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Carcass Variables and Chemical Composition of Commercial Broiler Chickens and the Red Jungle Fowl

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ABSTRACT : The carcass characteristics and composition of both male and female commercial broiler chickens (CB) and the red jungle fowl (RJF) were compared at a common body weight of 800±25.6 g. The RJF and CB were 133 and 17 d of age, respectively, when they reached 800 g. The yields of breast and thigh portions and their muscle to bone ratios were higher for RJF as compared to CB. On the other hand, the latter had significantly greater hearts, livers and gizzards. The weights of the whole thigh and drumstick, and their muscles were lower in females than males. The CB had more abdominal fat than RJF. While sex had no significant effect on the absolute weights of abdominal fats in CB, the female RJF were fatter than their male counterparts. The fat and cholesterol contents of the breast and leg muscles of CB were significantly higher than those of RJF. The opposite was noted for protein content of both muscles. The effect of sex on fat and cholesterol contents varied according to muscle type. Comparison of CB and RJF at a common body weight suggested that the rate of development of body components have changed concomitantly with selection for rapid growth in the former. (**Key Words :** Carcass Characteristics, Red Jungle Fowl, Broiler Chickens)

INTRODUCTION

Domestication, genetic selection and environmental manipulations have resulted in vast changes in anatomy, physiology and behaviour of the domestic fowl both during development and when birds attained maturity. Intense artificial genetic selection for rapid growth rate has engineered the commercial broiler chickens to the extent that they may have several undesirable characteristics such as excess deposition of adipose tissue, and inability to tolerate the stress of climatic insults and mismanagement. Siegel et al. (1992) compared domestic and the red jungle fowl (RJF) and found a considerable degree of genetic divergence between them as measured by band sharing. Today's commercial stocks varied from their RJF ancestor because of different geographical route (West and Zhou, 1988) and selection for egg and meat stocks. Although the behaviour of the RJF has been studied previously (Dawkins, 1989; Zulkifli et al., 1998; 2001), there is a paucity of information on their carcass characteristics and chemical composition.

Growth pattern, organ development and carcass characteristics of various breeds and strains of poultry have been extensively studied (Edwards and Denman, 1975; Evans et al., 1976; Becker et al., 1984; Orr and Hunt, 1984; Li et al., 2006). Those studies have emphasised comparisons at a set point of time. Chronological age as a standard for comparison has been a commonly acceptable method to examine differences in growth and carcass characteristics (Chambers, 1990). However, for strains or breeds known to have large disparity in growth pattern and mature body weight, comparison at a common body weight might be a better measure than chronological age because it relates growth to other physiological processes (Calder, 1982). Dror et al. (1977) and Barbato et al. (1983) reported that utilising lines divergently selected for body weight often demonstrated differences in body weight and composition at various predetermined chronological ages. Hence, the use of a common body weight to compare the carcass characteristics and composition of the red jungle fowl and commercial broiler allows a more precise comparison to be made. The objective of the study was to compare the carcass characteristics and composition of RJF and commercial broiler chickens (CB) at a common body

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weight of 800 g.

MATERIALS AND METHODS

Breed and management

The RJF and CB (Arbor Acres) chicks of both sexes were used in the study. The RJF breeding stock was originally captured from the secondary forests and oil palm plantations in Peninsular Malaysia and were assumed to be genetically pure. Purity of the RJF was assessed by gross characteristics, namely shape and size of the bird, colour of the plumage, colour of the shank, and ear lobes, pattern of arrangements of the tail feathers, and size and thickness of the comb (Vidyadaran, 1987). The stock was maintained as a closed flock at Universiti Putra Malaysia. The CB chicks were obtained from a local hatchery and they were feather-sexed.

At hatch (d 0) all chicks were wing banded and weighed to the nearest gram. Fifty four chicks of each genotype were assigned at random to nine battery cages (6 birds per cage) with wire floors. The batteries were in a conventional open-sided house with cyclic temperatures (minimum, 25°C; maximum 35°C). Relative humidity was between 75-90%. The chicks were vaccinated against Newcastle disease (d 7 and 21). Starter (mash form; 220.0 g/kg crude protein; 13.06 MJ ME/kg) and finisher (mash form; 199.9 g/kg crude protein; 13.06 MJ ME/kg) diets were provided to from d 1 to 20 and d 21 onwards, respectively. Because the CB were raised to 17 d of age, they were only provided starter diet. Food and water were available at all times and lighting was continuous.

Slaughter, dissection procedure and chemical analyses

Due to the large disparity in reaching market weight, comparison was made at a common body weight of 800± 25.6 g. The RJF and CB were 133 and 17 d of age, respectively when they reached 800 g. Following a 12-h period of fasting, 12 birds form each genotype-sex subgroup were individually weighed and killed by bleeding from a neck cut, which severed the carotid arteries and jugular veins. After bleeding, birds were processed and dissected by a trained team. The heads and necks were removed by cutting through the last cervical and the first thoracic vertebrae, and the shank at the tibiotarso-tarsometatarsal joints (Vidyadaran et al., 1988). The carcass dressing percentage was calculated as weight of carcass (without blood, feather, head neck, shank and giblet) divided by live weight multiplied by 100 (Vidyadaran et al., 1988).

The skin and the under-lying sub-cutaneous fat were removed and weighed. The abdominal fat was also removed and weighed according to the procedures of Kubena et al. (1974). Fat surrounding the gizzard and intestines extending within the ischium and surrounding the bursa of fabricius was considered as abdominal fat. Hearts, livers, gizzards, spleens, and lungs were removed and weighed.

The carcasses were then sectioned into breast, thigh and drumstick portions and weighed. The breast muscle (*Pectoralis major*) was carefully dissected. Essentially, this involved the removal of the *pars thoracicus*, *pars propatragialis* and the *pars abdominal* (Vidyadaran et al., 1988). Bones of breast, thigh and drumstick were separated from the muscle and connective tissue remnant and weighed. The muscles of breast, thigh and drumstick were wrapped in polyethylene bags and stored at -22°C until further analysis. The samples were homogenised using a blender and analysed for total content of moisture, ash, crude protein, crude fat and carbohydrate in accordance with the AOAC (1984). In order to determine total cholesterol content of muscles, tissue samples were thawed and extracted with 2:1 chloroform:methanol (Bligh and Deyer, 1959). The total cholesterol levels of samples were then determined enzymatically by the method of Allain et al. (1974).

Statistical analysis

Data of carcass composition, carcass characteristics and cholesterol content were subjected to analysis of variance with a factorial arrangement. The main factors were genotype (CB and RJF), sex and the interaction between them. Prior to analyses, the weight of carcass characteristics and cholesterol content were transformed to common logarithm and the percentage of carcass composition was transformed into arcsine square roots. Analyses of data were conducted wit the aid of General Linear Model procedure of SAS software (SAS Institute, 1997). When significant effects were found, comparisons among multiple means were made by Duncan's multiple range test. When interactions between main effects were significant, comparisons were made within each experimental variable. Statistical significance was considered as $p \leq 0.05$.

RESULTS

The carcass-dressing percentages of RJF were significantly higher than those of CB (Table 1). Sex had no significant effect on the parameter measured for both RJF and CB. The yields of breast and thigh portions, and their muscle to bone ratios were higher for RJF as compared to CB (Tables 2 and 3). The weights of total breast with bone included and breast muscles were not significantly affected by sex, female chickens had higher muscle to bone ratio for the breast portion. However, sex had an effect on muscle to bone ratio and the female chicken had the higher value for the breast portion. Total thigh with bone included and thigh muscle weights were heavier for males but there was no difference in muscle to bone ratio between the two sexes.

Table 1. Effects of genotype and sex on the carcass-dressing percentage at a common body weight (800 g)

	CB	RJF
Male	70.7	72.1
Female	70.9	72.5
	(70.8[b])	(72.3[a])
Source of variation	Probability	
Genotype (G)	*	
Sex (S)	NS	
G×S	NS	
Pooled SEM	0.38	

[a, b] Means within a row with no common superscripts differ significantly.
* p≤0.05; NS = Not significant.
CB = Commercial broiler chicken; RJF = Red jungle fowl.

Except for muscle to bone ratio, genotype had no significant influence on the yield of drumstick portion (Table 4). The weights of the whole drumstick with bone included and drumstick muscle were greater in males than females. There were significant genotype×sex interactions for the weights of skins, abdominal fats, necks and shanks at a common body weight (Table 5). The weights of abdominal fats and shanks of male and female CB were not significantly different. On the contrary, the weights of shanks and abdominal fats of male RJF were bigger and smaller, respectively, as compared to their female counterparts. The weights of skin and neck of CB and RJF were not significantly different in the male chicks but otherwise for the females. Irrespective of sex, the head of CB weighed higher than those of RJF. The weights of organs, namely the heart, liver, gizzard and lungs at a common body weight are presented in Table 6. The CB had significantly greater hearts, livers and gizzards but smaller spleen as compared to the RJF. Genotype had no significant effect on the weight of lungs. Except for liver, sex had no significant effect on the weights of other organs.

There were significant genotype×sex interactions for the cholesterol and carbohydrate contents of the breast muscle (Table 7). While the cholesterol content of the breast muscle of RJF was not significantly affected by sex, the female CB had significantly higher values than their male counterparts. Irrespective of sex, the cholesterol content of the breast muscle of CB was higher than those of RJF. Genotype had no significant effect on carbohydrate content of the breast muscle among the male chicks. Among the females, however, the breast muscle of CB had higher carbohydrate content than RJF. Genotype×sex interaction was not significant for water, ash, fat and protein contents of the breast muscle. Regardless of genotype, the breast muscle of the male chicks had higher water content but less protein than females. The fat and protein contents of the breast muscle of RJF were significantly lower and higher, respectively as compared to the CB. Neither genotype nor

Table 2. Effects of genotype and sex on the breast portion yield (g) at a common body weight (800 g)

Sex	Whole breast		Breast muscle		Muscle to bone ratio of breast	
	CB	RJF	CB	RJF	CB	RJF
Male	104.7	158.8	86.2	138.9	3.91 (5.48[b])	7.05
Female	104.6	147.6	87.8	130.8	5.38 (6.73[a])	8.08
	(104.6[y])	(153.2[x])	(87.0[y])	(134.8[x])	(4.64[y])	(7.56[x])
Source of variation	Probability					
Genotype (G)	***		***		***	
Sex (S)	NS		NS		*	
G×S	NS		NS		NS	
Pooled SEM	2.59		2.50		0.32	

[a, b] Means within a column with no common superscripts differ significantly.
[x, y] Means within a row with no common superscripts differ significantly.
* p≤ 0.05; *** p≤0.001; NS = Not significant. CB = Commercial broiler chicken; RJF = Red jungle fowl.

Table 3. Effects of genotype and sex on the thigh portion yield (g) at a common body weight (800 g)

Sex	Whole thigh		Thigh muscle		Muscle to bone ratio of thigh	
	CB	RJF	CB	RJF	CB	RJF
Male	77.5 (83.1[a])	88.8	65.4 (71.1[a])	76.8	5.63	6.43
Female	73.2 (74.9[b])	76.6	61.3 (64.3[b])	67.3	5.18	7.36
	(75.3[y])	(82.7[x])	(63.3[y])	(72.1[x])	(5.41[y])	(6.89[x])
Source of variation	Probability					
Genotype (G)	**		***		***	
Sex (S)	**		**		NS	
G×S	NS		NS		NS	
Pooled SEM	1.18		1.18		0.19	

[a, b] Means within a column with no common superscripts differ significantly.
[x, y] Means within a row with no common superscripts differ significantly.
** p≤0.01. *** p≤0.001. NS = Not significant. CB = Commercial broiler chicken; RJF = Red jungle fowl.

Table 4. Effects of genotype and sex on the drumstick portion yield (g) at a common body weight (800 g)

Sex	Whole drumstick		Drumstick muscle		Muscle to bone ratio of drumstick	
	CB	RJF	CB	RJF	CB	RJF
Male	67.1 (70.3[a])	73.5	52.1 (54.8[a])	57.6	3.48	3.62
Female	62.5 (60.9[b])	59.4	47.5 (47.3[b])	47.2	3.17	3.88
					(3.32[y])	(3.75[x])
Source of variation	Probability					
Genotype (G)	NS		NS		**	
Sex (S)	***		**		NS	
G×S	NS		NS		NS	
Pooled SEM	1.44		1.26		0.08	

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[x, y] Means within a row with no common superscripts differ significantly.
** p≤0.01; *** p≤0.001; NS = Not significant. CB = Commercial broiler chicken; RJF = Red jungle fowl.

Table 5. Effects of genotype and sex on the weights (g) of skin, abdominal fat, head, neck and shanks at a common body weight (800 g)

Sex	Skin		Abdominal fat		Head		Neck		Shank	
	CB	RJF	CB	RJF	CB	RJF	CB	RJF	CB	RJF
Male	54.37[a]	56.09[a]	8.09[x]	5.78[by]	35.22	30.35	27.27[a]	27.45[a]	39.07[x]	29.59[ay]
Female	47.40[bx]	40.96[by]	8.04[x]	7.39[ay]	34.01	30.62	25.33[bx]	17.28[by]	35.87[x]	20.54[by]
					(34.61[x])	(30.48[y])				
Source of variation	Probability									
Genotype (G)	***		NS		***		*		***	
Sex (S)	NS		**		NS		***		***	
G×S	**		**		NS		**		***	
Pooled SEM	0.94		0.38		0.42		0.83		0.62	

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[x, y] Means within a row with no common superscripts differ significantly.
* p≤0.05; ** p≤0.01; *** p≤0.001; NS = Not significant. CB = Commercial broiler chicken; RJF = Red jungle fowl.

Table 6. Effects of genotype and sex on the weights (g) of heart, liver, gizzard, spleen and lungs at a common body weight (800 g)

Sex	Heart		Liver		Gizzard		Spleen		Lungs	
	CB	RJF	CB	RJF	CB	RJF	CB	RJF	CB	RJF
Male	5.38	4.14	29.47 (23.35[a])	17.23	20.78	17.14	0.94	2.47	7.24	6.94
Female	5.61	4.59	30.60 (25.03[b])	19.47	22.36	16.22	0.87	2.58	6.77	6.79
	(5.49[x])	(4.36[y])	(30.03[x])	(18.35[y])	(21.57[x])	(16.68[y])	(0.91[y])	(2.52[x])		
Source of variation	Probability									
Genotype (G)	***		***		***		***		NS	
Sex (S)	NS		*		NS		NS		NS	
G×S	NS		NS		NS		NS		NS	
Pooled SEM	0.12		0.37		0.44		0.13		0.20	

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[x, y] Means within a row with no common superscripts differ significantly.
* p≤0.05; *** p≤0.001. NS = Not significant. CB = Commercial broiler chicken; RJF = Red jungle fowl.

sex had significant effect on the ash content of the breast muscle.

Genotype×sex interactions was significant for the protein, carbohydrate and cholesterol contents of the leg muscle (Table 8). The cholesterol and protein contents of RJF were similar for both sexes. However, the leg muscle of the CB males had lower cholesterol and higher protein contents than females. For the carbohydrate content, sex had no significant effect among CB but otherwise was noted for RJF. The leg muscle of CB had significantly lower water content than their RJF counterparts. Neither genotype nor sex had significant effect on the level of ash in the leg muscle.

DISCUSSION

Muscle growth is one of the most important factors in poultry meat production. The breast, thigh and drumstick are the components yielding most of the meat and the portions that are mostly consumed (Broadbent et al., 1981). The weights of the whole breast, thigh and drumstick, and their muscles were greater in RJF than CB. There is a possibility that a large part of these differences were probably due to the growth of muscle of the RJF by 133 d

Table 7. Effects of genotype and sex on the water, ash, fat, protein, carbohydrate (%) and cholesterol (mg/100 g) contents of the breast muscle at a common body weight (800 g)

Sex	Water		Ash		Fat		Protein		Carbohydrate		Cholesterol	
	CB	RJF	CB	RJF	CB	RJF	CB	RJF	CB	RJF	CB	RJF
Male	74.0 (73.8^{a})	73.7	1.09	1.09	3.76	1.92	17.8 (18.7^{b})	19.7	3.59^{b}	3.34^{a}	275.3^{bx}	168.3^{y}
Female	72.4 (72.5^{b})	72.7	1.12	1.01	3.26	2.27	19.3 (20.3^{a})	21.3	4.50^{ax}	2.68^{by}	300.7^{ax}	146.3^{y}
					(3.51^{x})	(2.09^{y})	(18.5^{y})	(20.5^{x})				
Source of variation	------ Probability ------											
Genotype (G)	NS		NS		***		***		**		***	
Sex (S)	**		NS		NS		***		NS		NS	
G×S	NS		NS		NS		NS		***		*	
Pooled SEM	0.24		0.04		0.16		0.17		0.12		6.15	

[a, b] Means within a column with no common superscripts differ significantly.

[x, y] Means within a row with no common superscripts differ significantly.

** p≤0.01; *** p≤0.001. NS = Not significant. CB = Commercial broiler chicken; RJF = Red jungle fowl.

Table 8. Effects of genotype and sex on the water, ash, fat, protein, carbohydrate (%) and cholesterol (mg/100 g) contents of the leg muscle at a common body weight (800 g)

Sex	Water		Ash		Fat		Protein		Carbohydrate		Cholesterol	
	CB	RJF	CB	RJF	CB	RJF	CB	RJF	CB	RJF	CB	RJF
Male	73.1	74.9	1.05	1.35	5.45 (3.86^{b})	2.28	17.2^{ay}	19.5^{x}	3.19^{x}	2.03^{ay}	298.5^{ax}	181.8^{y}
Female	73.0	75.2	1.07	1.12	6.49 (4.84^{a})	3.19	15.4^{by}	19.2^{x}	3.98^{x}	1.34^{by}	334.0^{bx}	158.0^{y}
	(73.0^{y})	(75.0^{x})			(5.97^{x})	(2.73^{y})						
Source of variation	------ Probability ------											
Genotype (G)	*		NS		***		***		***		***	
Sex (S)	NS		NS		*		**		NS		NS	
G×S	NS		NS		NS		*		*		*	
Pooled SEM	0.39		0.06		0.20		0.16		0.21		7.76	

[a, b] Means within a column with no common superscripts differ significantly.

[x, y] Means within a row with no common superscripts differ significantly.

* p≤0.05; ** p≤0.01; *** p≤0.001. NS = Not significant. CB = Commercial broiler chicken; RJF = Red jungle fowl.

of age. At that age, the RJF are taller and capable of short bursts of flight. Thus, it is likely that the RJF would invest in heavier leg and breast muscle. On the contrary, the CB reached 800 g at 17 d of age and still in the growing stage. At that stage, the muscle develops later after bones and organs (Lawrence, 1980).

Irrespective of genotype, the weights of the whole thigh and drumstick, and their muscles were lower in females than males. This could be associated with activity and function of the birds. The leg muscles of males were more developed than females and this could be due to the behavioural differences between sexes. Working on broilers, Moran and Orr (1969) also observed that the proportion of thigh and drumstick of females were smaller than the males, and the proportion of the breast in males increased abruptly at 8 weeks of age after which it remained constant with increasing age. Females also have a finer bone structure and a more rounded body, a shorter keel and drumsticks and thighs comparatively shorter than males (Mountney, 1976).

The value of muscle to bone ratio is an important index since it predicts the amount of muscle in a carcass. The breast, thigh and drumstick are components of prime meat and important for commercial cut. The muscle to bone ratio of breast yields of RJF was higher than CB and females were higher than males. These differences could be associated with the function of muscles according to genotype. In the 'natural' environment, jungle fowl has to survive in a harsh environment and competes with other animals for food, growth and reproduction. It is also capable of explosive flying, running and fighting (Vidyadaran, 1987). Further, it has to escape from the predators. Thus, it is reasonable to suggest that the bones and muscles of RJF were more developed than CB. Although the reason for the phenomenon that the female had higher muscle to bone ratio of breast yield than male is not clear, it should be considered as more than coincidence, because it was noted in both RJF and CB.

As expected, the CB was fatter than the RJF. The increase in percent abdominal fat in CB is due to higher absolute fat values associated with genetic increases in body size and also the marketing of broilers at heavier weights (Leenstra, 1986). Selection for rapid growth enhanced tendencies for large abdominal fat depots and subcutaneous fats, traits positively associated with total carcass lipids (Becker et al., 1979). The significant effect of sex on the weights of abdominal fats was noted in RJF but not among the CB. These discrepancies were probably due to age at onset of sexual maturity, where some of the RJF matured by 133 d of age. Gyles et al. (1982) reported that sex differences in abdominal fat of broilers was much greater at sexual maturity, where females had more fat deposition than the male birds. This could be attributed primarily to the relatively large ovaries in the sexually matured females (Wilson et al., 1961). In the female birds, fat is responsible for reproduction process. When birds matured, the production of egg yolk is influenced by lipid metabolism. Most of the lipids exist in lipoprotein form and accumulated in the egg yolk.

The weights of heart, liver and gizzard were greater for CB than RJF. The greater heart weight in CB could be associated with the nature of the function of this organ as the supplier of blood to the birds (Wall and Anthony, 1995). The higher liver weight in CB may reflect excessive fat deposition and increased rate of lipogenesis (Hood and Pym, 1982). The strong positive correlation between liver weight and total body weight has been well documented (Kawahara and Saito, 1976; Maeda et al., 1986; Toelle et al., 1991). It is possible that the variations in growth rate between RJF and CB were due to the supply and demand organs having undergone modifications, at least in size, to accommodate the different growth rates. In this study, the weights of lungs of CB and RJF were similar, consistent with those of Wall and Anthony (1995). Vidyadaran (1987) reported that the lung volume of the adult female domestic fowl, whether it is from a layer or broiler strain, has become smaller relative to body weight than the lung of the adult female of RJF. The author postulated that the increased pressure for meat selection has ignored the selection pressures for survival.

Irrespective of genotype, the current results revealed that the weights of organs, namely heart, gizzard, spleen and lung were similar between male and female, but not the liver, which was heavier in the females than males. It could be associated with the total fat and reproduction function of females. On the contrary, Plavnik and Hurwitz (1982) reported that the weights of hearts and livers of chickens did not differ between sexes from 1 to 10 weeks of age.

Genotype, age, diet and gender are important factors in determining the chemical compositions of poultry meat, particularly in fat and protein contents (Grey et al., 1983; Summers and Leeson, 1985; Leenstra, 1986; Liu et al., 2006). The fat and protein contents of breast and leg muscles were higher in RJF as compared to those CB. It is possible that intense selection for body weight resulted in increase in fat deposition, consequently increases in carcass fat (Edwards and Denman, 1975; Lin, 1981; Leenstra, 1986). Another reason is related to the activity of the birds, where RJF are active birds and thus carcass fat remained low until the bird reaches sexual maturity Kirkpinar and Oguz (1995) in Japanese quail. The present findings also indicated that protein content is higher in the breast than in leg muscle in both measurements, in contrast with fat content. The reason of this phenomenon is not clear, however a similar trend has been documented earlier (Evans et al., 1976; Grey et al., 1983; Kassim and Suwanpradit, 1996).

Almost one-third of the body's cholesterol is in muscle, where it is a structural component (Akoh and Min, 1998). The function of cholesterol is as an insulator and it is one of the more important biological substances. Because of the link between increased plasma cholesterol concentrations and coronary heart disease in humans, researchers focused their attention in studying the possibility of producing healthier meat. The present findings suggest that the breast and leg muscles of RJF had lower cholesterol levels than those of CB. This is probably due to the differences in the type of muscle fibre and activity between the two genotypes. The type of muscle fibre is determined genetically (Lawrence, 1980). Another explanation is associated with the fat content of carcass. The level of cholesterol has been reported to be higher in fatter carcass (Gillespie, 1998).

It can be concluded that selection for growth and body weight for many decades has resulted in tremendous changes in the size and function of commercial broiler chickens as compared to their ancestors, the red jungle fowl. The rate of development of body components have changed concomitant to selection for rapid growth. It is apparent that at a common body weight of 800 g, CB had a more rapid development of "supply organs" such as lungs and liver than those of RJF. Such a large early investment into these organs may have been at the expense of growth directed to "demand" organs such as muscles.

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