Carcass Composition and Skeletal Muscle Distribution in Broilers Produced under Different Nutrition Regime-2. Male Broilers Fed for Rapid Later Growth Following Severe Nutritional Restriction during Early Growth

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Carcass Composition and Skeletal Muscle Distribution in Broilers Produced under Different Nutrition Regimes–2. Male Broilers Fed for Rapid Later Growth Following Severe Nutritional Restriction during Early Growth

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1. The results of a previous experiment indicated that chicks whose growth was severely restricted through under nutrition, had the larger than normal hind limb muscles relative to wing muscles at 21 days of age (Das *et al.*, 2008). In this study, we investigated whether the large relative size of hind limb muscle was maintained in the broilers when their growth was accelerated after 3 weeks.
2. The chicks at 21 days of age, which were reared with layer grower (LG, ME 11.92 MJ/kg, CP 170 g/kg) or pre–layer (PL, ME 11.72 MJ/kg, CP 140 g/kg) feeds, had their growth accelerated by feeding a broiler finisher (BF, ME 13.47 MJ/kg, CP 180 g/kg) diet and were then killed at 80 days of age (LGBF80d and PLBF80d groups, respectively).
3. Both broiler groups had attained an adequate body size compared with conventionally–fed chicks at 80 days of age (Nakamura *et al.*, 2004; Roy *et al.*, 2007). PLBF80d broilers gained more live weight (3298 g) than LGBF80d (3088 g) broilers. The carcass accounted for 84–85% of live weight and skeletal muscle made up 48% of carcass weight.
4. Total muscle weight as a percentage of carcass weight was 24% for wing muscle, 18% for hind limb muscle and 4.5% for cervicodorsal muscle. The size of the hind limb muscle relative to wing muscle was 75.9–76.5% and this did not differ from the value of 76.5% reported for conventionally–fed broilers (Roy *et al.*, 2007). The high percentage of hind limb compared to wing muscle weight in LG (83.3%) and PL (96.7%) chicks at 21 days of age had returned to normal levels following stimulation of growth with the BF feed from days 22 to 80.
5. These results suggest that wing muscle growth limitation with under nutrition during the first 3 weeks post–hatching did not influence the final size of the muscle at 80 days when a BF diet was fed from days 22 to 80.

INTRODUCTION

Feed with high metabolizable energy concentrations promotes growth and improves feed efficiency in broiler production (Farrell *et al.*, 1976; Waldroup, 1981; Jackson *et al.*, 1982; Sohn and Han, 1983a, b; Bartov, 1992; Leeson *et al.*, 1996). High energy feed does not lead to excess fat deposition provided that the energy to protein ratio in the feed remains constant (Bartov *et al.*, 1974; Skinner *et al.*, 1992). Relative meat yield in different carcass components of broilers can be influenced by various factors including strain, sex, age, health, nutrition and live weight (Bouwkamp *et al.*, 1973; Moran, 1977; Siegel *et al.*, 1984).

In a previous study (Das *et al.*, 2008), chicks whose growth was severely restricted in the first three weeks post–hatching showed an increased hind limb to wing muscle ratio. These chicks had to be fed on a high plane of nutrition after 3 weeks to produce compensatory growth to allow them to reach sufficient body size for broiler production. Since a relatively constant growth rate is observed across individual muscles of both hind limb and wing parts between 2 and 15 weeks of age (Iwamoto *et al.*, 1993), we hypothesized that the larger relative weight of hind limb muscle would be maintained throughout the compensatory growth phase. However, a high plane of nutrition promotes more muscle development in the wing (forelimbs) than in the hind limb of broilers (Roy *et al.*, 2007) and conversely limitation of body growth induced by feeding on a low nutritional plane reduces growth of wing muscle (Gordon and Charles, 2002).

In the present study, the body growth of chicks was restricted by feeding on a low nutritional plane for 21 days post–hatching. Growth was then accelerated by feeding on a high nutritional plane to ensuring production of broilers of sufficient body size for slaughter at 80 days of age. The meat–producing ability of the broilers was investigated in terms of body growth, carcass composition and skeletal muscle development, with special attention to size of the hind limb relative to wing mus-

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cle size.

MATERIALS AND METHODS

Experimental chicks

Male chicks (Red Cornish × New Hampshire, Shaver, Fort Médoc, France) were reared on a layer grower complete feed (LG; metabolizable energy 11.92 MJ/kg, crude protein 170 g/kg) or a pre–layer complete feed (PL; ME 11.72 MJ/kg, CP 140 g/kg) (Marubeni Nisshin Feed Co. Ltd, Tokyo, Japan) and attained, at most, half the body size of normal growing chicks by 21 days of age (Das *et al*., 2008). The growth of both groups was then enhanced using a broiler finisher complete feed (BF, ME 13.47 MJ/kg, CP 180 g/kg) to achieve sufficient body size for the chicks to be classed as broilers by 80 days of age. The broiler groups were named LGBF80d and PLBF80d, respectively. Throughout the experimental period, the chicks were kept within a pen house and had *ad libitum* access to the experimental feeds and water.

Seven of the LGBF80d broilers and eight of the PLBF80d broilers were selected at random and killed by bleeding with a conventional neck cut following a 12 hr overnight fast. The carcasses were then immersed in water at 60 °C for 120 sec. prior to plucking the feather and down. The carcasses were then chilled in an ice–water mixture for at least 1hr and weighed after decapitation at the atlanto–occipital joint and removal of the feet at the intertarsal joint. Carcass weight as a percentage of live weight was then calculated.

Dissection of carcass

Details of the dissection method for carcasses are given in a previous paper (Das *et al*., 2008). Total weight of skin, visceral organs and abdominal fat were measured. Wing, hind limb and cervicodorsal parts were dissected into skeletal muscle, intermuscular fat and bone tissues and the combined weight of each part was measured from these components.

Skeletal muscle weight was measured in 4 subparts of the wing, 3 subparts of the hind limb and 2 subparts of the cervicodorsal portion on the left side of the carcass (Vollmehrhaus, 1992). The 4 subparts of wing muscle were shoulder girdle, brachial, antebrachial and abdominal muscles. The hind limb muscle was composed of pelvic, femoral and crural subparts and the cervicodorsal muscle was divided into the dorsocaudal and cervical muscle subparts.

The weights of the *pectoralis, supracoracoideus, triceps brachii, biceps brachii, iliotrochanterici, iliotibialis cranialis, iliotibialis lateralis, femorotibiales, flexor cruris lateralis, puboischiofemoralis* and *gastrocnemius* muscles were measured on the right side of the carcass.

Statistical analysis

In this study, all the parameters were expressed as relative weight (%) of the total carcass. Means and standard errors were calculated for the chicks in each group and used for t–tests to assess the significance of differences between the two broiler groups.

RESULTS

Live weight and carcass weight

For producing meat suitable for Japanese traditional cooking, chickens are reared for 80 days or more, post–hatching, and reach live weights of over 3 kg in male broilers (Nakamura *et al*., 2004; Roy *et al*., 2007). In this study, LGBF80d and PLBF80d cockerels gained sufficient body weight following severe growth restriction up to 3 weeks of age (Table 1, Das *et al*., 2008). Carcass weight as a percentage of live weight was 84–85%.

Carcass composition

Carcass composition did not differ between the LGBF80d and PLBF80d broiler groups in terms of total muscle, total intermuscular fat, viscera, skin and abdominal fat weight (Table 1). Total bone weight as a percentage of carcass weight was significantly higher in LGBF80d broilers than in PLBF80d broilers. Skeletal muscle was the largest component of the carcass and accounted for 48% of carcass weight. The viscera represented 18–19%, total bone, 14–15%, and skin, 11–12% of total carcass weight. Total intermuscular and abdominal fat accounted for 3–4% of carcass weight each.

Skeletal muscle weights of parts and subparts

Skeletal muscle as a percentage of carcass weight did not differ by parts (i.e., wing, hind limb or cervicodorsal components) or subparts between the LGBF80d and PLBF80d broilers (Table 2). Wing muscle represented 24% of carcass weight; hind limb muscle made up 18% of carcass weight; the cervicodorsal muscle

Table 1. Live weight, carcass weight and percentage, and percentage weights of total muscle, bone, intermuscular fatty tissues, viscera, skin, and abdominal fat on carcass weight in the broilers

Broiler groups	LGBF80d	PLBF80d
No of birds	7	8
Live weight (g)	3088±73b	3298±42a
Carcass weight (g)	2585±59b	2795±40a
Carcass percentage	83.7	84.7
Carcass composition (%)		
Total muscle	48.3±0.7a	48.0±0.7a
Total bone	14.5±0.2a	13.6±0.3b
Total intermuscular fat	3.25±0.25a	3.39±0.20a
Viscera	19.4±0.5a	18.0±0.4a
Skin	11.1±0.3a	11.9±0.4a
Abdominal fat	3.07±0.36a	3.81±0.36a

Means±standard errors

LGBF80d; Feeding Layer grower diet by 21 days and then Broiler finisher diet up to 80 days of age.

PLBF80d; Feeding Pre–layer diet by 21 days and then Broiler finisher diet up to 80 days of age.

a, b; Means with the same letter did not differ significantly between the broiler types at 5% level.

Table 2. Percentage weights of muscle group and subgroup to carcass weight in the broilers

Broiler groups	LGBF80d	PLBF80d
Wing muscles		
Shoulder girdle m.	19.14±0.65a	19.08±0.51a
Brachial m.	2.25±0.02a	2.09±0.06b
Antebrachial m.	1.87±0.07a	1.83±0.04a
Abdominal m.	1.02±0.01a	1.03±0.03a
Combined	24.28±0.69a	24.03±0.51a
Hindlimb muscles		
Pelvic m.	1.76±0.04a	1.64±0.05a
Femoral m.	9.04±0.17a	8.83±0.12a
Crural m.	7.64±0.11a	7.91±0.10a
Combined	18.44±0.19a	18.38±0.21a
Cervicodorsal muscles		
Dorsocaudal m.	1.84±0.04a	2.02±0.08a
Cervical m.	2.43±0.05a	2.52±0.10a
Combined	4.27±0.08a	4.54±0.17a
% of hindlimb to wing muscles	75.9±2.1a	76.5±1.3a

Means±standard errors
LGBF80d; Feeding Layer grower diet by 21 days and then Broiler finisher diet up to 80 days of age.
PLBF80d; Feeding Pre–layer diet by 21 days and then Broiler finisher diet up to 80 days of age.
a, b; Means with the same letter did not differ significantly between the broiler types at 5% level.

accounted for 4–4.5% of carcass weight. The relative weight of hind limb to wing muscle was 75.9% in LGBF80d broilers and 76.5% in PLBF80d broilers.

In the wing, the percentage weight of brachial muscle was significantly greater in LGBF80d broilers than in PLBF80d broilers (Table 2). However, the relative weight of other subparts of wing muscle did not differ between chick groups; neither did the various subparts of hind limb and cervicodorsal muscle. The shoulder girdle a subpart of the wing muscle was very large (19% of carcass weight) and accounted for 79% of total wing muscle. The second largest subpart was the femoral muscle of the hind limb muscle (9%), followed by the crural muscle (8%) of the hind limb. These three large subparts are very important for chicken production because they represent 74% or more of total muscle weight.

Individual muscle weights

There was no significant difference in the weight of any muscle, expressed relative to carcass weight, between the LGBF80d and PLBF80d broilers (Table 3). Breast meat contained the largest *pectoralis* muscle (12.4% of carcass weight) and the second largest *supracoracoideus* muscle (3.8–3.9%) and the two muscles accounted for 85% of the shoulder girdle muscle weight. In the crural subpart, the *gastrocnemius* muscle represented 3.1% of carcass weight and 40% of crural muscle weight. The *iliotibialis lateralis* and *femorotibiales* muscles in the femoral muscle were 2.0–2.3% of the carcass weight. The other muscles were very small compared with the large muscles in the chicken carcass. These results indicate that although the individual muscle weight of chickens varied markedly, they were not influenced by feeding regime.

Table 3. Percentage weights of individual muscle to carcass weight in the broilers

Broiler group	LGBF80d	PLBF80d
M. pectoralis	12.41±0.39a	12.41±0.35a
M. supracoracoideus	3.91±0.19a	3.78±0.09a
M. triceps brachii	0.99±0.03a	0.94±0.02a
M. biceps brachii	0.50±0.01a	0.47±0.02a
Mm. iliotrochanterici	1.24±0.03a	1.19±0.03a
M. iliotibialis cranialis	0.76±0.02a	0.70±0.03a
M. iliotibialis lateralis	2.32±0.06a	2.15±0.05a
Mm. femorotibiales	2.21±0.05a	1.97±0.11a
M. flexor cruris lateralis	1.21±0.03a	1.23±0.04a
M. puboischiofemoralis	0.89±0.02a	0.87±0.02a
M. gastrocnemius	3.14±0.03a	3.16±0.06a

Means±standard errors
LGBF80d; Feeding Layer grower diet by 21 days and then Broiler finisher diet up to 80 days of age.
PLBF80d; Feeding Pre–layer diet by 21 days and then Broiler finisher diet up to 80 days of age.
a, b; Means with the same letter did not differ significantly between the broiler types at 5% level.

DISCUSSION

Body growth is restricted when low energy feeds are offered (Leeson *et al*., 1996), and the chicks in this study which were fed LG or PL feed had reached only half the body size attained by equivalent chicks fed a conventional broiler diet by 21 days of age (Das *et al*., 2008). However, LGBF80d and PLBF80d broilers showed a marked recovery of body size after being fed the BF diet, a high energy feed, and had attained body weights of 3088 g or 3298 g and carcass weights of 2585 g or 2795 g, which were similar to conventionally–fed broilers (Nakamura *et al*., 2004; Roy *et al*., 2006, 2007). The percentage of carcass to live weight increased from 81–82% at 21 days to 84% in these broilers indicating a relatively smaller percentage of non–meat components such as blood, head, feet and feather.

About half of the carcass in LGBF80d and PLBF80d broilers was made up of skeletal muscle and the percentage weight of muscle increased from 34–37% in the 21 days old chicks to 48% by slaughter at 80 days of age (Das *et al*., 2008). Conversely, the percentage weight of viscera decreased markedly from 30–33% in chicks at 21 days to 18–19% in broilers at 80 days of age. Except for these two components, the remaining body components (bone, skin and fatty tissues) showed only a slight change in percentage weight with growth. Cockerels reared on layer diets gain viscera weight to a greater extent than do conventionally–fed broilers (Roy *et al*., 2007) and the birds in this study showed a percentage weight of viscera to carcass weight that was similar to cockerels. The chicks in this study gained viscera weight like the cockerels reared on layer diets in the study of Roy *et al*. (2007). These results indicate that LGBF80d and PLBF80d broilers increased their intake markedly to compensate for the low nutritional plane during the first three weeks of growth, thus recovering from early growth restriction.

Previous work has shown that the thigh and neck muscles, but not the breast muscle, of broilers respond to variation in nutritional plane and thus vary in terms of their percentage of carcass weight (Shahin and Elazeem, 2005). However, in the broiler breed used in this study, the wing (breast) muscles appeared to respond more readily than the other muscle groups. The wing muscle, as a percentage of carcass weight, increased by 7–10% in the LG and PL chicks from 3 weeks old to slaughter while the relative hind limb muscle weight increased by only 4%. Both the LGBF80d and PLBF80d broilers appeared, therefore, to show a high percentage of skeletal muscle to carcass weight; the relative weight of hind limb to wing muscle was equivalent to values found in conventionally–fed broilers (76%) by 80 days (Roy *et al*., 2007). Although 21 days old chicks which had been fed the LG and PL diets showed different hind limb to wing muscle percentages at 83.3% and 96.7%, respectively (Das *et al*., 2008), this marked difference was no longer evident at 80 days. The wing muscle appears to have responded well to the high nutritional plane and was more responsive to diet than the hind limb muscle. From these results, it appears that the ability of broilers to produce breast meat could be improved by feeding on a high nutritional plane during the pre–slaughtering period regardless of variation in growth rates during the early growth stages. However, details of how the duration of feeding on a high nutritional plane during the pre–slaughter period influences carcass composition remain to be elucidated.

In the wing muscle, the shoulder girdle muscle increased by 1.85 and 1.52 times in PLBF80d and LGBF80d broilers, respectively, from 22 to 80 days. These increases were greater than the values of 1.04–1.45 and 1.09–1.35 times in the hindlimbs and cervicodorsal subparts, respectively. The major *pectoralis* muscle in the shoulder girdle increased by 1.90 and 1.57 times and *supracoracoideus* muscle by 1.86 and 1.64 times in PLBF80d and LGBF80d broilers, respectively. It appears, therefore, that marked development of the wing muscle can be mainly attributed to vigorous growth of the *pectoralis* and *supracoracoideus* muscles. In the hindlimb muscle, various growth rates were observed among the different component muscles; the *flexor cruris lateralis* and *iliotibialis lateralis* (with its large postacetabular part in chickens) muscles in the caudolateral portion of thigh, and the *gastrocnemius* muscle in the caudal portion of the crus, increased 1.40–1.68 times. These muscles play an important role in locomotion (Vollmehrhaus, 1992).

In conclusion, although restricted early nutrition yielded chicks with relatively larger hind limb muscles, muscle composition returned to normal during an accelerated growth phase from day 22 to 80. Regardless of the different growth states at 21 days of age, the relative weight of hind limb to wing muscle attained its normal value of 76% after compensatory growth induced by feeding a BF diet. To achieve high meat production in the wing, and especially in the breast, growth must be promoted during the period prior to slaughter by feeding on a high nutritional diet.

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