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The Effects of Different Caponization Age on Growth Performance and Blood Parameters in Male Tibetan Chicken

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Abstract: In this experiment, forty triplets consisting of full-sib Tibetan Chicken cockerels were divided equally into two trial groups. In each group, the triplets were randomly assigned to caponization, sham treatment and intact groups. The birds of the two trials were caponized or sham-operated at either 6 weeks of age (early) or 18 weeks of age (late) and slaughtered at 24 weeks of age. The birds in the early caponization group showed significant increases in terms of intermuscular fat deposits, subcutaneous fat thickness, liver weight, triacylglycerol concentration ($p<0.05$) and abdominal fat weight ($p<0.01$) at 24 weeks of age compared with the intact and sham groups, while later caponization resulted in significant increase in liver weight, abdomiual fat weight, total cholesterol and triacylglycerol concentrations ($p<0.05$). In both trials, the capons exhibited lower leg muscle weight than did the intact ($p<0.05$). There were no significant effects on breast muscle weight on either the early or late caponization group. We concluded that late caponization accelerates the rate of fat deposition within the abdominal cavity compared to other areas after sexual maturity. Present results also suggest that the role of androgen on the growth of breast muscle is different from that on leg muscle in Tibetan Chicken cockerels. It seemed that the positive effects of androgen were reflected ouly on leg muscle growth.

Key words: Caponization, fat, growth, muscles, Tibetan Chicken

INTRODUCTION

Caponization is the surgical castration of male chickens, in which the testes are completely removed. The extraction sexual gonads are results in a lack of androgen and capons become quieter and more docile. As caponization could greatly reduce aggressive behaviors of cocks, energy could be saved and the efficiency of feed conversion and meat quality could be improved in capons. Capon meat is tender, juicier and more flavorful and delicious than that from intact birds (Chen *et al*., 2005, 2006). Caponization provides a special type of poultry meat production for market (Lin and Hsu, 2002; Chen *et al*., 2007; Mignel *et al*., 2008).

It is well known that the abdominal fat pad is significantly increased in capons, regardless of the breed and the age of caponization or slaughter (Cason *et al*., 1988; Tor *et al*., 2002). However, the effects of caponization on growth performance showed in previously published research reports are inconsistent. Lin and Hsu (2002) and Chen *et al*. (2007) reported that caponization could enhance chicken growth. But other studies did not show either positive effects (Fennell and Scanes, 1992b; Chen *et al*., 2005; Mignel *et al*., 2008) or negative effects on growth (Fennell and Scanes, 1992a). The reasons for these discrepancies may be attributable to differences in surgical age, slaughter age, species or strain, nutritional levels, or husbandry methods and conditions.

In industry and most previous research, caponization is typically conducted at early ages before sexual maturity. The effects of gonads on growth and development may begin very early

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(Raham *et al*., 1984), but the gonads only begin to fully express after reaching puberty. The gonadal steroid hormones are particularly important in stimulating the increased growth that is seen in all animals at puberty and as anabolic agents, they increase the efficiency of utilization of nitrogen (Lawrence and Fowler, 2002). The effects of caponization at the puberty age have not, to our knowledge, previously been reported.

The majority of agricultural research in chicken has been conducted in broiler or Leghorn and there is to our knowledge no report of the effects of caponization in Tibetan Chicken, whose growth pattern after caponization might therefore, differ from broiler or Leghorn. Tibetan Chicken, a unique indigenous chicken breed indigenous to Tibet, is well-adapted to high altitudes (Zhang *et al*., 2007) and extremely hardy and disease-resistant, but it grows more slowly than the broiler, a late-maturing breed. Tibetan Chicken is characterized by lower carcass and eviscerated yields, but high breast and leg muscle yields (Chamba *et al*., 2008). It is a good breed for developing high-quality production.

The aim of the present study is to examine the effects of different caponization ages on growth performance and blood parameters in Tibetan Chicken cockerels.

MATERIALS AND METHODS

Animals

All the birds were randomly selected from the Tibetan population in the Experimental Poultry Genetic Resource and Breeding Chicken Farm of the China Agricultural University and raised on the same farm. All the birds hatched out in August 2007 and were slaughtered in January 2008, a total of 24 weeks. Present experiment was initiated at 6 weeks of age. Forty broods of Tibetan Chicken cockerels were randomly selected and each brood consisted of three full-sibs. All of the birds were housed in individual cages (37×21×38 cm) during the experimental period. The room temperature was maintained at 33-35°C from birth to 3 days, 31-33°C from 4 to 7 days, 28-30°C from 8 to 14 days, 25-27°C from 15 to 21 days, 20-25°C from 4 to 17 weeks and 16-20°C from 18 to 24 weeks and the relative humidity was maintained at 40-70%. The length of illumination was 22 h day^{-1} from birth to 7 days, 18 h from 8 to 14 days, 16 from 15 to 21 days, 8 h day^{-1} from 4 to 17 weeks and 9, 10, 11, 12, 12.5, 13, 13.5 h for the 18, 19, 20, 21, 22, 23 and 24 weeks, respectively. Trials 1 and 2 each used 20 broods. Birds in each set of triplets were randomly assigued into either the intact group, the sham group, or the capon group in each trial. In Trial 1, the chickens in the sham group were shame-operated at 6 weeks of age and the chickens in the capon group were caponized at the same time. In Trial 2, the sham operations and surgical caponization were performed at 18 weeks of age. The age of caponization in Trial 2 was chosen to coincide with the onset of puberty. The caponization procedure was performed according to the methods described by Lin and Hsu (2002) and Chen *et al*. (2005, 2006). All the chickens were slaughtered at 24 weeks of age. Feed and water were provided *ad libitum* (Table 1).

Measurements

The growth performances were measured and calculated at the MOA (Ministry of Agriculture) Poultry Performance and Quality Testing Center (Beijing) according to the methods described by Yang *et al*. (2002). At the end of each trial (the studied birds at the age of 24 week), after 12 h of food and water deprivation, the body weight was measured and recorded and blood samples were collected from the brachial vein using the VACUETTE® Serum Clot Activators (Greiner Bio-One GmbH, Austria). Sera were obtained and stored at -40°C for further analysis. The birds were subsequently slaughtered. Carcass weights were measured and recorded after slaughter. The breast muscles, leg muscles and wings from both sides of the carcass were dissected and weighed. The heart, liver, gizzard and abdomiual fat (including the fat surrounding the gizzard and fat pad in the abdomiual cavity) were

Table 1: Composition (%) of experimental basal diets

	Week		
Ingredients	0-6	7-18	19-24
Corn	54.00	69.70	66.00
Wheat middling	2.00	2.00	2.00
Soybean meal	26.90	16.00	20.50
Cottonseed meal	2.00	3.00	3.00
Rapeseed meal	2.00	3.00	2.00
Corn gluten meal	4.00	0.00	0.00
Soybean oil	2.50	0.00	0.00
DL-methionine	0.15	0.05	0.15
$NaHCO_3$	2.00	2.00	2.00
$CaHPO_4$	1.40	1.50	1.50
Limestone	1.80	1.50	1.60
NaCl	0.25	0.25	0.25
Premix*	1.00	1.00	1.00
Total	100.00	100.00	100.00
Calculated composition			
ME (kcal kg^{-1})	2,850.00	2,800.00	2,780.00
Dry matter	87.50	87.50	87.50
Crude protein	20.00	15.00	16.50
Crude fibre	5.00	6.00	6.00
Calcium	1.00	0.90	1.00
Total phosphorous	0.60	0.60	0.60
Salt	0.40	0.40	0.40
Methionine+cystine	0.77	0.55	0.64

*Provided per kg of diet vitamin A 2,475 μg; vitamin D_3 11.25 μg; vitamin E 50 mg; menadione 1.5 mg; vitamin B_{12} 0.02 mg; D-biotin 0.6 mg; folacin 6 mg; niacin 50 mg; D-pantothenic acid 18.3 mg; pyridoxine 6.4 mg; riboflavin, 15 mg; thiamin 13.4 mg; copper 4 mg, iodine 1.0 mg; iron 60 mg; manganese 60 mg; selenium 0.1 mg and zinc 44 mg

completely dissected and weighed. The intermuscular fat width, subcutaneous fat thickness and comb height were measured by using a Mitutoyo Digimatic sliding gauge (Mitutoyo Ltd., U.K.). The skin of the breast was opened and the width of the fat layer was measured at the pleurosteron position, providing an index of intermuscular fat width. Subcutaneous fat thickness was measured near the tail head. The two parameters (intermuscular fat width and subcutaneous fat thickness) were measured shortly after slaughter and the mean of three measures was calculated to determine the thickness. Blood parameters were measured at Xiyuan Hospital of China Academy of Chinese Medical Sciences (Beijing). Testosterone concentration was determined using a γ-counter (GC-911) with a radioimmunoassay kit (Sino-UK Institute of Biological Technology, Beijing). Blood serum glucose, Total Cholesterol (TC) and triacylglycerol (TG) concentrations were analyzed using an automatic bio-chemical analyzer (Hitachi 7600-020), a Glucose kit (Biosino Bio-Technology and Science Inc., Beijing), a Pureauto S CHO-N kit and a Pureauto S TG-N kit (Sekisui Medical Co., Ltd.).

Statistical Analysis

Statistical Product and Service Solutions (SPSS) 13.0 for windows (SPSS Inc., US) was used in statistical analysis (Norucεis, 2005). All data were subjected to one-way ANOVA analysis. Differences between means were compared using the Duncan's new multiple range method (Steel and Torrie, 1980).

RESULTS

Trial 1

The effects of early caponization on growth performance and blood parameters in 24 week-old Tibetan Chicken cockerels are given in Table 2-4. There were no significant differences among the three treatment groups in terms of feed intake, body weight, carcass weight, breast muscle weight, wing

Table 2: Effects of early caponization (at 6 weeks of age) on feed intake, body weight, carcass traits and comb height in 24 week-old Tibetan Chicken cockerels

Treatments	Feed intake 6-17 weeks (g/day/bird)	Feed intake 18-24 weeks (g/day/bird)	Body weight at 6 weeks of age (g)	Body weight at 24 weeks of age (g)
Intact (n = 20)	64.82±6.13	85.26±5.49	340.21±9.64	1505.22±29.68
Sham (n = 20)	61.91±5.62	84.37±4.81	351.19±9.21	1471.26±41.60
Capon (n = 20)	63.44±5.28	81.41±4.93	349.71±11.33	1431.05±44.72
Significance	ns	ns	ns	ns

Treatments	Carcass weight (g)	Dressing percentage (%)	Intermuscular fat width (mm)	Subcutaneous fat thickness (mm)	Comb height (mm)
Intact (n = 20)	1300.50±28.70	86.40±0.88^{a}	5.83±0.64^{b}	3.69±0.21^{b}	32.93±1.73^{a}
Sham (n = 20)	1272.37±44.16	86.25±1.06^{a}	4.89±0.70^{b}	3.66±0.22^{b}	32.64±1.60^{a}
Capon (n = 20)	1198.29±38.31	83.72±0.45^{b}	8.15±0.95^{a}	4.33±0.23^{a}	10.18±0.77^{b}
Significance	ns	*	*	*	**

Values are expressed as Mean±SD, ns: Not significant (p>0.05), *Significant difference (p<0.05), **Significant difference (p<0.01). Mean in the same row with different superscript are significantly different (p<0.05 or p<0.01)

Table 3: Effects of early caponization (at 6 weeks of age) on different tissues and organs weight in 24 week-old tibetan chicken cockerels

	Weight (g)			
Treatments	Breast muscles	Leg muscles	Wings	Heart
Intact (n = 20)	150.46±5.39	268.37±9.76^{a}	116.66±2.85	9.54±0.25^{a}
Sham (n = 20)	151.62±7.43	244.39±12.63^{ab}	112.47±3.58	9.20±0.40^{a}
Capon (n = 20)	154.38±6.39	231.04±9.31^{b}	110.34±3.85	7.17±0.24^{b}
Significance	ns	*	ns	**

	Weight (g)			
Treatments	Liver	Gizzard	Abdominal fat	Testes
Intact (n = 20)	22.56±1.23^{b}	22.27±0.89	1.03±0.41^{b}	15.89±1.91
Sham (n = 20)	22.54±1.66^{b}	2.12±0.99	0.78±0.20^{b}	14.75±1.46
Capon (n = 20)	27.46±1.83^{a}	23.31±0.85	8.41±2.92^{a}	-
Significance	*	ns	**	ns

Values are expressed as Mean±SD, ns: Not significant (p>0.05), *Significant difference (p<0.05), **Significant difference (p<0.01). Mean in the same row with different superscript are significantly different (p<0.05 or p<0.01)

Table 4: Effects of early caponization (at 6 weeks of age) on blood parameters in 24 week-old tibetan chicken cockerels

Treatments	Testosterone (pg mL^{-1})	Glucose (mmol L^{-1})	Total Cholesterol (mmol L^{-1})	Triacylglycerol (mmol L^{-1})
Intact (n = 20)	896.18±35.36^{a}	11.98±0.43	2.79±0.29	0.79±0.14^{b}
Sham (n = 20)	844.50±30.81^{a}	12.91±0.48	3.15±0.42	0.85±0.12^{b}
Capon (n = 20)	96.40±30.30^{b}	12.90±0.75	3.12±0.18	1.04±0.12^{a}
Significance	**	ns	ns	*

Values are expressed as Mean±SD, ns: Not significant (p>0.05), *Significant difference (p<0.05), **Significant difference (p<0.01). Mean in the same row with different superscript are significantly different (p<0.05 or p<0.01)

weight, gizzard weight, glucose, or total cholesterol concentrations (p>0.05). On the contrary, early caponization significantly increased intermuscular fat width, subcutaneous fat thickness, liver weight, triacylglycerol concentration (all p<0.05), abdominal fat weight (p<0.01), decreased dressing percentage (p<0.05), heart weight and comb height (p<0.01) compared with the intact and sham at 24 weeks of age.

Trial 2

The effects of late caponization on growth performance and blood parameters in 24 week old Tibetan Chicken cockerels are shown in Table 5-7. There were no significant differences among the three treatment groups in feed intake, dressing percentage, intermuscular fat width, subcutaneous fat thickness, breast muscle weight, wing weight, gizzard weight, or glucose concentration (p>0.05). The capons had heavier liver weight, abdominal fat weight, higher total cholesterol and triacylglycerol concentrations (p<0.05) and lower heart weight and comb height (p<0.01) compared with the intact and sham at 24 weeks of age. The capons had lower body and carcass weights than did the intact in Trial 2 and lower leg muscle weight than the intact in both trials (p<0.05).

Table 5: Effects of late caponization (at 18 weeks of age) on feed intake, body weight, carcass traits and comb height in 24 week-old tibetan chicken cockerels

Treatments	Feed intake 6-17 weeks (g/day/bird)	Feed intake 18-24 weeks (g/day/bird)	Body weight (g) 18 weeks of age	Body weight (g) 24 weeks of age
Intact (n = 20)	62.79±5.97	83.68±4.36	1210.35±31.13	1482.27±30.31^{a}
Sham (n = 20)	63.28±4.96	80.12±5.19	1201.03±37.04	1438.80±35.92^{ab}
Capon (n = 20)	60.93±5.28	80.19±4.88	1190.29±33.83	1357.13±32.12^{b}
Significance	ns	ns	ns	*

Treatments	Carcass weight (g)	Dressing percentage (%)	Intermuscular fat width (mm)	Subcutaneous fat thickness (mm)	Comb height (mm)
Intact (n = 20)	1273.23±30.70^{a}	85.79±0.51	5.82±0.61	3.48±0.17	35.37±1.43^{a}
Sham (n = 20)	1248.40±33.72^{ab}	86.71±0.36	5.61±0.60	3.53±0.25	33.42±1.99^{a}
Capon (n = 20)	1161.96±29.39^{b}	85.56±0.36	6.01±0.51	3.94±0.52	17.27±0.75^{b}
Significance	*	ns	ns	ns	**

Values are expressed as Mean±SD, ns: Not significant (p>0.05), *Significant difference (p<0.05), **Significant difference (p<0.01). Mean in the same row with different superscript are significantly different (p<0.05 or p<0.01)

Table 6: Effects of later caponization (at 18 weeks of age) on different tissues and organs weight in 24 week-old tibetan chicken cockerels

Treatments	Weight (g) Breast muscles	Weight (g) Leg muscles	Weight (g) Wings	Weight (g) Heart
Intact (n = 20)	147.15±4.71	265.71±9.74^{a}	112.88±3.66	8.78±0.27^{a}
Sham (n = 20)	148.71±6.39	249.81±8.22^{ab}	106.96±3.05	8.64±0.35^{a}
Capon (n = 20)	150.03±4.99	223.63±9.41^{b}	107.38±2.94	7.12±0.20^{b}
Significance	ns	*	ns	**

Treatments	Weight (g) Liver	Weight (g) Gizzard	Weight (g) Abdominal fat	Weight (g) Testes
Intact (n=20)	21.26±0.84^{b}	21.38±0.79	0.75±0.25^{b}	17.17±1.36
Sham (n=20)	22.35±1.14^{b}	22.49±1.42	0.66±0.23^{b}	16.26±1.26
Capon (n=20)	24.19±0.89^{a}	23.48±0.79	4.79±1.95^{a}	-
Significance	*	ns	*	ns

Values are expressed as Mean±SD, ns: Not significant (p>0.05), *Significant difference (p<0.05), **Significant difference (p<0.01) Mean in the same row with different superscript are significantly different (p<0.05 or p<0.01)

Table 7: Effects of later caponization (at 18 weeks of age) on blood parameters in 24-week-old tibetan chicken cockerels

Treatments	Testosterone (pg mL^{-1})	Glucose (mmol L^{-1})	Total cholesterol (mmol L^{-1})	Triacylglycerol (mmol L^{-1})
Intact(n = 20)	900.26±32.87^{a}	13.25±0.68	2.69±0.19^{b}	0.80±0.10^{b}
Sham(n = 20)	854.49±32.66a	12.82±0.36	2.73±0.29^{b}	0.77±0.16^{b}
Capon(n = 20)	123.00±33.17^{b}	13.94±0.51	3.52±0.15^{a}	1.09±0.10^{a}
Significance	**	ns	*	*

Values are expressed as Mean±SD, ns: Not significant (p>0.05), *Significant difference (p<0.05), **Significant difference (p<0.01). Mean in the same row with different superscript are significantly different (p<0.05 or p<0.01)

There were no differences in comb height, or testosterone concentration between intact and sham, but these traits were significantly higher than in capons (p<0.01). There was no significant difference in the weight of testes, between intact and sham (p>0.05) in either trial.

DISCUSSION

Body and carcass weights in the intact group were significantly greater than in the capon group in Trial 2 (p<0.05); these weights in the sham group were intermediate to those of the capons and intact birds. These results are consistent with those of Cason *et al.* (1988), Burke and Edwards (1994) and Severin *et al.* (2006), who found that cocks were heavier than capons. Present results indicate that surgical stress may be an important consideration (Lin and Hsu, 2002). The capons had lower body

weight, which might be attributable to the short time for recovery and growth from the time of caponization to slaughter in Trial 2. However, the capons had more time to adapt and grow from caponization to slaughter in Trial 1 and the young chickens suffered fewer adverse effects and recovered more quickly than did the older chickens. But, there were no significant differences between the sham and intact groups in either trial, indicating that the surgical stress had no significant disadvantageous effects. The main reason may be that the gonads began to fully express after reaching puberty. Capons grew slower and deposited more fat than did the intact males, particularly after sexual maturity, suggesting that the influence of sexual maturity had a greater effect on growth did than the surgical stress. The sham-operated control groups were important for evaluating the effects of surgery in these experiments. The dressing percentage of capons was lower than that of the sham and intact in Trial 1 ($p<0.05$), which contrasts to Severin *et al.* (2006). This difference might be due primarily to fat deposition, which was much higher in capons. However, Severin *et al.* (2007) found dressing percentage was similar in both intact and castrated birds.

There was no significant difference in intermuscular fat width or subcutaneous fat thickness among the three groups in Trial 2. However, in Trial 1 the parameters of capons increased significantly ($p<0.05$). This agrees in part with the study conducted by Tor *et al.* (2002), whose studies showed that both subcutaneous and intermuscular fat of capons were always significantly ($p<0.001$) higher than those of cocks. Chen *et al.* (2006) reported that caponization significantly increased the lipid deposition of subcutaneous fat ($p<0.05$). In this experiment, it took the capons 6 weeks from the time of caponization to slaughter to deposit abdominal fat, which is about six times more than that in the intact males in Trial 2, while the capons in Trial 1, which had 18 weeks to accumulate abdominal fat after caponization, deposited about eight times more abdominal fat than the intact males did in Trial 1. This might be because the gonads began to fully express after reaching puberty and release more testosterone. Given that there was no significant difference in abdominal fat weight in the intact males between Trial 1 and 2, the results suggest that the fat deposit efficiency of the capons was different at different growth stages and that late caponization accelerated the rate of fat deposition within the abdominal cavity compared to other areas after sexual maturity.

Androgens may be important for growth regulation, besides their gender-specific effects on somatotrophic function (Decuypere and Buyse, 2005). In mammals androgen stimulates protein synthesis and increases muscular mass, improves nitrogen, phosphorous and potassium retention in the body, resulting in increased muscle growth (Ford and Klindt, 1989). Male animals are generally larger than females (Glucksmann, 1974) and have more muscle, especially in the neck and the forequarters. In chickens, the male usually develops a larger body than the female. Breast and leg muscles are two of the most economically important and valuable parts of the chicken carcass. The leg muscle weights of capons were lighter than those of intact cocks ($p<0.05$) in both trials; this may be attributable to the deficiency of androgen. This result suggests that androgen can enhance muscular growth. However, there was no significant difference in breast muscle weight in capons compared to the other groups in present experiment, indicating that the growth of breast muscle was unaffected by the lack of androgen. This is very interesting and may be the area for further investigation. It has been reported that pectoral major weight of castrated chickens is less than that of intact controls (Cason *et al.*, 1988; Burke and Edwards, 1994). In contrast, Tor *et al.* (2002), Chen *et al.* (2007) and Miguel *et al.* (2008) found that caponized birds had heavier pectoral muscles than those of uncastrated birds. Tor *et al.* (2002) reported a higher thigh weight, but lower drumstick weight, in capons, indicating that the effects of androgen on the growth of individual muscles or muscle groups are different in chickens, especially for breast and leg muscles. This may presumably vary in different breeds as well.

Present studies showed that weight of the heart in intact and sham cocks was greater than that in capons ($p<0.01$). This agrees with the findings of Severin *et al.* (2007) and Miguel *et al.* (2008).

Chen *et al.* (2006) reported that caponization increased the weight of the gizzard, but we found that there was no significant difference among the three treatments on gizzard weight in either trial.

In birds, lipogenesis is confined to the liver, where it is particularly important in providing lipids (Murray *et al.*, 2000). Fat accumulation has been attributed to increased hepatic lipogenesis after caponization. Chen *et al.* (2006) and Severin *et al.* (2006) reported no significant difference in liver weight between capons and intact cocks, while Miguel *et al.* (2008) reported that liver content was higher in cocks than in capons. In present study, the capons had higher liver weights than did cocks or sham ($p<0.05$) in both trials; these were closely associated with fat deposition.

The testosterone concentration of capons declined significantly ($p<0.01$) due to the complete removal of the testes, in agreement with Chen *et al.* (2005, 2006). Due to the resultant androgen deficiency, the comb height of capons as a secondary male sexual characteristic was lower than that of the intact and sham males in both trials ($p<0.01$). Chen *et al.* (2006) found that capons had smaller combs than did intact cocks. In our study, capons failed to develop this characteristic (Trial 1) or tended to lose it after development (Trial 2).

In addition to secondary male sex characteristics, lipid metabolism is also affected by testosterone. Chen *et al.* (2006) found that the testosterone concentration was negatively correlated with fat deposition. It has also been reported that decreased serum testosterone levels depress the lipase and enzymes related to the Kreb's cycle, following increased serum total cholesterol and triacylglycerol levels (Xu *et al.*, 2002). Triacylglycerol is both a source and a reserve of energy in all higher animals (Sturkie, 1976). It is well known that cholesterol acts as an amphipathic lipid and a necessary structural component of plasma lipoproteins, which is directly involved in membrane synthesis and cell growth and function. Lipoproteins transport cholesterol in the circulation (Russell, 1992; Murray *et al.*, 2000). Caponization increased triacylglycerol concentration in Trial 1 and raised total cholesterol and triacylglycerol concentrations in Trial 2 in present study. Caponization of male chickens increased the blood triacylglycerol content in other studies as well (Chen *et al.*, 2005, 2006). In a earlier report, capons showed a higher total cholesterol concentration over intact males in blood constituents (Chen *et al.*, 2006), indicating that lipids syntheses is increased in capons compared with intact males, resulting in increases in total cholesterol and triacylglycerol concentrations. In most mammals, glucose is the primary substrate for lipogenesis. Glycerol 3-phosphate for the synthesis of triacylglycerols in adipose tissue is derived from blood glucose (Murray *et al.*, 2000). High glucose concentration can inhibit the fatty acid degradation to provide energy and accelerate fat deposition (Sturkie, 1976). But, there was no significant difference in glucose concentration among the three groups in either of the trials in present study, which agrees with Chen *et al.* (2005, 2006) and Severin *et al.* (2006). This indicates that caponization does not accelerate fat deposition by raising the glucose concentration and that glucose concentration was unaffected by testosterone level.

The feed intake was similar among the three treatment groups in both trials. But body and carcass weights in the late caponization group were significantly lower than in the intact males, while the two parameters of the early caponization group were not significantly different from those of the intact males. There were more subcutaneous fat and greater intermuscular fat deposits in the early caponization group. As a result, the capon meat would become more tender and juicier with better taste properties, than that of intact males, indicating that capon meat would generally meet the consumer demand for high-quality meat (Chen *et al.*, 2006, 2007; Miguel *et al.*, 2008). There was a higher abdominal fat accumulation rate in the late caponization group, but subcutaneous fat and intermuscular fat deposition were not significantly increased. There was no significant difference in meat yield among the three treatment groups in valuable parts, such as breast muscle and wing weight, with the exception of leg muscle weight. Taken collectively, present findings suggest that the economic benefit of the early castrated chickens is higher than that of late castrated chickens.

The major effects of caponization are mainly related to fat deposition and muscle growth. Present study indicates that late caponization accelerates the rate of fat deposition within the abdominal cavity compared to other areas and that capons caponized after sexual maturity grow more slowly than do intact males. The fat deposit efficiency in capons was different at different growth stages and the role of androgen was different on the growth of muscles in different body parts in Tibetan Chicken cockerels, especially for breast and leg muscles. The positive effects of androgen appear to be solely on the growth of leg muscle. Castration depressed the growth of leg muscles compared with intact birds, but castration had no significant effects on the growth of breast muscles in this study.

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