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Effects of Free-range Farming on Carcass and Meat Qualities of Black-feathered Taiwan Native Chicken

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ABSTRACT : The effects of free-range farming, compared to a conventional production system, on carcass and meat qualities were studied using black-feathered Taiwan native chickens. Twenty 16-week old females were purchased separately from a free-range farm and a conventional production farm and used for this study. The results showed similarities in the live weight (roughly 2.1 kg), dressing percentage (69%) and meat percentage (19%) of deboned leg quarter. Significant differences ($p<0.05$) found for the free-range chickens included: a higher percentage of meat for the breast, an increased crude protein content and chewiness value for the breast, but decreased crude fat content and lower hardness and fracturablility values for the leg quarter. Significantly higher L* values were found for the breast and leg meat of conventionally produced chickens, whereas no significant differences were found for WHC and purge loss between the breast and the leg, and between the two production systems as well. Results of sensory evaluation showed a significant preference for leg over breast meat ($p<0.05$). The scores of all the attributes including aroma, flavor, firmness, tenderness, juiciness and overall acceptability of leg meat from free-range chickens were slightly higher than for conventional chickens, while the reverse was true for breast meat, though no significant difference could be found. Free-range Taiwan native chicken appeared to yield the best of the results, with flavorful yet tender leg meat for higher sensory satisfaction, and high-protein but low-fat breast meat for healthier diet choice. (**Key Words :** Taiwan Native Chicken, Meat Quality, Free-range Farming)

INTRODUCTION

The so-called Taiwan native chicken represents a number of locally developed slow-growth breeds favored by Taiwanese consumers, and the black-feathered native chicken used for this study is one of them. In general, the rearing period is longer (16-20 weeks), compared with that of the broilers; and the live weight is also heavier (Chen et al., 2006; 2007; Tsai et al., 2006). According to a governmental survey, for the last 5 years, about 30 kg of chicken meat are consumed per capita per year in Taiwan (COA, 2006), with nearly half of the consumptions come from Taiwan native chickens. This points out the importance of consumer preference as the major underlying cause for differences in market shares in Taiwan compared to that in the West where nearly all of the consumptions comes from the broilers.

Organic production system, among many other improved conditions and standards in rearing, provides free-range area for greater physical activity, and that seems to be an important contributing factor for the production of higher quality meat in chickens and livestock as well (Farmer et al., 1997; Angood et al., 2008). The sensory quality of the breast muscle of broiler chickens was reported to be better when produced organically (Farmer et al., 1997). Although organic livestock production has not received as much attention in Taiwan as in many other industrialized countries, the Taiwanese consumers traditionally have always favored free-range chickens to the broilers, and are willing to pay a premium for free-range Taiwan native chickens. The purpose of this study was to provide information on carcass and meat qualities of free-range chickens, in comparison with those reared under conventional system for Taiwan native chickens.

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MATERIALS AND METHODS

Animals and sample collection

Two groups of black-feathered Taiwan native chickens, twenty female and 16 weeks of age in each group, were purchased separately from a local free-range farm and a

Table 1. Diet[1] formulations, compositions and feeding schedules for the Black-feathered Taiwan Native Chicken

Diet	Feeding schedule and ages (in weeks)		
	0-4	5-12	13-16
Ingredient (%)			
Cornmeal	47.3	58.0	61.5
Soybean meal[2]	22.0	21.7	21.7
Full-fat soybean powder	19.0	11.2	7.6
Wheat middling	5.0	5.0	5.0
Wheat bran	0	3.0	6.0
Soybean oil	2.2	0.0	0.0
Dicalcium phosphate	1.7	1.2	1.1
Limestone	1.4	1.5	1.4
Salt	0.4	0.4	0.4
DL-methionine	0.18	0.08	0.05
Vitamin premix	0.12	0.1	0.1
Mineral premix	0.12	0.1	0.1
Choline chloride (50%)	0.1	0.1	0.1
Calculated composition			
Crude protein (%)	21.04	19.02	18.06
Crude fat (%)	7.61	4.40	3.89
Crude fiber (%)	3.83	3.69	3.62
Ash (%)	3.08	2.89	2.80
Metabolizable energy (kcal/kg)	3,000	2,900	2,900
Calcium (%)	1.01	0.91	0.84
Available phosphorus (%)	0.46	0.36	0.34
Lysine (%)	1.16	1.01	0.94
Methionine (%)	0.51	0.38	0.34
Methionine+cyctine (%)	0.67	0.63	0.60

[1] All diets contain anticoccidial *Salinomycin*. [2] Containing 44% crude protein.

conventional production farm in Tai-Chung, Taiwan. Both farms were known to use the same commercial diet and feeding schedule management as reported by Chao et al. (2005). Details of the diet formulations, compositional analyses and feeding schedules are summarized in Table 1. Feed and water were provided and feeding was *ad libitum* in both farms. The conventional farm adopts the pen-rearing method for a total of 500 chickens, with 50 chickens housed in each of the 10 pens and each pen measuring 2.6 m×2.5 m in size (0.13 m^2/bird). Whereas the free-range farm has a total of 200 chickens (2.64 m^2/bird) in a fenced area with a few scattered trees and mostly clay-surfaced terrain of 528 m^2 (17.6 m×30 m) in which about one fifth of the area (roughly 7.04 m×15 m) was occupied by a shelter where feed and water were provided. No forage was provided for in the free-range farm. Both farms delivered their16-week old chickens in group of 10 per plastic cage to the same slaughter house, about 15 minutes drive from either farm. For this study, ten chickens were selected randomly from each of the two farms at the slaughter house and used for evaluation. Roughly a month later, a second batch of 10 each were again selected at random to replicate the evaluation. Data from both batches were then combined (n = 20, Tables 2, 3 and 4) for statistical analyses.

Live weight of the birds was determined after fasting for 12 h. The chickens were then slaughtered at this local commercial slaughter house, under conventional conditions (electrically stunned, scalded at 56°C for 90 sec., feather picked, vent opened, eviscerated, carcasses chilled in a chilling tank at 1°C for 55 min and dripped for 5 min). After measuring the carcasses weight, the carcass was stored in a food grade high density polyethyelene bag at 4°C for 24 h and dissected manually. The deboned breast and leg quarter were weighed. Dressing percentage was based on the live weight, while the meat percentages of the breast and leg quarter were based on the carcass weight.

Analytical determinations

The moisture, crude fat, crude protein, and ash content were analyzed by the standard procedures of the Association of Official Analytical Chemists (AOAC, 1995). The pH values of meats from the breast and leg quarter were measured at 15 min and 24 h post-mortem, according to the method of Nassar and Emam (2002). Five grams of meat sample was homogenized with 50 ml of distilled water and then the pH value was measured using a FET (Field Effect Transistor) pH electrode (Model PY-P30; Sartorius, Goettingen, Germany) attached to a pH meter (Model PB-20; Sartorius). The L* value was measured with a Dr. Lange Micro Color Data Station (Dr. Lange, Berlin, Germany). Each sample was measured at six different positions and the results are given in Hunter color scales (CIE, 1976). Water

Table 2. The effect of production systems on carcass traits[1]

Trait	Free-range	Conventional
Live weight (LW)	2,095±183[a]	2,141±189[a]
Carcass weight (CW)	1,446±178[a]	1,504±189[a]
Dressing (CW/LW) (%)	69.0±6.3[a]	70.2±5.2[a]
Breast (%)	23.8±3.0[a]	19.6±2.4[b]
Leg (%)	19.6±2.4[a]	19.2±2.9[a]

[1] Data are expressed as mean±standard deviation.
[a-b] Data within the same row with different superscripts are significantly different ($p<0.05$). (n = 20).

holding capacity (WHC) was determined with a modified method of Musa et al. (2006). One gram of meat sample was placed on a piece of filter paper (No. 1, Adventec), covered with a hard plastic plate and then pressure was applied slowly to reach 3,000 psi and hold for 1 min. WHC was calculated as the percentage of wetted area before the press, to that after the press was applied. For purge loss measurement, the boneless breast or leg meat was weighted initially, vacuum packaged, equilibrated at 4°C for 24 h and weighed again. Purge loss was expressed as the percentage of weigh loss after vacuum package and equilibration (Sutton et al., 1997).

Texture analyses

The boneless breast or leg meat was placed in a plastic bag and boiled at 80°C for 40 min. Cooked meat samples were then cooled to ambient temperature and cut into stripes, 30×10×10 mm in size, and used for both sensory evaluation and texture analyses. Shear force was measured with the Rheometer (Model Compac-100II, Sun Scientific Co., Japan) equipped with a No. 10 (0.26-mm-thick) blade, and set at 10 kg load and 60 mm/min of crosshead speed (Ali et al., 2007). For determining texture profile analysis parameters, meat sample was compressed twice to 75% of their original height using the Rheometer with a No.21 (10 mm round shape) blade and set at 10 kg load and 60 mm/min of crosshead speed. Hardness, fracturability and chewiness were calculated according to the texture profile analysis parameters (Bourne, 1976).

Sensory evaluation

Twelve graduate students at Meat Science Laboratory who were trained and had experience in sensory evaluation for meat served as the panelists, ranked preferences in the following categories: aroma, flavor, firmness, tenderness, juiciness and overall acceptability. A seven-point hedonic scale was used, 1 referring to extremely dislike, and 7 to extremely like.

Statistical analyses

All data were analyzed using a general linear model including production system and kind of chicken meat with the GLM procedure in SAS System (SAS, 2006). Differences among mean values were compared using the Duncan's new multiple range tests. Significance is reported at the $p<0.05$ level.

RESULTS AND DISCUSSION

Carcass traits and physical-chemical characteristics

Only female birds of Taiwan native chickens were used for this study for two reasons: first, female birds at 16 weeks of age are commonly the size sold in market for household consumption; second, male chickens tend to show larger variations in growth rate, carcass and meat traits. No significant difference in the live and carcass weights, as well as the dressing percentages were observed between the free-range chickens and the conventional ones

Table 3. The physical-chemical characteristics[1] of the breast and leg meat

Characteristic	Free-range		Conventional	
	Breast	Leg	Breast	Leg
Moisture	71.30±0.91[a]	72.85±3.24[a]	68.78±2.19[a]	70.67±4.46[a]
Ash	1.20±0.23[ab]	0.93±0.15[c]	1.32±0.19[a]	1.02±0.20[bc]
Crude protein	29.16±1.43[a]	23.34±3.23[bc]	26.83±2.33[b]	21.52±3.17[c]
Crude fat	1.16±0.29[c]	3.80±1.57[b]	2.55±0.66[bc]	6.21±1.95[a]
pH value				
15 min	6.08±0.33[bc]	6.44±0.26[a]	5.98±0.26[c]	6.23±0.22[b]
24 h	5.77±0.09[b]	6.05±0.09[a]	5.73±0.08[b]	6.01±0.13[a]
L* value[2]	55.86±2.28[bc]	53.77±2.18[c]	60.08±3.96[a]	56.98±2.70[b]
WHC[3] (%)	45.44±6.43[a]	51.09±5.58[a]	47.13±4.83[a]	50.77±5.48[a]
Purge loss (%)	0.95±0.02[a]	0.97±0.01[a]	0.94±0.02[a]	0.97±0.01[a]
Shear force (kg/cm^2)	10.5±3.2[a]	10.4±3.9[a]	6.2±2.1[b]	7.8±2.6[ab]
Hardness (g)	535.1±81.3[a]	385.9±66.2[b]	619.4±87.5[a]	528.1±80.2[a]
Fracturability (g)	454.0±65.1[a]	290.4±68.9[b]	506.9±83.4[a]	463.6±89.6[a]
Chewiness (g)	169.5±36.8[a]	124.8±42.8[b]	97.3±42.8[b]	123.1±42.0[b]

[1] Data are expressed as mean±standard deviation. [2] L* value: Lightness value. [3] WHC: Water holding capacity.
[a-c] Data within the same row with different superscripts are significantly different ($p<0.05$). (n = 20).

(Table 2). The percentage of breast meat of the free-range chickens was significantly higher ($p<0.05$), but not that of the leg meat. This is in agreement with the report of Lei and Van Beek (1997) and Lewis et al. (1997) that the lower stocking density and increased physical activity could reduce the abdominal fat and increase the percentage of breast meat. However, lower stocking density did not seem to have any effect in the percentages of meat in the leg quarter as no significant difference ($p>0.05$) was observed between the two production systems (Table 2). In general, the contents of ash and crude protein in breast meat were significantly higher than those in leg meat ($p<0.05$) (Table 3). This is true for both types of chickens, free-range and conventional. The crude protein contents of the breast and leg meat of free-range chickens were consistently higher. While differences in the crude protein content of the breast meat and differences in the crude fat content of the leg were found to be significant when chickens from two production systems were compared. Interesting enough, the leg meat of conventionally produced chicken appeared to have the highest fat content and lowest protein content.

The pH values of the legs were found to be significantly higher than those of the breasts for both types of chickens (Table 3). A small decline in the pH values in all types of meat were observed, but the differences of the final pH values (24 h post-mortem), for both the breast and leg, between the two production systems were insignificant. The observations of Nilzén et al. (2001) and Sather et al. (1997) seemed to suggest that different production systems (free-range or organically produced) would not affect the ultimate pH of animal meat. The results of Castellini et al. (2002), on the contrary, indicated that meat of broilers in organic production system had a lower ultimate pH compared to that of the conventional production system. Interesting enough, we have noticed the final pH values for the breast (5.7 to 5.8) and leg (6.0 to 6.1) for both production system in our study were very close to the values reported by Castellini et al. (2002) for organic broilers. The L* values were found significantly higher for the breast and leg of conventionally produced chickens, whereas no significant differences ($p>0.05$) were found for WHC and purge loss between the breast and the leg, and also between the two production systems. A high correlation has been reported for the pH values, L* values and WHC (Boulianne and King, 1998; Abril et al., 2001), and WHC is known to be one of the major factors affecting the characteristics of cooked meat such as cook loss, juiciness, appearance and other sensory properties (Van Oeckel et al., 1999; Karakaya et al., 2005). Qiao et al. (2001) reported that there is a significant positive correlation (0.8) between the pH values and WHC, and a significant negative correlation (-0.9) between the L* values and WHC in broiler breast meat. Judging by the mean WHC values alone in our study, there seemed to be a difference between the breast meats of the two production systems. However, such difference was statistically insignificant. As no significant differences were found using Taiwan native chickens, we can only conclude the above mentioned correlations in the literature between the WHC, the pH values and L values do not apply. The reason for such discrepancy could be due to the difference of breeds chosen for the study. Difference in the methods used for WHC determination could conceivably be another reason. Our data indicated that significant differences of pH values could be found between the leg and breast meat, but not between the two production systems. Hence the difference in the pH values, more of less, reflects the type of meat used in the study and not necessarily the results of the production system as suggested by Castellini et al. (2002). Though significantly high L* values could be found for the leg and the breast for the conventionally produced chickens, a correlation with the pH values, and/or WHC could not be found. To complicate this matter further, an increased L* values which was taken as an attribute for the organic broilers by Castellini et al. (2002) could only be found in conventionally produced chickens in our study, a complete turnaround of their results. And consequently, our study would suggest that the light scattering property (as measured by the L* value) could be caused by some additional factors yet unknown, and a mechanism other than that based on the pH values and WHC as suggested by Warris (2000). Judging from our data, a higher L* values may not be a desirable characteristic for meat in Taiwan native chickens considering that those meat samples tend to have a higher crude fat content also (Table 3). On a glance, there appeared to be a big difference in shear force between meats from the two production systems. However, the only significant difference found was those between those of the breast meats. A slightly lower but still comparable shear force, as found in meats of free-range chickens, could be seen in the leg meat of conventionally produced chickens. Similar findings have been reported by Farmer et al. (1997) that broilers reared in low stocking density exhibited higher shear values in either breast or drumstick meat, presumably as a consequence of their greater motor activity. Interesting enough, significant lower values for the hardness and the fracturability were found for the leg, whereas significant higher chewiness values were found for the breast, of the free-range chickens. This would indicate that the tenderest meat of all is the leg meat and the toughest meat is the breast meat of free-range chickens. Differences in the chewiness of the breast were also significant between the two production systems. A higher shear value, cohesiveness, but lower in hardness value has been reported by Lee and Lin (1993) to contribute to a better eating quality of Taiwan native chicken when compared with the broilers. In the same report they also found that breast meat had higher

Table 4. The effect of production systems on the sensory scores[1] of the breast and leg meat

Attribute	Free-range		Conventional	
	Breast	Leg	Breast	Leg
Aroma	3.62 ± 0.94^{b}	4.69 ± 1.09^{a}	3.88 ± 1.11^{b}	4.58 ± 1.27^{a}
Flavor	3.46 ± 1.21^{b}	4.73 ± 1.2^{a}	3.62 ± 1.50^{b}	4.35 ± 1.35^{a}
Firmness	3.77 ± 1.45^{b}	4.65 ± 1.32^{a}	3.96 ± 1.46^{ab}	4.46 ± 1.42^{ab}
Tenderness	3.69 ± 1.62^{b}	4.62 ± 1.47^{a}	3.62 ± 1.53^{b}	4.19 ± 1.39^{ab}
Juiciness	3.65 ± 1.38^{c}	4.58 ± 1.06^{a}	3.73 ± 1.34^{bc}	4.38 ± 1.20^{ab}
Overall acceptability	3.60 ± 1.47^{b}	5.16 ± 1.07^{a}	3.84 ± 1.49^{b}	4.80 ± 1.35^{a}

[1] Data are expressed as mean±standard deviation.

Preference score ranged from 1 = extremely dislike; 2 = dislike; 3 = slightly dislike; 4 = neither dislike nor like, no preference; 5 = slightly like; 6 = moderately like; 7 = extremely like.

[a-c] Data within the same row with different superscripts are significantly different ($p<0.05$). (n = 20).

shear value but lower hardness value (tender) than the leg which however, was not the case in our study. Higher shear force appeared to be a function of the production method in our study as the shear force of meat of free-range chickens was higher, in general, than those of the conventional ones (Table 3). However, high shear force alone does not seem to be related to the hardness or the fracturability. Take the comparison of breast and leg meat of free-range chickens as an example, both had similar shear force values, but significant lower values in or hardness, fracturability and chewiness were observed for the leg meat. The lower hardness and fractuarability seen in the leg meat for free-range chickens is particularly interesting because it seems to defy the expectation that increased physical would increase the hardness of the meat as seen in the breast. As there was very little ground covering and no forage was provided in the free-range farm, textural differences in meat caused by forage can be excluded. Moritz et al. (2005) also indicated that forage intake had very little influence on meat texture for free-range chickens.

Sensory evaluation

The results of sensory evaluation of breast and leg meat are presented in Table 4. It is quite obvious that the panelists preferred the leg meat over the breast meat. That is in agreement with the consumer preference in Taiwan. The most common consumer complaints about the breast meat are sapless, dry, flaccid and tasteless, as in lacking flavors. The scores of all the attributes including aroma, flavor, firmness tenderness and juiciness of leg meat from free-range chickens were slightly higher than those of conventional ones while the reverse was true for breast meat, though no significant difference could be found. Lei and Van Beek (1997) suggested that physical activity had little effect on sensory quality in broilers. Also Farmer et al. (1997) revealed that decreased stocking density and increased age caused consistent, but non-significant increase in flavor of chicken meat. Similar observations were found in our study. Our results would seem to suggest besides tenderness and juiciness which was to be expected, special preference for additional attributes such as aroma, flavor and firmness in chicken meat are important criteria dictate consumers' choice in Taiwan. Consequently, leg meat was preferred over breast meat. If high protein but low fat content were the criteria, then the breast of free-range chickens, the leanest of all, would be the number 1 choice, yet it received the lowest ranking from the sensory evaluation. Another interesting observation from this study was the fact that the top two preferred meat were both leg meat which contained relatively higher crude fat content than the breast. However, the most favorably ranked meat was the leg meat of free-range chickens with only moderate content of crude fat. This study seems to suggest that subtle flavorings of the leg meat play an important role in consumer preference thus provides a basis for future study in order to identify the contributing factors, be it fatty acids or other aromatic compounds. In summary, free-range chickens yielded the best of the results, the leg meat for higher sensory satisfaction and the breast meat for healthier diet choice.

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