $pH_{24\ hr.}$						
M. Semimembranosus	5.20	5.36	5.36	5.30	0.040	0.148
M. Longissimus dorsi	5.17	5.32	5.28	5.26	0.035	0.133
Color$_{48\ hr.}$ (*M. Longissimus dorsi*)						
- Luminosity (L*)	61.5	59.9	60.0	60.5	0.97	0.772
- Red-green index (a*)	8.86	8.44	9.11	8.81	0.313	0.701
- Yellow-blue index (b*)	7.71	6.75	7.72	7.39	0.345	0.439

aggressive behavior of boars, which contributes to stress susceptibility.[34-36] This, in turn, causes muscle glycogen to be degraded to a higher extent. This enhances the post mortem glycolysis process leading to high lactic acid accumulation and hence a low early-post mortem pH value of the meat. The $pH_{24\,hr}$ values did not differ significantly among groups, similar to the findings of Mottram *et al.* [37] and Wood *et al.*[38]. In the present experiment, no single animal had a late-post mortem pH of over 6.1, indicating that no dark firm dry (DFD) meat was developing.[39] It has to be kept in mind, though, that the length of the fasting period (high or low glycogen stores) and slaughter conditions (enhancing or preventing fights among boars, etc.) will determine whether boars tend more towards PSE or DFD compared to barrows and gilts.

The L* values were not statistically different among groups, but boars tended to have the lowest L* value, followed by gilts and barrows (Table 5). Weatherup *et al.*[6] and Uttaro *et al.*[40], reporting the same effect in boar ham, discussed that meat with a high water-holding capacity results in a low light reflection, making the meat appear to be dark. However, in the present study, the ultimate pH data had excluded DFD incidence as a reason and, as shown later on, differences in water holding capacity did not support this either. The a* and b* values were also not statistically different among the three groups studied, but boars again tended to have the lowest a* and b* values followed by barrows and gilts, which was similar to the results obtained by Weatherup *et al.*[6]. However, Nold *et al* [41] reported that the a* value of boar meat was significantly higher than that in barrows and gilts. The low a* and b* values indicate a low content of oxymyoglobin which is created in the oxidiation process of myoglobin when exposed to air in meat. [40,42] The low a* and b* values obviously were not related to the same factors affecting lightness, as then a light boar meat would have been expected.

LD from boars and gilts had higher ($p<0.05$) boiling losses than that of barrows (+36% and +42%, respectively), but there were no significant differences in drip loss, thawing loss and grilling loss among the three groups (Table 6). However, boar meat had a weak tendency to higher grilling losses compared to that of the barrows (+15%) as was also noted by Lundstrom *et al.*[43], Kempster *et al.*[7], Weatherup *et al.*[6] and Blanchard *et al.*[8]. This is more or less in line with the findings in early-post mortem pH and meat color. Moisture content of LD was not significantly different among groups. Weatherup *et al* [6] and Nold *et al* [41] found that boar meat had a higher moisture content than that of gilts and barrows. Meat protein contents also did not differ significantly in the present study. The slightly higher protein content of boar meat compared to that of gilts and barrows is in accordance with results of Kumar and Barsual.[4] Barrows had the highest ($p<0.05$) intramuscular fat content. This result is supported by the findings of Friesen *et al.* [44]. Any difference in the nutrient content of the meat could be ascribed to the different hormone profiles in the different genders. Especially, testosterone enhances protein synthesis, while reducing fat accumulation.[38,44] In line with Nold *et al.* [41], the LD from boars was clearly inferior ($p<0.01$) to that of barrows and gilts in terms of tenderness scoring. Shear force was accordingly higher ($p<0.05$) in boar meat compared to barrow meat, but the difference to meat from gilts in shear force was lower than expected from the sensory evaluation. Juiciness and overall acceptability of boars' LD were also lower ($p<0.05$) than in meat from barrows and gilts. Juiciness might have been impaired in boars compared to barrows because of the lower intramuscular fat content. However, meat from boars and gilts did not differ in these variables and gilt meat was scored higher ($p<0.05$) in juiciness nevertheless.

Boar Taint

The testosterone concentration in boar blood plasma was far higher ($p<0.01$) than that in barrows and gilts (3×10^3 and 14×10^3 fold; respectively; Table 6). Patterson[45] and Baltic *et al.*[46] reported that the pathway of androstrenone and testosterone synthesis is the same, so that in this study plasma testosterone was taken as an indirect indicator of the formation of androstenone, the major component of boar taint, suggesting the presence of an intensive boar taint in the animals investigated in this study. Nonetheless, this was not reflected in sensory flavor scores and panelist could not detect off-flavors, including the boar taint components, in boar meat. A considerable proportion of humans are not able to detect androstenone[47], but the panelists carrying out the sensory testing had a confirmed ability to recognize boar taint. The skatole concentration in backfat is another component of the off-flavor often observed in boar meat. Accordingly, boar backfat was found to have higher ($p<0.05$) skatole concentrations than those of barrows and gilts (+31 % and +52 %, respectively) similar to the findings of Brook and Pearson[48], Claus *et al.*[49], Moss *et al.*[50] and Nold *et al.*[5]. However, skatole concentrations in boar meat were still lower than those allowed by EU regulations.[51] One reason for that may have been the use of a pig fattening diet with relatively low tryptophan content, since tryptophan is an important precursor of skatole formation in the hindgut of pigs.[52-53]

Fat Tissue Quality

No significant group differences were found in individual fatty acids, groups of fatty acids and in various fatty acid ratios in backfat (Table 7). There was a weak

Table 6. Quality traits of meat from pigs of different genders.

Traits	Barrows	Boars	Gilts	Mean	S.E.	P-value
Water holding capacity						
Drip loss, %	8.6	10.5	9.5	9.5	0.83	0.662
Thawing loss, %	17.9	15.9	17.0	17.0	0.92	0.685
Boiling loss, %	16.2[b]	22.1[a]	23.1[a]	20.5	0.91	0.001
Grilling loss, %	17.6	20.2	19.8	19.2	0.96	0.504
Chemical composition*						
Moisture, %	73.2	73.4	73.4	73.3	0.18	0.898
Protein, %	21.3	21.7	21.5	21.5	0.12	0.470
Fat, %	2.55[a]	1.63[b]	1.57[b]	1.92	0.195	0.067
Panel score**						
Tenderness	3.55[a]	2.86[b]	3.53[a]	3.30	0.017	0.001
Flavor	3.24	3.10	3.30	3.21	0.068	0.453
Juiciness	3.29[a]	2.82[b]	3.11[a]	3.06	0.081	0.063
Overall acceptance	3.41[a]	2.97[b]	3.31[ab]	3.22	0.080	0.060
Shear values						
Maximum force, N	26.5[b]	35.8[a]	33.9[a]	32.1	1.32	0.004
Total energy, mJ	102[b]	141[a]	122[ab]	122	5.71	0.014
Extension, mm	17.9	18.0	17.2	17.7	0.21	0.252
Indicators of boar taint						
Plasma testosterone (pg/ml)	0.09[b]	277.67[a]	0.020[b]	92.59	45.90x	0.001
Backfat skatole (mg/g)	37.6[b]	49.9[a]	32.9[b]	40.13	2.31	0.506

* Percentage in original substance.
** Score of 1 to 5 : 1=extremely tough, extremely strong off-flavor, dry, extremely disliked; 5=extremely tender, no off flavor, extremely juicy, extremely liked.
[a, b] Means within rows showing different superscripts are significantly different ($p<0.05$).

Table 7. Fat tissue properties as determined in backfat of pigs of different genders.

Traits	Barrows	Boars	Gilts	Mean	S.E.	P-value
Fatty acids, % of total FA						
Saturated fatty acids						
Palmitic acid	28.62	27.66	28.55	28.27	0.509	0.690
Stearic acid	17.16	15.68	16.51	16.45	0.344	0.245
Arachidic acid	0.30[b]	1.10[a]	0.79[ab]	0.73	0.123	0.041
Total saturated fatty acid	46.08	44.40	45.85	45.41	0.696	0.589
Unsaturated fatty acids						
Oleic acid	43.02	43.14	43.70	43.29	0.449	0.813
Linoleic acid	10.03	11.60	9.64	10.42	0.847	0.609
Linolenic acid	0.66	0.67	0.62	0.65	0.054	0.932
Arachidonic acid	0.23[b]	0.30[a]	0.22[b]	0.25	0.014	0.050
Total unsaturated fatty acids	53.94	55.71	54.19	54.64	0.685	0.544
Fatty acid ratio*	1.17	1.25	1.18	1.20	0.033	0.521
P/S ratio	0.23	0.28	0.22	0.24	0.023	0.542
Adjusted P/S ratio*	0.37	0.43	0.35	0.38	0.035	0.567
Backfat firmness						
Force, N	5.22[a]	2.12[b]	3.94[a]	3.76	0.415	0.004
Energy, mJ	34.9[a]	12.6[b]	26.6[a]	24.7	2.95	0.003
Pressure, N/m^2 (X 10^2)	266[a]	110[b]	200[a]	192	20.9	0.004
Extension, mm	33.9[a]	32.9[b]	33.6[ab]	33.4	0.20	0.092
TBA value of backfat (mg malonaldehyde/kg backfat)						
0 days of storage	1.12	1.42	1.05	1.20	0.057	0.748
7 days of storage	1.70	2.56	1.64	1.97	0.074	0.835
14 days of storage	2.63	2.87	2.30	2.06	0.127	0.452
TBA value of intramuscular fat (mg malonaldehyde/kg *M. longissimus dorsi*)						
0 days of storage	0.17	0.16	0.16	0.16	0.026	0.999
7 day of storage	0.37	0.42	0.25	0.35	0.053	0.317
14 day of storage	0.58	0.64	0.41	0.54	0.063	0.423

* Fatty acid ratio = ratio of unsaturated to saturated fatty acids, P/S ratio = polyunsatured to saturated fatty acids, and Adjusted P/S ratio = ratio calculated without considering stearic acid.
[a, b] Means within row showing different superscripts are significantly different ($p<0.05$).

tendency for boar fat tissue to have higher proportions of unsaturated fatty acids (significant for the dietetically undesired arachidonic acid, $p<0.05$). Obviously the influence of the sex hormones on fatty acid accretion in the body is minor. Firmness of backfat from boars was significantly lower than that from gilts and barrows ($p<0.05$). Although it is known that fat firmness declines with the proportion of unsaturated fatty acids[54], the differences found in fatty acid profile were probably too small to explain such clear differences in fat firmness. Fat tissue firmness is also influenced by its contents of water and connective tissue, variables which were not analyzed here. Also thiobarbituric acid (TBA) values of the backfat and intramuscular fat of boars tended to be reduced at every stage of storage, but these values were not significantly different from those found in barrows and gilts. This also would be in line with a higher content of unsaturated fatty acids. However, gender differences in the utilization of antioxidative substances in feed such as vitamin E and selenium cannot be excluded, too.

Conclusion

Boar meat was found to be clearly inferior in various aspects (water-holding capacity, tenderness, fat firmness and shelf life) to meat from barrows and gilts raised under identical conditions and on the same diet. Considering the small differences in growth performance and feed conversion efficiency among the gender groups, it does not seem economically feasible to fatten boars, due to the risk of rejection by consumers because of the risk of boar taint and reduced tenderness. Slaughtering at lower live-weights might be helpful in many respects, but this might also adversely affect cost-efficiency. Another way to support the fattening of boars would be to provide subsidies to allow the marketing of boar meat at a lower price, in order to avoid the stressful castration and the risk that farmers use illegal drugs such as beta-adrenergic agonists.

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References

1. Jaturasitha S, Wudthithumkanaporn Y, Rurksasen P and Kreuzer M (2002) Enrichment of pork in omega-3 fatty acids by tuna oil supplements: effects on performance as well as sensory, nutritional and technological properties of pork. *Asian-Aust J Anim Sci* **15**, 1622-33.
2. Wood JP and Riley JE (1982) Comparison of boar and castrates for bacon production. I. Growth data, and carcass and joint composition. *Anim Prod* **35**, 55-63.
3. Judge MD, Mills EW, Orcutt MW, Forrest JC, Diekman MA, Harmon BG and Lis RS, *et al* (1990) Utilization of boar meat: Composition, quality and odor incidence in relation to androstenone and skatole. *J Anim Sci* **68**, 1030-3.
4. Kumar A and Barsaul CS (1991) Evaluation of best sex and economic slaughter weight standard feeding in large white pigs under Indian conditions. *Aust J Anim Sci* **4**, 227-30.
5. Nold RA, Romans JR, Costello WJ, Itenson JA and Libal GW (1997). Sensory characteristics and carcass traits of boar, barrows, and gilt fed high- or adequte-protein diets and slaughtered at 100 or 110 kilograms. *J Anim Sci* **75**, 2641-51.
6. Weatherup RN, Beattie VE, Moss BW, Kilpatrick DJ and Walker N (1998) The effect of increasing slaughter weight on the production performance and meat quality of finishing pigs. *J Anim Sci* **67**, 591-600.
7. Kempster AJ, Dilworth AW, Evans DG and Fisher KD (1986) The effect of fat thickness and sex on pig meat quality with special reference to the problems associated with overleaness. *Anim Prod* **43**, 517-33.
8. Blanchard PJ, Ellis M, Warkup CC, Chardwick JP and Willis MB (1999) The influence of sex (boar and gilt) on growth, carcass and pork eating quality characteristics. *J Anim Sci* **68**, 487-93.
9. NRC (National Research Council) (1998) Nutrient Requirements of Swine, 10th ed., National Academy Press, Washington DC, 190.
10. Pongpiachan P (1996) The Principle of Feed (2) : Principle of Nutrition and Application, Odean Store Press, Bangkok, 211.
11. Jaturasitha S (2004) Meat Management, Mingmuang Press, Chiang Mai, 170.
12. AOAC (1992) Official Methods of Analysis of the Association of Official Analytical Chemists, 15th ed., Arlington Inc., Washington DC, USA.
13. Wiriyajaree P (1992) Experiment and Analysis of Organoleptic Test, Department of Food Science and Technology, Faculty of Agriculture, Chiang Mai University, Chiang Mai, 275.
14. Wasser SK, Thomas R, Nair PP, Guidry C, Southers J, Lucas J and Wildt DE, *et al* (1993) Effect of dietary fiber on fecal steroids measurement in baboons (*Papiocynocephalus cynocephalus*). *J Reprod Fert* **97**, 569-74.
15. Dehnhard M, Claus R, Hillenbrand M and Herzog A (1993) High-performance liquid chromatographic method for the determination of 3-methylindole (skatole) and indole in adipose tissue of pigs. *J Chromatogr* **616**, 205-9.
16. Jaturasitha S, Kreuzer M, Lange M and Köhler P (1996) Quality of subcutaneous, intermuscular and intramuscular fat tissue using elevated quantities of medium chain fatty acids in pig fattening. *Fett/Lipid* **98**, 149-56.
17. Folch J, Lees M and Stanley GHS (1957) A simple method for the isolation and purification of total lipids from animal tissue. *J Biol Chem* **226**, 497-509.
18. Morrison WR and Smith LM (1964) Preparation of fatty acid methyl esters and dimethyl acetals from lipids with boron fluoride-methanol. *J Lipid Res* **5**, 600-8.
19. Chantaluckhana C (1997) Statistics and Experimental Design, Thai Wattanapanit Press, Bangkok, 468.
20. Phugphong B (1989) Swine Production, Department of

Animal Science, Faculty of Agriculture, Chiang Mai University, Chiang Mai, 299.
21. Snochowski M, Lundstrom K, Dahlberg E, Petersson H and Edqvist LE (1981) Androgen and glucocorticoid reception in porcine skeletal muscle. *J Anim Sci* **53**, 80-90.
22. Squires EJ, Adeola O, Young LG and Hacker RR (1993) The role of growth hormone, β-adrenergic agent and intact males in pork production. A review. *Can J Anim Sci* **73**, 1-9.
23. David DW (1997) Reproductive Hormones. Laboratory Animal Endrocrinology, John Wiley & Sons Ltd., West Sussex, 567.
24. Norman AW and Litwack G (1997) Hormones. 2nd ed., Harcourt Brace & Company, California, 558.
25. Goodman HM (1988) Basic Medical Endocrinology, Raven Press, New York, 346.
26. Campbell RG and King RH (1982) The influence of dietary protein and level of feeding on the growth performance and carcass characteristics of entire and castrated male pigs. *Anim Prod* **35**, 177-84.
27. Sather AP, Jones SDM and Joyal S (1991) Feedlot performance, carcass composition and pork quality from entire male and female Landrace and Large White market-weight pigs. *Can J Anim Sci* **71**, 29-42.
28. Johansen S, Hakanssonm J and Anderson K (1993) Effect of selecting for increased lean tissue growth rate in swine on low or high dietary protein levels. *J Anim Sci* **71**, 1203-8.
29. Chadd SA, Cole DJA and Walters JR (1993) The food intake, performance and carcass characteristics of two pig genotype grown to 120 kg live weight. *Anim Prod* **57**, 473-81.
30. Klindt J, Buonomo FC and Yen JT (1995) Administration of porcine somatotropin by sustained-release implant: growth, carcass and sensory responses in crossbred white and genetically lean and obes boars and gilts. *J Anim Sci* **73**, 1337-9.
31. Henry Y, Seve B, Mounier A and Ganier P (1996) Growth performance and brain neurotransmitters in pigs as affected by tryptophan, protein and sex. *J Anim Sci* **74**, 2700.
32. Ellis M, Webb AJ, Avery PJ and Brown N (1996) The influence of terminal sire genotype, sex, slaughter weight, feeding regime and slaughter house on growth performance and carcass and meat quality in pigs and on the organoleptic properties of fresh pork. *J Anim Sci* **62**, 521-30.
33. Cisneros F, Ellis M, McKeith FK, McCaw J and Fernando RL (1996) Influence of slaughter weight on growth and carcass characteristics, commercial cutting and curing yield, and meat quality of barrows and gilts from two genotypes. *J Anim Sci* **74**, 925-33.
34. Ellis M, Smith WC, Clark JBK and Innes N (1983) A comparison of boars, gilts and castrates for bacon manufacture. *Anim Prod* **73**, 1-9.
35 Schwagele F, Lopes Buesa PL and Honikel KO (1996b) Enzymological investigations on the causes for the PSE-syndrome II. Comparative studies on glycogen phosphorylase from pig muscles. *Meat Sci* **44**, 41-53.
36. Snochowski M, Lundstrom K, Dahlberg E, Petersson H and Edqvist LE (1981) Androgen and glucocorticoid reception in porcine skeletal muscle. *J Anim Sci* **53**, 80-90.
37. Mottram DS, Wood JD and Patterson RLS (1982) Comparison of boars and castrates for bacon production. *Anim Prod* **35**, 75-80.
38. Wood JD, Jones RCD, Francombe MA and Whelehan OP (1986) The effect on fat thickness and sex on pig meat quality with special reference to the problems associated with overleaness. *Anim Prod* **43**, 535-44.39.
39. Jaturasitha S (2000) Meat Technology, Thanabun Press, Chiang Mai, 244.
40. Uttaro BE, Ball RO, Dick P, Rae W, Vessie G and Jeremiah LE (1993) Effect of ractopamine and sex on growth, carcass characteristic, processing yield, and meat quality characteristic of crossbred swine. *J Anim Sci* **71**, 2439-49.
41. Nold RA, Romans JR, Cosetello WJ, Henson JA and Libal GW (1999) Characteristics of muscle from boars, barrows, and gilts slaughtered at 100 or 110 kilograms: difference in fat, moisture, color, water-holding capacity, and collagen. *J Anim Sci* **77**, 1746-54.
42. Forrest JC, Abele ED, Hedrick HB, Judge MD and Merkel RA (1975) Princples of Meat Science, W.H. Freeman and Company, New York, 417.
43. Lundstrom K, Malmfors B, Vahlun S, Kempster AJ, Andresen Q and Hagelso AM (1985) Recent research on the use of boar for meat production - a report from the EAAP Working Group Meeting in Denmark, 1984. *Livest Prod Sci* **13**, 303-9.
44. Friesen KG, Nelssen JL, Unruh JA, Goodband RD and Tokach MD (1994) Effect of the interrelationship between genotype, sex, and dietary lysine on growth performance and carcass composition in finishing pigs fed to either 104 or 127 kilograms. *J Anim Sci* **72**, 946-54.
45. Patterson P (1968) 5-androst-16-ene-3-one: compound responsible for boar taint fat. *J Sci Food Agric* **19**, 31-7.
46. Baltic M, Raicevic S, Tadic I and Drljacic A (1997) Influence of zeolite on skatole content of swine fat tissue. In: Boar taint in entire male pigs. "Production and utilization of meat from entire male pigs". *EAAP Publication* **92**, 97-9.
47. Dijksterhuis G, Walstra P, Agerhem H, Font i Fernols M, Oliver MA, Siret F and Beague MP, *et al* (1997) EU research program on boar taint: characteristics of the samples selected for sensory evaluations by test panels. "Production and utilization of meat from entire male pigs". *EAAP Publication* **92**, 20-8.
48. Brook RI and Pearson AM (1989) Odor threshold of the C_{19}-D16 steroids responsible for boar odor in pork. *Meat Sci* **25**, 11-9.
49. Claus R, Weiler U and Herzog A (1994) Physiological aspects of androstenone and skatole formation in the boar – a review with experimental data. *Meat Sci* **38**, 289-305.
50. Moss BW, Beattie VE and Weatherup N (1997) Effect of increasing slaughter weight on meat quality and boar taint. In: Boar taint in entire male pigs. "Production and utilization of meat from entire male pigs". *EAAP Publication* **92**, 100-3.
51. Lundstrom K, Malmfors B, Malmfors G, Stern S, Peterson H, Mortenson AB and Sorenson SE (1988) Skatole, androsterone and taint in boar fed two different diets. *Livest Prod Sci* **18**, 55-67.
52. Jensen MT and Jensen BB (1997) Tasty meat through diet design: production of the boar taint compound skatole can be reduced through selecting the right ingredients to use in pig diets. *Feed Mix* **5**, 8-12.
53. Melvin T and Carlson JR (1979) Microbial metabolites of tryptophan in the intestinal tract with special reference to skatole. *Am J Clini Nutr* **32**, 173-8.
54. Van Oeckel MJ, Casteels M, Warnants N, Van Damme L and Boucque CV (1996) Omega-3 fatty acids in pig nutrition: implications for the intrinsic and sensory quality of meat. *Meat Sci* **44**, 55-63.