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Carcass and Meat Quality Characteristics of *Lechon*-Size Black Tiaong and Kalinga Native Pigs (Organic-like Farm) and Landrace, Large White, and their F1 Crosses (Conventional Farm)

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This study aimed to compare carcass characteristics and meat quality traits of *lechon*-size (less than 30 kg) pigs belonging to Philippine native breeds (i.e., Black Tiaong and Kalinga) raised in organic-like production system and commercial breeds [i.e., Landrace (LDR), Large White (LRW) and their F1 crosses] obtained from a conventional swine breeding farm. Native breeds had shorter body length and shorter carcass length than commercial breeds ($P < 0.01$). Weight of ham, fore shank and hind shank were lower ($P < 0.01$) in native breeds than in the commercial breeds. However, weight of belly was higher ($P < 0.01$) in native pig breeds. Among the native breeds, Black Tiaong had heavier ham and higher ham proportion than Kalinga pigs ($P < 0.01$). Among commercial breeds, Landrace had the biggest ham and the smallest was that of the F1 LRW x LDR cross ($P < 0.01$). Pork carcass from native breeds had lower weight of lean and bones ($P < 0.01$) but more fat and skin ($P < 0.01$) than the commercial breeds. Loin eye area was smaller ($P < 0.01$) in native breeds than in the commercial breeds. Pre-slaughter backfat thickness was higher in native breeds than in the commercial breeds. However, carcass backfat thickness was higher ($P < 0.01$) in native breeds than in the commercial breeds. The correlation between live and carcass backfat thickness ranged from $r = 0.59$ to 0.79. Kalinga pigs had higher ($P < 0.01$) ultimate pH (24 h post-mortem) than Black Tiaong pigs. Ultimate pH was highest in Landrace, followed by F1 LDR x LRW cross and F1 LRW x LDR cross, and Large White ($P < 0.01$). Color of loin muscle was lighter and pale in native breeds in the organic-like production system than in the commercial breeds from the conventional production system ($P < 0.05$). Kalinga pigs had lighter color than Black Tiaong pigs ($P < 0.05$). Color of pork was lightest in the F1 LRW x LDR cross, followed by the F1 LDR x LRW cross, Landrace, and Large White ($P < 0.01$).

Key Words: carcass characteristics, conventional production system, meat quality, native and commercial pig breeds, organic-like production system

Abbreviations: LDR – Landrace, LRW – Large White

INTRODUCTION

As farmers and consumers are increasingly interested in the quality of food and in the circumstances of its production, a growing amount of food may now be produced according to the standards of organic farming. This applies to the production of *lechon*-size (less than 30 kg) pigs that are slow-roasted over charcoal. Organic livestock farming aims to prevent inputs with potentially harmful health effects, and is based on living ecological systems and cycles, while providing conditions for animals to meet their physiological needs and ensure animal welfare (IFOAM 2014). In the Philippines, for example, adapted native pig breeds from organic or organic-like farms are especially preferred for the production of *lechon* (roast suckling pig) (Bondoc 2015).

In general, the quality of organic pork may be considered higher than the quality of conventional pork in terms of fatty acid profile, mineral and antioxidant contents, and risk of chemical and growth promotant residuals (Braghieri and Napolitano 2009). However, the higher quality of organic pork may also be related to process characteristics rather than to differences in the end product.

Pork quality traits are commonly influenced by

Table 1. Number and distribution of lechon-size pigs used in the study.

Type of Production System	Breed or F_1 Cross	Barrows	Gilts	Breed Total	Production System Total
Organic-like farm (with native breeds)	Black Tiaong	6	6	12	24
	Kalinga	6	6	12	
Conventional breeding farm (with commercial breeds and F1 crosses)	Landrace (LDR)	2	2	4	16
	Large White (LRW)	2	2	4	
	F1 LDR x LRW cross	2	2	4	
	F1 LRW x LDR cross	2	2	4	
Total		20	20	40	40

Note: Group total per sex for each native breed (N = 6) consisted of 3 pigs per weight class (< 20 kg and > 20 kg). All commercial pigs weighed more than 20 kg at slaughter.

several ante-mortem and post-mortem factors (Sellier and Monin 1994). For example, selection of pigs according to growth performance has modified the sensorial and nutritional qualities of pork (Mourot 2009). As commercial pigs have been selected for growth performance, they are slaughtered younger at the same weight or size. Since the intramuscular adipose is laid down at a later stage in their life, commercial pigs are less fat. The lipid content of pork is thus less developed in pigs that are slaughtered younger. In a similar study, Serra et al. (1998) reported that at equivalent weight, the animals of local breeds with a slow growth rate are slaughtered when older than those selected for rapid growth. Their covering fat is more developed and lipid content higher in both backfat tissue and in the muscle (*longissimus dorsi*). In a separate taste trial, Labroue et al. (2001) showed fatter and less firm texture of roast pork from local breeds, which could explain why consumers prefer these. On the other hand, the reduced lipid content of meat may allow consumers to consider pork as dry and tasteless.

Despite the increasing importance of meat quality (chemical composition, mechanical properties, etc.) or meat eating quality traits (sensory characteristics) to consumers, local research studies on them especially *lechon*-size (less than 30 kg) pigs are very limited if at all available. In this regard, this study was conducted to evaluate carcass characteristics and meat quality traits from *lechon*-size pigs belonging to different native pig breeds (Black Tiaong and Kalinga) obtained from an organic-like pig production farm and commercial breeds (Landrace - LDR, Large White – LRW), and F1 crosses (F1 LDR x LRW cross, and F1 LRW x LDR cross) purchased from a private, conventional pig breeding farm. This study also determined the possible effects of type of production system (confounded as genetic effect of breed groups), breed within a particular production system, sex, weight group, age and weight at slaughter on carcass characteristics and meat quality traits. Such information will not only be important in the design of genetic improvement (selection) programs within the native pig breeds, but also promote their conservation and utilization in local *lechon* production.

MATERIALS AND METHODS

This study was conducted in compliance with the requirements of the Institutional Animal Care and Use Committee (IACUC) of the University of the Philippines Los Baños in collaboration with the National Swine and Poultry Research and Development Center, Bureau of Animal Industry (BAI), Department of Agriculture which promotes organic or organic-like agriculture in smallholder pig farming based on native pig breeds.

Data

A total of 40 *lechon*-size (less than 30 kg) pigs, divided equally by sex (20 barrows and 20 gilts), from two native pig breeds (Black Tiaong and Kalinga) and four commercial pure breeds and F1 crosses [Landrace (LDR), Large White (LRW), F1 LDR x LRW cross, and F1 LRW x LDR cross] was used in the study (see Table 1). Native pig samples (N = 24) from the organic-like swine farm were divided equally into two weight classes, namely < 20 kg (i.e., average of 17.8 ± 1.3 kg at 161.7 ± 29.0 d old) and > 20 kg (i.e., average of 23.0 ± 1.1 kg at 117.2 ± 30.0 d old). On the other hand, commercial pigs (N = 16) from the conventional/commercial breeding farm were all more than 20 kg at slaughter (i.e., average of 24.0 ± 1.9 kg at 86.7 ± 14.1 d old).

Pig samples were randomly chosen for each breed,

Table 2. Comparison of type of production system.

	Organic-like Production System	Conventional Swine Breeding Farm
Location	NSPRDC, BAI, DA, Lagalag, Tiaong, Quezon (approx. 13° 56' 36.96" N, 121° 22' 22.97" E)	INFARMCO, San Isidro, Cabuyao, Laguna (approx. 14 ° 14' 49.69" N, 121° 8' 34.41" E)
No. of animals used	24	16
Breeds used	Black Tiaong, Kalinga	Landrace (LDR), Large White (LRW), F_1 LDR x LRW cross, F_1 LRW x LDR cross
Housing system	Semi-confined housing system which provides a house with adjoining fenced-off roaming/ loafing area for breeder animals (15 m x 20 m pen with wallowing area) and pregnant and lactating sows (2 m x 2 m individual pens with small openings allowing piglets free access to roaming area). Flooring material is composed of garden soil, coconut husk, coconut coir, rice hull, and salt. Complete confinement for weaners/ growers (5 m x 3 m) with cement flooring.	Indoors, using elevated cast iron slatted floors in lactation pens from day 1 to weaning (30 d old) and in group pens (up to 8 pigs per 3 m x 3 m pen) with solid concrete floor from post-weaning (31-77 d old) and growing-finishing (78-180 d old).
Feeds	Specially-formulated feed concentrate rations for boars, sows, and growers containing corn, soybean, rice bran, copra meal, molasses, salt and limestone. Fresh fodder from "madre de agua" (*Trichantera gigantea*), "malunggay" (*Moringa oleifera*), sweet potato (*Ipomea batatas*),"gabi" (*Colocasia esculentum*), "kulape" (*Paspalum conjugatum*), and water fern (*Azolla filiculoides*) and vegetable wastes from the wet market - carrots (*Daucus carota*), eggplant (*Solanum melongena*), cabbage (*Brassica oleracea*), and cucumber (*Cucurbita maxima*).	Commercial feed rations are given - yoghurt (3-10 d old), booster (7-42 d old), booster - pre-starter (43-50 d old), pre-starter (51-70 d old), starter (78-98 d old), grower (99-133 d old) for gilts, gilt developer (134-180 d old), and performance test rations for boars (99-180 d).
Breeding methods	Natural mating	Artificial insemination using fresh diluted semen
General herd and health management practices	Male piglets are castrated at weaning. Navel cutting, teeth clipping and tail docking is not practice. All pigs are vaccinated against hog cholera. Mange, scabies and lice are treated using "Kakwate" (*Gliricidia sepium*). Common swine flu and diarrhea are treated using decoction of guava (*Psidium guajava*) and star apple (*Chrysoplyllum cainito*).	Male piglets are castrated as early as 3 d old. All pigs are injected with iron injection (3 d old) and vaccinated against Porcine Respiratory Syndrome or PRRS (21 d old), hog cholera (56 d old), and pseudo rabies (70 d old). Anti-scouring/diarrhea agents in oral suspension are given to pigs.

representing the typical *lechon*-size pigs available from existing organic-like and conventional production farms (see comparisons of organic-like and conventional pig production systems in Table 2). In the former, *lechon*-size pigs belong to the pure native breeds, while in the latter farm, *lechon*-size pigs commonly consist of "defective" market hogs (slow growers) weighing at least 7 kg at weaning. Commercial stocks are not usually slaughtered for *lechon* production since they have the potential to be slaughtered more profitably at heavier weights with less effect on carcass merit and(or) feed conversion efficiency. The effect of type of farm, with respect to housing and feeding under real production conditions, is confounded with genetic effects, since native pig breeds are not yet produced under commercial production systems - which in turn, consider only the production of commercial pure breeds and their F_1 crosses.

Pigs were transported from the farm a day before slaughter and fasted for at least 12 h prior to slaughter at the university abattoir of the Institute of Animal Science, College of Agriculture and Food Science, University of the Philippines Los Baños. Body length before slaughter was measured as the distance from the *occipital proturberance* and the pin bone. Animals were slaughtered according to standard slaughtering practice (Ibarra 1983). About 6 to 8 pigs were slaughtered in six slaughter dates from May to June 2016. Pigs were stunned prior to bleeding. Pigs were then scalded by pouring hot water over the body and dehaired manually. Subsequent to evisceration, the head, feet and leaf fat were removed.

Carcass Characteristics

After chilling at 2–4°C for 24 h, the carcass was split along the backbone. Carcass length was measured from the anterior part of the first rib (thoracic vertebra) to the dorsal tip of the exposed *symphysis* pubis. Carcass halves were weighed and fabricated into standard primal and minor cuts, according to the Philippine National Standard for Pork Cuts as recommended by BAFPS (2008), i.e., whole shoulder (boston shoulder or "*paypay*" and picnic shoulder or "*kasim*"), loin (longissimus thoracis et lumborum), belly ("*liempo*"), ham or hind leg (*semimembranosus* or "*pigue*"), fore shank ("*pata unahan*"), hind shank ("*pata hulihan*"), and tenderloin ("*lomo*"). Whole shoulder cut is from the 1st cervical vertebrae up to the 4th rib. Loin is composed of the 5th rib down to the 6th lumbar vertebrae. Ham or hind leg cut includes the 7th lumbar vertebrae up to the last caudal vertebrae.

Weight of Lean, Fat and Skin, and Bones

Pork cuts were weighed and percent cut yields were computed relative to the half carcass weight. Left carcass was then dissected into soft tissues (lean, fat and skin) and bones (including tendons and cartilages). The carcass components were weighed and tissue composition was expressed relative to the half carcass weight.

Loin Eye Area

Loin eye area (LEA) was measured on the cross-section of the *longissimus dorsi* muscle in between the 10th and 11th thoracic vertebras and averaged over the left and right carcasses. Loin eye area was computed out of the scanned perimeter of the loin muscle drawn on tracing paper, using the ImageJ software (Schneider et al. 2012).

Backfat Thickness

Backfat thickness was recorded in the live animal prior to slaughter using Renco® Lean-Meater Ultrasonic Back Fat Detector (Minneapolis, Minnesota, USA) in three sites, namely, dorsal fat layer at the shoulder (LivBFT1 or shoulder fat thickness), 10th or last rib (LivBFT2), and ham or above the *gluteus medius* situated on the outer surface of the pelvis (LivBFT3 or ham fat thickness). Carcass backfat thickness corresponding to the fat thickness measured at the point opposite the first rib (cBFT1), last rib (cBFT2) and last lumbar vertebra (cBFT3) were measured using a digital caliper. Carcass backfat thickness measures were then averaged for the three sites and over the left and right carcasses.

Meat Quality

Meat quality parameters included pH and meat color.

pH

In this study, the pH values at 45 min and 24 h postmortem (ultimate pH) were measured in the middle of the *semimembranosus* muscle using a Milwaukee pH600 pocket-sized pH meter, calibrated at pH 4.0 and pH 7.0 buffers and recalibrated after every three readings.

Meat Color

Meat color (*Commission Internationale de l'Eclairage* or CIE L for lightness, CIE a* for redness, and CIE b* for yellowness) was measured in the longissimus dorsi at the 10th rib after 30 min of blooming using a chromameter (Capsure™ Pantone® X-Rite, USA) calibrated to a standard white tile.

Statistical Analysis

For the statistical analysis of each trait, the individual slaughtered pig was considered as an experimental unit.

The general least squares procedure (SAS 2009) was used to examine the principal sources of variation affecting each carcass characteristic and meat quality trait. The following linear "fixed effects" model was used to determine, using an F-test, the appropriate model that would best describe each trait:

$$yijklmn = \mu + PS_i + Breed_j (PS_i) + Sex_k + WtClass_l + Age_m + e_{ijklmn}$$

where $\mathbf{y_{ijklmn}}$ is the dependent variable (carcass characteristics and meat quality traits associated with each slaughtered pig); **μ** is the overall mean; $\mathbf{PS_i}$ is the fixed effect of the ith type of production system (organic-like and conventional swine production system); $\mathbf{Breed_i}$ $\mathbf{(PS_j)}$ is the fixed effect of the jth breed of pig [Landrace (LDR), Large White (LRW), "F_1 LDR x LRW cross", and "F_1 LRW x LDR cross"], nested within the ith farm type; $\mathbf{Sex_k}$ is the fixed effect for the kth sex of the pig (barrow and gilt); $\mathbf{WtClass_l}$ is the fixed effect for the lth weight class of the pig (< 20 kg and > 20 kg); $\mathbf{Age_m}$ is the random covariate effect of the mth age of the pig at slaughter (in

Table 3. Least square means (LSM) ± standard error (S.E.) for carcass characteristics, by type of production system.

Carcass Characteristics	Organic-like Farm	Conventional Farm	Difference
Body length (pre-slaughter), cm	59.97 ± 0.95	69.76 ± 1.51	-9.79 **
Carcass Length, cm	44.12 ± 0.42	50.91 ± 0.52	-6.97 **
Weight of pork cuts, kg			
- Shoulder	1.79 ± 0.03	1.84 ± 0.04	-0.05 ns
- Loin	1.10 ± 0.02	1.12 ± 0.03	-0.02 ns
- Belly	1.20 ± 0.02	1.07 ± 0.02	0.13
- Ham	1.81 ± 0.02	2.09 ± 0.03	-0.28 **
- Fore shank	0.36 ± 0.01	0.46 ± 0.01	-0.10 **
- Hind shank	0.34 ± 0.01	0.41 ± 0.01	-0.07 **
- Tenderloin	0.09 ± 0.00	0.08 ± 0.00	0.01 ns
Total (halfcarcass)	6.69 ± 0.06	7.09 ± 0.08	-0.40 **
Weight of lean, fat and skin, and bone from half carcass, kg			
- Lean	3.42 ± 0.05	3.84 ± 0.07	-0.42 **
- Fat & skin	1.36 ± 0.04	0.94 ± 0.05	0.42 **
- Bones	1.27 ± 0.03	1.54 ± 0.04	-0.27 **
Total weight	6.05 ± 0.06	6.32 ± 0.07	-0.27 **
Lean: Fat & skin: Bonesratio	1.00: 0.40: 0.37	1.00: 0.24: 0.40	
Lean, fat and skin, and bone - as percent of total weight, %			
- Percent Lean (%L)	57.00 ± 0.50	60.05 ± 0.61	-3.05 **
- Percent fat and skin (%FS)	21.56 ± 0.56	16.42 ± 0.69	5.14 **
- Percent bones (%B)	21.48 ± 0.49	23.58 ± 0.60	-2.10 *
%L: %F: %B ratio	1.00: 0.38: 0.38	1.00: 0.27: 0.39	
Loin eye area (LEA), cm^2	10.54 ± 0.32	12.32 ± 0.40	-1.78 **
Live backfat thickness (LivBFT), mm			
- LivBFT1	8.88 ± 0.36	5.56 ± 0.44	3.32 **
- LivBFT2	6.21 ± 0.36	5.10 ± 0.43	1.09 ns
- LivBFT3	8.57 ± 0.52	4.65 ± 0.66	3.92 **
- Average LivBFT	7.66 ± 0.32	5.43 ± 0.39	2.23 **
Carcass backfat thickness (cBFT), mm			
- cBFT1	20.14 ± 0.99	10.56 ±1.21	9.58 **
- cBFT2	8.74 ± 0.49	2.65 ± 0.63	6.09 **
- cBFT3	9.27 ± 0.57	0.74 ± 0.87	8.53 **
- Average cBFT	13.23 ± 0.50	4.34 ± 0.64	8.89 **
cBFT1: cBFT2: cBFT3 ratio	1.00: 0.43: 0.46	1.00: 0.25: 0.07	-

* Significant difference between type of production system ($P < 0.05$).
** Highly significant difference between type of production system ($P < 0.01$).

days); and e_{ijklmn} is the error term assumed to be normally distributed with variance of errors as constant across observations.

Only those significant (P < 0.05) fixed effects and covariates including the main effect of the production system and breed nested within the production system were included in the final linear models. The least square means and standard error for each trait were then computed to represent the "breed standard" and used to compare between breeds in a particular production system.

RESULTS AND DISCUSSION

Least square means and standard error for carcass characteristics and meat quality traits and least square differences between production systems are given in Table 3 and 4, respectively. Breed performance standards within the pig production system for various carcass characteristics, backfat thickness and meat quality traits, are summarized in Tables 5, 6, and 7, respectively.

Carcass Characteristics

Body Length (Pre-slaughter) and Carcass Length

Body length (pre-slaughter) in commercial *lechon*-size

Table 4. Least square means (LSM) ± standard error (S.E.) for meat quality traits, by type of production system.

Carcass Characteristics	Organic-like Farm	Conventional Farm	Difference
pH			
- pH, 45 min post mortem	6.43 ± 0.06	6.45 ± 0.08	-0.02 ns
- Ultimate pH, 24 h post mortem	5.70 ± 0.04	5.70 ± 0.07	0.0 ns
- pH difference (pH_{45min} - pH_{24h})	0.72 ± 0.07	0.81 ± 0.11	0.09 ns
Color			
- CIE L. lightness	52.85 ± 0.80	56.90 ± 0.96	-4.05 **
- CIE a* - redness	-2.22 ± 0.52	-0.10 ± 0.62	-2.12 *
- CIE b* - yellowness	12.03 ± 1.17	11.50 ± 1.40	0.53 ns

ns: No significant difference between type of production system ($P > 0.05$).
* Significant difference type of production system ($P < 0.05$).
** Highly significant difference between type of production system ($P < 0.01$).

pigs produced in the conventional swine breeding farm (69.76 cm) was significantly longer (P < 0.01) than in the native pigs raised in an organic-like production system (59.97 cm). Body length was also significantly longer (P < 0.01) in *lechon*-size pigs weighing more than 20 kg (69.48cm) than those weighing below 20 kg (60.24 cm). Body length, however, was not significantly affected (P > 0.05) by breeds raised in the same production system, sex, and age at weight slaughter.

As expected, carcass length in *lechon*-size pigs was significantly longer (P < 0.01) in native breeds (50.91 cm) than in the commercial breeds (44.12 cm). Carcass length was also significantly related (P < 0.01) to slaughter weight (r = 0.74). However, carcass length was not significantly influenced (P > 0.05) by breeds in the same production system, sex, weight class, and age at slaughter. Similar findings were observed by other researchers who reported significant increases in carcass length as slaughter weight of heavy pigs increased from 90 to 120 kg in Duroc x Landrace x Large White crossbred pigs (García-Macías et al. 1996), from 100 to 130 kg in Duroc x Landrace x Yorkshire crossbred pigs (Piao et al. 2004), and from 116 to 133 kg in Pietrain x Landrace x Large White crossbred pigs intended for the production of dry-cured hams (Latorre et al. 2003).

Carcass Weight and Weight of Various Pork Cuts

Half carcass weight of *lechon*-size native breeds (6.69 kg) was significantly lower (P < 0.01) than that of the commercial breeds (7.09 kg). Carcass weight was significantly affected (P > 0.01) by slaughter weight, but

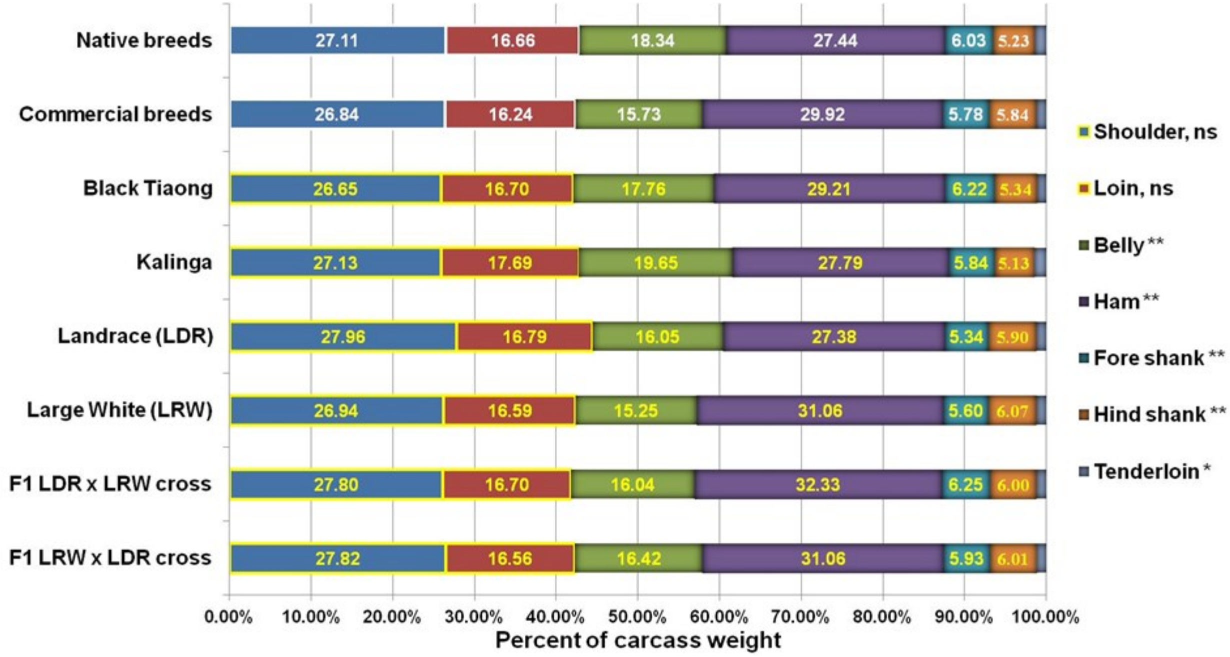

Fig. 1. Weight of pork cuts expressed as percent of carcass weight in *lechon*-size pigs.

ns: No significant difference between breed groups and between breeds in the same type of production system (P > 0.05).
* Significant difference between breed groups and between breeds in the same type of production system (P < 0.05).
** Highly significant difference between breed groups and between breeds in the same type of production system (P < 0.01)

Table 5. Least square means (LSM) ± standard error (S.E.) for carcass data, by breed within the type of production system.

Carcass Characteristics	Native Pig Breeds		Commercial Pig Breeds			
	Black Tiaong	Kalinga	Landrace (LDR)	Large White (LRW)	F_1 Cross (LDR x F1)	F_1 Cross (F1)
Body length (pre-slaughter)^{ns}, cm	59.97 ± 1.34	60.44 ± 1.35	70.38 ± 2.51	69.88 ± 2.51	70.88 ± 2.51	67.88 ± 2.51
Carcass Length^{ns}, cm	44.63 ± 0.60	43.61 ± 0.60	50.88 ± 1.04	50.62 ± 1.04	51.98 ± 1.04	50.15 ± 1.04
Weight of pork cuts, kg						
- Shoulder^{ns}	1.80 ± 0.04	1.78 ± 0.04	1.81 ± 0.08	1.97 ± 0.07	1.80 ± 0.07	1.79 ± 0.07
- Loin^{ns}	1.08 ± 0.03	1.11 ± 0.03	1.16 ± 0.06	1.20 ± 0.05	1.08 ± 0.05	1.05 ± 0.05
- Belly^{ns}	1.17 ± 0.02	1.23 ± 0.02	1.05 ± 0.05	1.12 ± 0.05	1.09 ± 0.04	1.04 ± 0.04
- Ham**	1.87 ± 0.03	1.75 ± 0.04	2.24 ± 0.06	1.98 ± 0.06	2.11 ± 0.05	2.01 ± 0.05
- Fore shank^{ns}	0.38 ± 0.01	0.33 ± 0.01	0.49 ± 0.02	0.45 ± 0.02	0.47 ± 0.02	0.45 ± 0.02
- Hind shank^{ns}	0.34 ± 0.01	0.32 ± 0.01	0.43 ± 0.02	0.43 ± 0.02	0.42 ± 0.01	0.40 ± 0.01
- Tenderloin^{ns}	0.09 ± 0.00	0.10 ± 0.00	0.09 ± 0.01	0.08 ± 0.01	0.09 ± 0.01	0.08 ± 0.01
Total (half carcass)	6.74 ± 0.08	6.64 ± 0.09	7.27 ± 0.15	7.22 ± 0.14	7.06 ± 0.13	6.81 ± 0.13
Weight of lean, fat and skin, and bone from half carcass, kg						
- Lean^{ns}	3.47 ± 0.07	3.39 ± 0.07	3.97 ± 0.13	4.05 ± 0.12	3.75 ± 0.11	3.61 ± 0.11
- Fat & skin^{ns}	1.31 ± 0.04	1.40 ± 0.05	0.91 ± 0.09	0.89 ± 0.09	1.00 ± 0.08	0.98 ± 0.08
- Bones^{ns}	1.27 ± 0.04	1.27 ± 0.04	1.63 ± 0.08	1.48 ± 0.07	1.51 ± 0.07	1.53 ± 0.07
Total weight^{ns}	6.04 ± 0.07	6.06 ± 0.08	6.50 ± 0.14	6.42 ± 0.13	6.26 ± 0.12	6.12 ± 0.12
Lean: Fat & skin: Bones ratio	1: 0.38: 0.36	1: 0.41: 0.37	1: 0.23: 0.41	1: 0.22: 0.36	1: 0.27: 0.40	1:0.27:0.42
Lean, fat and skin, and bone - as percent of total weight, %						
- Percent lean^{ns}	57.76 ± 0.71	56.23 ± 0.71	59.82 ± 1.22	61.96 ± 1.22	56.69 ± 1.22	58.75 ± 1.22
- Percent fat and skin^{ns}	21.05 ± 0.80	22.07 ± 0.80	16.61 ± 1.38	15.80 ± 1.38	16.77 ± 1.38	16.48 ± 1.38
- Percent bones^{ns}	21.26 ± 0.70	21.71 ± 0.70	23.64 ± 1.21	22.24 ± 1.21	23.61± 1.21	24.84 ± 1.21
%Lean: %Fat & skin: %Bones ratio	1: 0.36: 0.37	1: 0.39: 0.39	1: 0.28: 0.40	1: 0.26: 0.36	1: 0.28: 0.40	1:0.28:0.43
Loin eye area (LEA) ns	10.32 ± 0.50	10.66 ± 0.50	11.39 ± 0.87	14.42 ± 0.87	11.95 ± 0.87	11.24 ± 0.87

ns: No significant difference between breeds in the same type of production system (P > 0.05).
* Significant difference between breeds in the same type of production system (P < 0.05).
** Highly significant difference between breeds in the same type of production system (P < 0.01).

not significantly influenced (P > 0.05) by breeds raised in the same production system, sex, and weight class. Carcass weight was significantly correlated (P < 0.01) with slaughter weight (r = 0.97).

Weights of various pork cuts in *lechon*-size pigs were all significantly affected (P < 0.01) by slaughter weight, but were not significantly different (P > 0.05) between sexes, weight class, and age at slaughter. The positive correlation of slaughter weight with weight of shoulder, loin, belly, ham, fore shank, hind shank, and tenderloin was r = 0.91, r = 0.87, r = 0.79, r = 0.92, r = 0.78, r = 0.84, and r = 0.69, respectively.

Weight of shoulder (1.81 ± 0.32 kg), loin (1.11 ± 0.20 kg), and tenderloin (0.09 ± 0.02 kg) were also not significantly influenced (P > 0.05) by the type of production system, breed within the production system, and weight class.

On the other hand, weight of belly in native breeds (1.20 kg) was significantly higher (P < 0.01) than in the

Table 6. Least square means (LSM) ± standard error (S.E.) for backfat thickness by breed within the production system.

Carcass Characteristics	Native Pig Breeds		Commercial Pig Breeds			
	Black Tiaong	Kalinga	Landrace (LDR)	Large White (LRW)	F_1 Cross (LDR x F1)	F_1 Cross (F1)
Live backfat thickness (LBFT)						
- LivBFT1 ^{ns}	9.33 ± 0.51	8.42 ± 0.51	6.00 ± 0.89	5.50 ± 0.89	5.00 ± 0.89	5.75 ± 0.89
- LivBFT2 ^{ns}	6.58 ± 0.50	5.83 ± 0.50	5.00 ± 0.86	6.50 ± 0.86	4.25 ± 0.86	4.75 ± 0.86
- LivBFT3 ^{ns}	9.08 ± 0.66	8.05 ± 0.74	4.46 ± 1.30	4.75 ± 1.21	4.04 ± 1.13	5.34 ± 1.13
Average LivBFT ^{ns}	8.22 ± 0.45	7.11 ± 0.45	5.75 ± 0.45	6.00 ± 0.78	4.58 ± 0.78	5.40 ± 0.78
LBFT1 : LBFT2 : LBFT3 ratio	1: 0.71: 0.97	1: 0.69: 0.96	1: 0.83:0.74	1: 1.18: 0.86	1: 0.85: 0.81	1: 0.83: 0.93
Carcass backfat thickness (cBFT)						
- cBFT1 ^{ns}	19.30 ± 1.40	20.98 ± 1.40	10.34 ± 2.42	11.59 ± 2.42	10.85 ± 2.42	9.48 ± 2.42
- cBFT2 ^{ns}	8.82 ± 0.62	8.65 ± 0.70	2.24 ± 1.23	2.72 ± 1.15	2.44 ± 1.07	3.19 ± 1.07
- cBFT3 ^{ns}	9.01 ± 0.60	9.52 ± 0.74	0.32 ± 1.21	2.73 ± 1.09	0.03 ± 1.08	0.51 ± 1.28
Average cBFT ^{ns}	12.57 ± 0.63	13.90 ± 0.71	2.81 ± 1.25	4.99± 1.16	4.67± 1.09	4.91 ± 1.09
cBFT1 :cBFT2 :cBFT3 ratio	1: 0.46: 0.47	1: 0.41: 0.45	1: 0.22: 0.03	1: 0.23: 0.24	1: 0.22: 0.03	1:0.34:0.05
Difference (live vs. carcass) **	-4.91 ± 0.56	-7.21 ± 0.67	3.50 ± 1.14	1.51 ± 0.99	0.50 ± 0.87	1.78 ± 1.02

ns: No significant difference between breeds in the same type of production system (P > 0.05).
* Significant difference between breeds in the same type of production system (P < 0.05).
** Highly significant difference between breeds in the same type of production system (P < 0.01).

commercial breeds (1.07 kg). The heavier commercial pigs in the conventional production system, however, had significantly bigger (P < 0.01) ham, fore shank and hind shank than the native pig breeds in the organic-like production system, by about 280 g, 100 g, and 70 g, respectively.

Except for the ham and the fore shank, weight of different pork cuts was not significantly different (P >0.05) between breeds in the same production system. Weight of ham was significantly higher (P < 0.01) in Black Tiaong (1.87 kg) than in Kalinga (1.75 kg). Weight of ham was significantly (P < 0.01) highest in Landrace (2.24 kg), followed by F1 LDR x LRW cross (2.11 kg), F1 LRW x LDR cross (2.01 kg), and Large White (1.98 kg). Weight of fore shank was also significantly higher (P < 0.01) in Black Tiaong (0.38 kg) than in Kalinga (0.33 kg). Average weight of fore shank was significantly (P < 0.01) highest in Landrace (0.49 kg), followed by F_1 LDR x LRW cross (0.47 kg), and smallest in both F1 LRW x LDR cross and Large White (0.45 kg).

Percentage of various pork cuts in *lechon*-size pigs was not significantly affected (P > 0.05) by sex, weight class, age at slaughter, and slaughter weight (see Fig. 1). On the contrary, Cisneros et al. (1996) showed that percentage of loin increased and ham, shoulder, and spare rib percentages decreased with slaughter weight. The percentage of belly, boston butt, and carcass trim did not change with slaughter weight of heavy pigs slaughtered at 100 to 160 kg.

While percent shoulder and percent loin were not significantly different (P > 0.05) between the two production systems, it was noted that native breeds had significantly larger (P < 0.01) belly (18.34%) and fore shank (6.03%) than the belly (15.73%) and fore shank (5.78%) of commercial breeds. Percent ham (29.92%) and percent hind shank (5.84%) in commercial breeds, however, were significantly bigger (P < 0.01) than the ham (27.44%) and hind shank (5.23%) in native breeds. Percent fore shank was negatively correlated (P < 0.01) with slaughter weight (r = -0.63).

On the contrary, the size of the ham and hind shank was bigger in the commercial breeds than in the native breeds, by about 2.48% and 0.67%, respectively.

Ham weight was also significantly bigger (P < 0.01) in

Table 7. Least square means (LSM) ± standard error (S.E.) for meat quality traits, by breed within the production system

Meat Quality Trait	Native Pig Breeds		Commercial Pig Breeds			
	Black Tiaong	Kalinga	Landrace (LDR)	Large White (LRW)	F_1 Cross (LDR x F1)	F_1 Cross (F1)
pH						
- pH - 45 min post mortem ^{ns}	6.36 ± 0.09	6.50 ± 0.09	6.30 ± 0.15	6.55 ± 0.15	6.45 ± 0.15	6.50 ± 0.15
- Ult. pH - 24 h post mortem **	5.58 ± 0.06	5.83 ± 0.06	5.85 ± 0.11	5.38 ± 0.11	5.80 ± 0.11	5.75 ± 0.11
- pH diff. (pH_{24h} - pH_{45min}) ^{ns}	0.78 ± 0.11	0.65 ± 0.11	0.50 ± 0.19	1.23 ± 0.19	0.70 ± 0.19	0.80 ± 0.19
Color						
- CIE L – lightness *	55.37 ± 1.11	50.32 ± 1.16	55.91 ± 1.92	54.97 ± 1.92	59.60 ± 1.92	57.10 ± 1.92
- CIE a* - redness ^{ns}	-2.26 ± 0.71	-2.18 ± 0.75	1.51 ± 1.24	-1.75 ± 1.24	0.16 ± 1.24	-0.32 ± 1.24
- CIE b* - yellowness ^{ns}	13.06 ± 1.61	11.00 ± 1.69	12.25 ± 2.80	14.03 ± 2.80	11.91 ± 2.80	7.82 ± 2.80

ns: No significant difference between breeds in the same type of production system (P > 0.05).
* Significant difference between breeds in the same type of production system (P < 0.05).
** Highly significant difference between breeds in the same type of production system (P < 0.01).

pigs weighing more than 20 kg at slaughter (2.08 kg) than in pigs weighing less than 20 kg (1.72 kg).

Weight of Lean, Fat and Skin, and Bones

Weight of lean, fat and skin, and bones (including tendons and cartilages) in *lechon*-size pigs were significantly affected (P > 0.01) by the type of production system and slaughter weight, but not significantly influenced (P > 0.05) by breeds raised in the same production system, sex, age and weight class.

Weight of lean in commercial breeds in conventional production systems (3.84 kg) was significantly higher (P < 0.01) than in the native breeds in organic-like production systems (3.42 kg). Weight of bones was also significantly larger (P < 0.01) in the conventional production system (1.54 kg) than those in the organic-like production system (1.27 kg). On the other hand, weight of fat and skin was significantly greater (P < 0.01) in native breeds (1.36 kg) than in commercial breeds (0.94 kg).

Percentagewise, native breeds had significantly lower percent lean (P < 0.01) and percent bones (P < 0.05) but higher percent fat and skin (P < 0.01) than commercial breeds. The non-lean portion of native breeds consisted of almost equal proportions of bones (21.48%) and fat and skin (21.56%) while the non-lean portion of commercial breeds consisted mostly of bones (23.58%) than fat and skin (16.42%).

Significant correlations (P < 0.01) of slaughter weight with weight of lean, fat and skin, and bones were r = 0.91, r = 0.51, and r = 0.79, respectively. This is similar to the report by Ellis and Bertol (2001) which recommended increasing slaughter weight to improve meat to bone ratio that may lead to reducing chilling and processing losses, thereby reducing the overhead costs for producers, slaughterers and processors. On the other hand, Correa et al. (2006) reported that lean, fat and bone proportions were not affected by weight in heavier pigs slaughtered at 107, 115 and 125 kg.

Loin Eye Area

The loin eye size is associated with the lean growth of pigs when the pig primarily grows the muscles in its body during the starter and grower phases. The loin eye area together with hot carcass weight and backfat thickness are thus used to predict percent muscle. However, with selection for faster growing and leaner pigs, the lean deposition of the pig is extended to the finisher phase. Commercial pig breeds have been selected for lean growth and will continue to increase the loin eye size as the carcass weight is increased. This may not be the case for farms where the pigs grow slower or have unimproved genetics as in the case of native pig breeds.

In this study, loin eye area (LEA) was significantly smaller (P < 0.01) in native breeds (10.54 cm^2) than in the commercial breeds (12.32 cm^2). However, loin eye area was not significantly different (P > 0.05) between breeds in the same type of production system. Loin eye area was also not influenced by sex, weight class, age and weight at slaughter (P > 0.05). In this study, average loin eye area was significantly correlated (P < 0.01) with carcass weight (r = 0.47).

Backfat Thickness

Backfat thickness is considered the basic parameter of carcass fatness. Fat depth measured at the last rib is the primary factor in determining carcass grade in addition to the expected yield of the four lean cuts (ham, loin, picnic shoulder and Boston butt) in the USDA Grade. On the other hand, fat depth measured between the 10th and the 11th rib is used in calculating percent muscle – which is a more accurate and precise method of assessing differences in carcass yield of lean red meat.

Live backfat measurements. Pre-slaughter or live measurements of backfat thickness (LivBFT) using an ultrasound device in *lechon*-size pigs at the shoulder (LivBFT1), at the ham (LivBFT3), and average backfat thickness (LivBFT) taken from three sites were significantly higher ($P < 0.01$) in native breeds than in the commercial breeds. However, average LivBFT was not significantly affected ($P > 0.05$) by breed of a particular production system, sex, weight class, age and weight at slaughter.

While LivBFT1 is significantly thicker ($P < 0.01$) in native breeds (8.88 mm) than commercial breeds (5.56 mm), measurement of backfat thickness is more difficult and consistent because of the trapezius muscle at the shoulder (false lean).

Average backfat thickness taken at the 10th or last rib (LivBFT2) was (6.77 ± 1.91 mm) and was not significantly different ($P > 0.05$) between the types of production system. The difference in LivBFT2 between the production systems is about 1.09 mm. On the contrary, LivBFT2 is commonly known to provide a more accurate reading of the third layer of fat that becomes thicker and more widespread over the body. It is also the same location normally used in the old metal ruler probing technique, and shows the best correlation with overall carcass yield (Renco Corporation 2013). Many commercial hogs are also known to have a third layer of fat. As they increase in weight and age, the third layer becomes thicker and more widespread over the body. In native breeds, LivBFT2 measurements are lower than both LivBFT1 and LivBFT3 measurements. In commercial breeds, however, LivBFT2 is higher than LivBFT3.

LivBFT3, taken at the ham or just above the *gluteus medius* situated on the outer surface of the pelvis, was also significantly thicker ($P < 0.01$) in native breeds (8.57 mm) than in the commercial breeds (4.65 mm). LivBFT3 can give accurate measurement for two layers of fat but may not give an accurate measurement for three layers of fat due to the muscle tissue below the fat layers (Renco Corporation 2013).

Average live backftat thickness from the three sites was significantly thicker ($P < 0.01$) in *lechon*-size native breeds (7.66 mm) than in the commercial breeds (5.43 mm).

Carcass backfat measurements. Carcass backfat thickness at the shoulder (cBFT1), last rib (cBFT2), ham (cBFT3), and average backftat thickness from the three sites (cBFT) were significantly higher ($P < 0.01$) in native breeds than in the commercial breeds by about 9.58 mm, 6.09 mm, 8.53 mm, and 8.89 mm, respectively. Carcass backfat thickness measured in the different sites was, however, not significantly different ($P > 0.05$) between breeds in the same production system and between sexes. This is in contrast with the results of Correa et al. (2006) who reported thicker fat at the shoulder for barrows than gilts and for fast-growing pigs compared with slower growing ones that were slaughtered at 107 to 125 kg live weight.

In particular, cBFT1 was not significantly affected ($P > 0.05$) by weight class, age and weight at slaughter. Carcass backfat thickness at the last rib (cBFT2) was positively correlated ($P < 0.05$) with weight at slaughter ($r = 0.39$). Carcass backfat thickness at the ham (cBFT3) was significantly affected by weight class ($P < 0.01$). The cBFT3 is higher in pigs > 20 kg than those pigs < 20 kg, by about 3.23 mm. It was also positively correlated ($P < 0.05$) with age at slaughter ($r = 0.37$) and with weight at slaughter ($r = 0.37$). Average carcass backfat thickness from the three sites (cBFT) was positively correlated ($P < 0.01$) with weight at slaughter ($r = 0.56$).

Difference between live and carcass backfat thickness. In general, values obtained using ultrasonic devices on live animals may be different from those measured at slaughter because of differences in measurement sites and fat on a hanging carcass is distorted or cut.

In this study, agreement between live and carcass measurements of average backfat thickness was significantly poor between type of production system ($P < 0.01$) and between breeds in the same production system ($P < 0.01$) and was significantly affected by age ($P < 0.05$) and weight ($P < 0.01$) at slaughter. However, it was not significantly influenced ($P > 0.05$) by sex, and weight class. Furthermore, live and carcass measurements of backfat thickness at different sites were not significantly correlated ($P > 0.05$) with carcass yield.

Live backfat measurements were all underestimates of the carcass backfat thickness of native breeds raised in the organic-like production system (-6.06 ± 0.52 mm), but generally were overestimates in the case of commercial breeds in the conventional production system (1.82 ± 0.73 mm). In particular, live backfat measures are better predictors of carcass backfat thickness in Black Tiaong than in Kalinga. Among the commercial breeds, the live backfat thickness may provide the best prediction of average carcass backfat thickness in the F1 LDR x LRW cross, followed by Large White, F1 LRW x LDR cross, and least in Landrace.

Moreover, significant correlation coefficients ($P<0.01$) were found among the live BFT measurements in the three sites, namely, between LivBFT1 and LivBFT2 ($r = 0.43$), between LivBFT1 and LivBFT3 ($r = 0.56$), and between LivBFT2 and LivBFT3 ($r = 0.60$). In contrast, higher correlation values ($P<0.01$) were found among carcass backfat measurements in the three sites, namely, between cBFT1 and cBFT2 ($r = 0.73$), between cBFT1 and cBFT3 ($r = 0.68$), and between cBFT2 and cBFT3 ($r = 0.74$).

Meat Quality Traits

The pH and color of pork muscle are important measures of processing or technological attributes of meat quality (Andersen 1999). The pH values and meat color scores may, however, vary and sometimes be controversial depending on the genotype, pre- and post-slaughter handling and measuring methods/instruments (Piao et al. 2004).

pH

The most important meat quality indicator is the pH value, which is highly correlated to color, drip loss, and eating quality traits. As pH declines below the ideal range (5.8 to 6.2), meat becomes paler, softer and higher in drip loss or moisture loss through exudation (Hartung et al. 2009). Sellier (1998) enumerated three distinct pH-related abnormalities, namely, 1) Pale, soft, exudative (PSE) meat associated with pH values less than 5.9 depending on the muscle; 2) Dark, firm, dry (DFD) meat associated with ultimate pH values higher than 6.2; and 3) Acid meat condition associated with ultimate pH values lower than 5.4.

Initial and ultimate pH measurements can be used to indicate the rate and extent of postmortem glycolysis (Scheper 1971). Ultimate pH measurements can also be directly or indirectly related to many important quality attributes such as color, water-holding capacity, and tenderness (Bendall and Swatland 1988; Andrews et al. 2007). In particular, very low pH values in poor quality carcass may be a result of transport stress such as when animals are transported for too long or under inappropriate conditions (Hartung et al. 2009).

In this study, the pH values taken at 45 min post-mortem were not significantly different ($P > 0.05$) between the type of production system, breed of a particular production system, sex, weight class, age and weight at slaughter. In this study, pH45 was significantly correlated ($P < 0.05$) with carcass yield ($r = 0.36$).

Ultimate pH (24 h post-mortem) was, however, significantly higher ($P < 0.01$) in Kalinga (pH = 5.83) than in Black Tiaong (pH = 5.58). Among the commercial breeds, ultimate pH was highest in Landrace (pH = 5.85), followed by F_1 LDR x LRW cross (pH = 5.80) and F_1 LRW x LDR cross (pH = 5.75), and lowest in Large White (pH = 5.38). As suggested by Hartung et al. (2009), meat whose pH is below 5.8 such as the case of *lechon*-size Kalinga, Large White and F_1 LRW x LDR cross becomes paler, softer and higher in drip loss. The breed differences in ultimate pH may indicate differences in the post mortem metabolism of glycogen reserves (Rosenvold and Andersen 2003).

Ultimate pH was not significantly different ($P > 0.05$) between the type of production system, sex, age and weight at slaughter. Ultimate pH (24 h post-mortem) was also significantly higher ($P < 0.01$) in pigs less than 20 kg at slaughter (pH = 5.82) than in pigs that weighed more than 20 kg at slaughter (pH = 5.58).

For pigs slaughtered at heavier weights, García-Macías et al. (1996) and Latorre et al. (2003) found no effect of slaughter weight on ultimate pH taken 24 h post -mortem, although Piao et al. (2004) reported that the pH value of *longissimus* muscle was significantly higher at 110 and 130 kg than at 100 and 120 kg. Heavier pigs (110 kg compared to 85 kg) may have a greater ultimate pH because heavier pigs used more energy reserves during the pre-slaughter period (Tikk et al. 2008).

The average drop in pH values taken between 45 min and 24 h post-mortem (0.70 ± 0.38 or about 10.87% loss) was not significantly affected ($P > 0.05$) by the type of production system, breed in the same production system, sex, and age and weight at slaughter. The average drop in pH values taken between 45 min and 24 h post-mortem, however, was significantly higher ($P < 0.01$) in pigs less than 20 kg at slaughter (pH difference = 0.94 or 13.90%) than in pigs that weighed more than 20 kg at slaughter (pH difference = 0.58 or 9.42%). The reduction in pH values at 24 h post-mortem was generally in agreement with previous research (Henckel et al. 2002) and could have indicated a depletion of glycogen reserves prior to slaughter as a consequence of stress and higher physical activity, especially among lighter *lechon*-size pigs (< 20 kg). Cisneros et al. (1996) suggested that heavier pigs were more fat, which may depress heat transfer during chilling and result in more rapid postmortem metabolism and pH decline.

Color

Meat color has a big influence on the consumer's purchase decision. Consumers primarily use fresh meat color as an indicator of freshness and wholesomeness (Kropf et al. 1986).

The L* (reflectance) value is a measurement for brightness, ranging from 0 (black) to 100 (white). In meat classification, this means that the higher the L* value, the paler the meat. The a* value displays the color range from green to red (-150 to +100). Negative values stand for the green share, positives for the red share. The b* value is a scale unit for the color range from blue to yellow (-100 to +150). Negative values stand for the blue share, positives for the yellow share. A high and positive b* value indicates an intensive yellow coloring.

According to the meat color standards of NPPC (2000), the L* values of 37 to 49 are considered to be good. High L* values can be due to abnormal denaturation of the sarcoplasmic proteins during chilling that produce high amounts of exudatives that increase the reflection of light. This abnormal denaturation may also cause rapid decline of myoglobin in the meat, thus giving negative a* values (Fabrega et al. 2011).

In this study, the color of loin muscle in *lechon*-size pigs was significantly ($P < 0.01$) lighter (paler) in commercial breeds in the conventional farm (L* = 56.90) than *lechon*-size native breeds from the organic-like production system (L* = 52.85). This finding is in contrast with the lower L* values reported by Wariss et al. (1983) for pigs kept outdoors compared with the conventional confinement-reared pigs. Their pigs were, however, slaughtered at heavier weights (60 or 90 kg).

The color of native pork was paler ($P < 0.05$) in Black Tiaong (L* = 55.37) than in Kalinga (L* = 50.32). Among commercial breeds, pork was palest in F1 LDR x LRW cross (L* = 59.60) and F1 LRW x LDR cross (L* = 57.10), followed by pure breeds - Landrace (L* = 55.91) and Large White (L* = 54.97). The L* value of meat was not significantly affected ($P > 0.05$) by sex, weight class, age and weight at slaughter. This is in contrast with pigs slaughtered at heavier weights where the loin muscle was darker (lower L* values) and redder with more myoglobin (García-Macías et al. 1996; Latorre et al. 2004). Piao et al. (2004) also reported that L*, a* and b* values were increased as market weight increased.

Loin muscle had slightly more green share ($P < 0.05$) in native breeds (a* = -2.22) than in the commercial breeds (a* = -0.10). Measures of redness of the loin muscle (a* value) were not significantly affected ($P > 0.05$) by breed in the same production system, sex, weight class, and age and weight at slaughter.

Average measure of yellowness of the loin muscle (b* = 11.84 ± 5.49) was low (no intense yellow color) and was not significantly affected ($P > 0.05$) by the type of production system, breed in the same production system, sex, weight class, and age and weight at slaughter. In a related study, increased b* values (Lebret et al. 2006) have been reported for heavy pigs (slaughtered at approximately 110 kg live weight) kept outdoors compared with conventionally confinement-reared pigs.

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