# Comparison of Some Selected Growth, Physiological and Bone Characteristics of Capon, Slip and Intact Birds in Taiwan Country Chicken Cockerels**

**Cheng-Yung Lin[1] and Jenn-Chung Hsu***

Department of Animal Science, National Chung-Hsing University, 250 Kao-Kung Road, Taichung 402, Taiwan, ROC

**ABSTRACT :** An experiment was carried out to compare the body weight, shank length, rectal temperature, comb area, abdominal fat, blood parameters and bone traits of capon, slip and intact birds in Taiwan country chicken cockerels. One hundred and sixty-six Taiwan country chicken cockerels were randomly assigned to caponized or intact male groups. Caponized birds were surgically altered at 10 weeks old and raised to 28 weeks old. At 28 weeks of age, the capons were separated into capon and slip groups, depending on the atrophy of the comb and wattle in size. The results showed that body weight and shank length in slips were significantly ($p<0.05$) greater than in intact birds. Intact birds had the highest ($p<0.05$) feather scores and the lowest ($p<0.05$) rectal temperature. Compared with intact birds and slips, capons had a significantly ($p<0.05$) smaller comb area. Bone percentage, stress and cortical thickness, and bone and ash calcium content and plasma testosterone concentration, in intact birds were the highest ($p<0.05$) followed by slips and capons. However, intact birds had the lowest ($p<0.05$) plasma ionized calcium and phosphorus concentrations. Bone and ash manganese contents in capons were significantly ($p<0.05$)lower than those in others. These findings support the hypothesis that androgenic effects on secondary sexual characteristics are stronger than anabolic growth promoting response. Androgens can directly influence calcium fluxes in male chickens. Caponized caused a reduction in the bone percentage, stress, cortical thickness and bone calcium content. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 1 : 50-56)***

**Key Words :** Capon, Slip, Androgen, Rectal Temperature, Comb Area ,Blood Parameters, Bone Traits

## INTRODUCTION

Androgens have demonstrated high anabolic activities in a variety of tissues that can stimulate muscle, bone, and connective tissue growth and erythropesis; a high androgenic activities can stimulate the reproductive system, behavioral, psychological and the secondary sexual growth characteristics or changes in the male (Griggs et al., 1989; Wakley et al., 1991; Fennell and Scanes, 1992a,b; Katznelson et al., 1996; Lin, 1999; Wang, 2001). In chickens, the anabolic growth promoting response of androgens are still being debated. Fennell and Scanes (1992a) indicated that androgenic action were stronger than anabolic reactions in chickens, and suggested that a concentration threshold for androgen growth inhibition may exist. The effects of caponization on chicken growth, behavior, muscle quality and quantity have been reported (Mast et al., 1981; Lin, 1999; Chen et al., 2000; Wang, 2001; Lin and Hsu, 2002). The influence of castration or androgen administration on blood calcium, phosphorus, alkaline phosphatase, thyroxine, calcitonin and parathyroid hormone (PTH) concentrations have also been reported, but these results were not complete consistent (Griggs et al., 1989; Vandeschueren et al., 1992; Vandeschueren and Bouillon, 1995; Gill et al., 1998; Mauras et al., 1999). Pierson et al. (1981) found that capons demonstrated a significantly higher incidence of leg abnormalities than intact or testosterone fed birds. Hutt (1929) reported an increase in the length of the humerus, tibiotarsus and three phalanges of the third toe of caponized Leghorns, while Landauer (1937) and Burke and Edwards (1994) showed no differences in the length of bone in both normal and caponized fowl. Turner et al. (1989), Wakley et al. (1991) and Vandeschueren et al. (1992) indicated that orchiectomy results in increasing skeletal remodeling and loss of cancellous tibiae bone in young and old rats, and that this loss is prevented by testosterone or dihydrotestosterone replacement. However, little information is available concerning the influence and role of male sex hormones on the fluctuations in rectal temperature, feather score, blood parameter, bone percentage, length, stress, and cortical thickness, and bone and ash mineral content in chickens. In Taiwan, native chickens are raised to nearly the sexual maturation period (14 to 18 weeks of age). Taiwan country chicken cockerels exhibit significantly higher aggression and sexual behavior than female birds after 7 weeks of age. This behavior leds to decreased body weight, feed intake and feed efficiency (Peh and Lee, 1985; Gan, 1986). Cockerels caponization changes the temperament and improve growth performance and meat quality of cocks (Lin, 1999; Wang, 2001; Lin and Hsu, 2002). This study, therefore, was carried out to investigate the influence of testicular activity on body weight, shank length, feather

** Contribution No. 1043 from Taiwan Livestock Research Institute, Council of Agriculture.

* Address reprint request to Jenn-Chung Hsu. Tel: +886-4-22850315, Fax: +886-4-22860265, E-mail: jchsu@dragon.nchu. edu.tw

[1] Department of Technical and Service, Taiwan Livestock Research Institute, Council of Agriculture, 112, Muchang, Hsinhua, 712, Tainan, Taiwan, ROC.

Received May 14, 2002; Accepted August 26, 2002

score, comb area, blood contents, bone percentage, length, stress and cortical thickness, bone ash and mineral contents in 28 wks old Taiwan country chicken cockerels.

## MATERIALS AND METHODS

One hundred and sixty-six day-old Taiwan country chicken cockerels (TLRI native chicken Taishi meat No. 13.) bred by the Taiwan Livestock Research Institute, were reared in an open-sided broiler house, on a conventional country chicken diet, which was available *ad libitum*. At 10 weeks of age, the cockerels were individually weighed and randomly assigned to either caponized or intact groups. Birds from each group were allocated into tetrareplicates with 22 birds in each pen (200×450 cm). All birds in the four pens, for the designated caponized group, were deprived of feed for 24 h followed by caponization. The birds down feathers were removed from the lateral region just anterior to the thigh. The region was swabbed with a dilute disinfectant and the skin was incised. An incision was then made between the last two ribs and widened by a small spreader. The testis was exposed by blunt dissection and removed by simultaneously teasing its connective tissue supports free and applying gentle suction. The incision was closed using surgical silk and the operation was then repeated on the opposite side. From 10 to 18 weeks of age, birds were fed 19% protein and 3,000 kcal/kg metabolizable energy grower ration. From 19 to 28 weeks, the birds were fed 17% protein and 2,800 kcal/kg metabolizable energy finisher ration. Chicks received a daily photoperiod of 23 h light: 1 dark. Feed and water were provided for *ad libitum*. At 28 weeks of age, the capons were separated into capon and slip groups depending on the atrophy of the comb and wattle in size. Although, chicken cockerels were caponized in the same way, but have some chicken's castration incomplete leading to few testicle relict in abdominal cavity. Relict of testicle can be regrowth later several weeks result in these chickens redevelopment of comb and wattle, with which caponized birds can be divided into two group (capon and slip). The comb and wattle color was bright red and size change large in slip, whereas the capon appeared still maintains atrophy status. All birds were individually weighed and rectal temperature measured; thereafter, shank length, feather scores, and comb size were measured using the method of Lilburn et al. (1987), Yeh (1990), and Jones and Lamoreux (1943), respectively. After 12 h of feed deprivation, 20 birds from each group (5 birds from each replicate) blood was collected from the brachial vein using a syringe prerinsed in a solution .15 M NaCl containing 1,000 IU/mL of heparin-Li. It was then placed into a tube containing 50 μL of a 1,000 IU/mL heparin-Li solution per milliliter of blood. The blood was kept on ice, centrifuged (1,500 G for 30 min) at 5°C and the recovered plasma was placed into three vessels. One of these vessels was held at 0-4°C for determination of plasma ionized calcium. The remaining vessels were frozen at -20°C until plasma total calcium, phosphorus, magnesium, alkaline phosphatase, thyroxine and testosterone analysis. The plasma ionized calcium concentration was measured using the kit (Bayer, UK) and automatic analyzer (634 ISE $Ca^{2+}$/pH Analyzer, Ciba Corning, England) within 72 h after blood sampling. The plasma total calcium, phosphorus, magnesium and alkaline phosphatase concentrations were analyzed with different kits (Wako, Japan) and automatic analyzer (Hitachi 7050, Japan). Assays for the concentrations of plasma thyroxine and testosterone were carried out with an ELISA microtiter reader (MRX Dynex Technologies, USA), using different ELISA kits (HUMAN Thyroxine and NEOGEN Testosterone ELISA kit). After 24 h of feed deprivation, 20 birds from each group (5 birds from each replicate) were weighted and sacrificed using standard procedures as reported by Koch and Rossa (1973). The left and right tibiae were removed. Bone fat was extracted with petroleum ether in a Soxhlet extractor for continuative 48 h. Bone (free moisture and fat, right and left tibia) as a percentage of body mass were taken based on the fasting weight of the live birds. Bone ash and mineral contents as a percentage of bone mass were taken based on the free moisture and fat weight. Contents of ash mineral as a percentage of bone ash mass were also taken. Bone stress was measured with a Tension Compression Tester (HT-8116) as described by Crenshaw et al. (1981). Bone ash content was determined according to the approach of Johnson et al. (1992). Bone calcium, manganese, magnesium, or phosphorus contents were analyzed with a Polarized Zeeman Atomic Absorption Spectrophotometer (Hitachi Model Z 8100, Japan) or a Spectrophotometer (Hitachi Model U-2001, Japan) by of the approach Association of Official Analytical Chemists (1984).

Data collected were subjected to analysis of variance using the General Linear Models (GLM) procedure of SAS (SAS Institute Inc., 1988). When significant ($p<0.05$) differences were detected, means were separated using Least Squares Means (LSMeans).

## RESULTS AND DISCUSSION

### Growth traits

The body weight, shank length, feather scores, rectal temperature, comb area and abdominal fat percentage results obtained in this study are displayed in Table 1. At 28 weeks old, body weight was significantly ($p<0.05$) greater or tended ($p<0.10$) to be greater for slips or capons over intact birds. These results are in agreement with the findings of Mast et al. (1981), who reported that partial caponization

**Table 1.** Comparison of capons, slips and intact birds on the growth traits in Taiwan country chicken cockerels at 28 weeks of age

| Items | Capons (n=43) | Slips (n=41) | Males (n=82) | S.E. |
|---|---|---|---|---|
| Body weight, g | 2,414$^{ab}$ | 2,506$^{a}$ | 2,313$^{b}$ | 30.1 |
| Shank length, mm | 115.4$^{ab}$ | 116.3$^{a}$ | 114.2$^{b}$ | 0.48 |
| Feather scores[1] | 0.00$^{b}$ | 0.00$^{b}$ | 1.44$^{a}$ | 0.015 |
| Rectal temperature, °C | 41.7$^{a}$ | 41.6$^{a}$ | 41.3$^{b}$ | 0.07 |
| Comb area, $cm^2$ | 14.00$^{b}$ | 70.54$^{a}$ | 75.34$^{a}$ | 0.633 |
| Abdominal fat, % BW[2] | 2.92$^{a}$ | 1.96$^{b}$ | 0.61$^{c}$ | 0.113 |
| Testicles, % BW[2] | 0.00$^{b}$ | 0.08$^{b}$ | 1.17$^{a}$ | 0.025 |

[a-c] Means with in the same row without the same superscript are significantly different ($p<0.05$).

[1] Scoring system where 0 to 10 indicated integrity to very poor, respectively.

[2] Twenty of observation in capons, slips and males.

**Table 2.** Comparison of capons, slips and intact birds on the plasma traits in Taiwan country chicken cockerels at 28 weeks of age

| Items | Capons (n=20) | Slips (n=20) | Males (n=20) | S.E. |
|---|---|---|---|---|
| Thyroxine μg/dL | 1.26 | 1.31 | 1.51 | 0.119 |
| Testosterone, pg/mL | 48.30$^{c}$ | 184.26$^{b}$ | 314.04$^{a}$ | 14.238 |
| Ionized calcium, mmol/L | 1.80$^{a}$ | 1.56$^{b}$ | 1.50$^{b}$ | 0.024 |
| Total calcium, mg/dL | 10.08 | 9.90 | 10.10 | 0.234 |
| Phosphorus, mg/dL | 5.22$^{a}$ | 4.60$^{b}$ | 4.16$^{c}$ | 0.059 |
| Magnesium, mg/dL | 2.20 | 2.23 | 2.65 | 0.140 |
| Alkaline phosphatase, U/L | 780.2 | 908.0 | 615.8 | 150.44 |

[a-c] Means with in the same row without the same superscript are significantly different ($p<0.05$).

produced higher body weight than intact birds. Deyhim et al. (1992) and Fennell et al. (1996) indicated that testosterone administration inhibited chicken growth. Also, Fennell and Scanes (1992a) reported that a concentration threshold for androgen inhibition of growth might exist in chickens. Lin (1999) and Wang (2001) found that increased body weight with surgical caponization was probably caused by an altered temperament. In this study, we also found that intact birds had the highest plasma testosterone concentration followed by slips and capons. Accordingly, in this study, reduced body weight in intact birds may have been due to increased aggression and mount-bite behavior and decreased feed intake during the sexual maturation period, as suggested by Peh and Lee (1985), Gan (1986) and Yeh (1990).

Shank length in slips was significantly ($p<0.05$) greater than in intact birds at 28 weeks old. Previous work has shown a positive relationship between body weight and shank length (Jaap and Penquite, 1938; Lilburn et al., 1989). This study also showed that the shank length was altered, with a concomitant change in body weight ($r=0.75$, $p<0.01$).

Compared with capons or slips, intact birds had significantly ($p<0.05$) poorer feather integrity. Lin (1999) and Wang (2001) demonstrated that enhanced feather integrity in castrated cockerels was probably caused by the decreased aggression and sexual behavior. Gan (1986) found that in cockerels feather pecking and mount-bite behavior of Taiwan country chicken increased after 7 weeks of age. Peh and Lee (1985) also showed that cockerels with higher serum testosterone concentration spent more daily time acting and less time resting from 8 to 16 weeks old. In the present study, intact birds had significantly higher plasma testosterone concentration than the other birds (Table 2). Therefore, it is reasonable to expect that intact birds had lower plumage integrity, which was associated with higher aggression and mount-bite behavior, than those in others groups.

The comb area in intact birds and slips was significantly ($p<0.05$) greater than that in capons. This finding is in agreement with Fennell and Scanes (1992a). Similarly, an increase in comb area from androgen administration in castrated cockerels or normal cockerels has been reported in other studies (Peh and Lee, 1985; Deyhim et al., 1992; Fennell and Scanes, 1992b; Fennell et al., 1996). Although, the results from this study showed that the plasma testosterone concentration was significantly ($p<0.05$) lower in slips than intact birds (Table 2), whereas comb area was not significantly different between slips and intact birds, is probably because the castrated chicks were more sensitive to androgens than intact birds. Dahlberg et al. (1981) indicated that castrated rats and mice both have increased binding affinity and maximal binding capacity of androgen receptors compared to intact animals. Fennell and Scanes (1992a) demonstrated that androgenic action were stronger than anabolic reactions in chickens. These results support the current findings that the androgenic affects on secondary sexual characteristics are stronger than the anabolic growth effects.

The abdominal fat percentage in intact birds was the lowest followed by slips and capons ($p<0.05$). These results agree with Fennell and Scanes (1992a), Fennell et al. (1996) and Chen et al. (2000). Similarly, Prescott and Lamming (1964) found that castration caused an increase in back fat depth in pigs, cattle and sheep. Fennell and Scanes (1992b) also demonstrated that androgen implantation could decrease the abdominal fat weight in male turkeys. The reduction in the abdominal adipose tissue weight in intact birds may be due to the effects of androgen on the total lipid tissue content or to the decrease of lipogenic enzyme activity (Pearce, 1977). On the other hand, the enhance in the percentage of abdominal fat in capons is probably due to castration leading to less active (Lin, 1999; Wang, 2001).

In comparison with capons or slip groups, intact birds had significantly ($p<0.05$) lower rectal temperature. These results are in agreement with Hanssler and Prinzinger (1979) and Deyhim et al. (1992), who indicated that testosterone administration decreased rectal temperature than without administration birds. Why the capon and slip had higher rectal temperature than intact birds is presently unclear.

**Blood parameters**

Table 2 summarizes the blood parameters data. The plasma testosterone concentration in intact birds was the highest ($p<0.05$) followed by slips and capons. These results agree with of Pierson et al. (1981). Burke and Edwards (1994) and Gill et al. (1998), who reported that orchiectomy caused a reduction in the serum testosterone concentration, which could be prevented by testosterone replacement in rats.

Intact birds had the highest plasma thyroxine concentration followed by slips and capons. The plasma thyroxine concentration was as much as 16% higher in intact birds over capons, however, differences were not significant ($p>0.05$) for treatments, and slips only partially compensated for this difference. Similarly, Stewart and Washburn (1983) reported that the blood thyroxine concentration in male chickens was higher than in female chickens. However, these results are in agreement with the findings of Griggs et al. (1989), who indicated that testosterone administration were not affected plasma thyroxine concentration in normal man.

The plasma ionized calcium and phosphorus concentrations in capons were significantly ($p<0.05$) higher than that in the other birds, but were not significantly ($p>0.05$) different in the concentration of plasma total calcium, magnesium and alkaline phosphatase. These results agree with Mauras et al. (1999), who indicated that hypogonadism man did not affected plasma alkaline phosphatase between baseline and later 10 weeks. Similarly, Moghetti et al. (1999) showed that hypergonadism women given GnRH agonist alone or a GnRH agonist together with antiandrogen drugs for 6 months had significantly higher serum calcium and phosphorus concentrations than the baseline. Why the capon showed an increase in plasma ionized calcium and phosphorus concentration is presently unclear. We suggest that this is probably due to an increase in bone contents loss. In this study, we also found that intact birds had the highest cortical thickness, and bone percentage followed by slips and capons (Table 3). Phosphate calcium and carbonate calcium are the most content in bone cortical. Accordingly, it is reasonable to expect to that slips and capons had higher plasma ionized calcium and phosphorus concentration, which was associated with lower bone percentage and cortical thickness, than those in intact birds.

**Bone traits**

The bone trait results obtained in this study are displayed in Table 3. Capons demonstrated a more serious of tibiae abnormalities (bowed and swollen) than intacts or slips (Figure 1). These results are in agreement with Pierson et al. (1981), who reported that castration caused an increase in leg abnormalities incidence in turkey.

The bone percentage, stress and cortical thickness in intact birds were significantly ($p<0.05$) greater than in other birds, but were not significantly ($p>0.05$) different in the tibiae length among treatments. The slips only partially compensated for bone percentage, stress and cortical thickness, and agree with the results of Turner et al. (1989), Wakley et al. (1991) and Vandeschueren et al. (1992), who found that orchiectomy causes an incremental increase in the skeletal remodeling and a loss of cancellous bone in the tibia in young and old rats. This loss can be prevented by testosterone replacement or dihydrotestosterone. Similarly, Greendale et al. (1997) showed that higher bioavailable testosterone levels were associated with higher bone mineral density in men and women. Puche and Romano (1968, 1969) also demonstrated that the addition of testosterone to *in vitro* cultures of embryonic fowl bone

**Table 3.** Comparison of capon, slip and intact birds on the bone traits in Taiwan country chicken cockerels at 28 weeks of age

| Items | Capons (n=20) | Slips (n=20) | Males (n=20) | S.E. |
|---|---|---|---|---|
| Bone percentage, % BW | $0.77^b$ | $0.78^b$ | $0.85^a$ | 0.020 |
| Tibiae length, mm | 137.0 | 134.7 | 133.0 | 1.84 |
| Bone stress, kg/cm$^2$ | $132.9^b$ | $186.5^b$ | $271.6^a$ | 11.79 |
| Cortical thickness, μm | $839.8^b$ | $905.8^b$ | $1126.1^a$ | 39.27 |
| Bone ash, % | 58.09 | 58.97 | 59.94 | 0.422 |
| Bone calcium, % | $20.81^b$ | $20.52^b$ | $22.00^a$ | 0.211 |
| Bone phosphorus, % | 10.22 | 10.26 | 10.35 | 0.088 |
| Bone magnesium, % | 0.41 | 0.42 | 0.43 | 0.006 |
| Bone manganese, ppm | $2.60^b$ | $3.40^a$ | $3.15^a$ | 0.025 |
| Ash calcium, % | $34.78^b$ | $35.86^{ab}$ | $36.73^a$ | 0.273 |
| Ash phosphorus, % | 17.60 | 17.40 | 17.28 | 0.094 |
| Ash magnesium, % | 0.70 | 0.70 | 0.72 | 0.008 |
| Ash manganese, ppm | $4.47^b$ | $5.77^a$ | $5.28^a$ | 0.129 |

$^{a,b}$ Means with in the same row without the same superscript are significantly different ($p<0.05$).

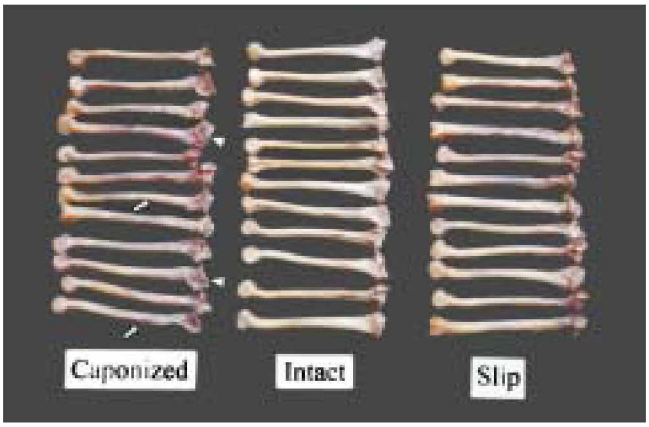


**Figure 1.** Comparision of capon, slip and intact birds on the tibiae appearance in Taiwan country chicken cockerels at 28 weeks of age. (⇧ denotes bowed; Δ denotes swollen)

enhanced calcification and the synthesis of osteoid tissue. However, Landauer (1937) and Burke and Edwards (1994) observed no bone length differences between caponized and intact fowls. Mauras et al. (1996) also indicated that insulin-like growth factor-I (IGF-I) and sex steroid hormones can impact bone formation independently and that the actions of IGF-I, growth hormone, and sex steroid hormones may synergize to maximally stimulate the attainment of peak bone mass in humans. Therefore, in this study, it is reasonable to expect intact birds to have a greater bone percentage, stress and cortical thickness, associated with higher plasma testosterone concentration (Wakley et al., 1991; Vandeschueren et al., 1992; Mauras et al., 1999). On the other hand, reduction in bone percentage, stress and cortical thickness in capons is probably due to an decrease in bone ash and calcium contents (Crenshaw, 1986).

No treatment differences were associated with the bone ash contents, although capons tended to have lower content than intact birds ($p<0.10$). The slips only partially compensated for this difference. Burke and Edwards (1994) reported no bone ash content differences between caponized and intact turkey.

The bone and ash calcium contents in intact birds were significantly ($p<0.05$) higher than those in the other birds. Compared with slips or intact birds, the capons had significantly ($p<0.05$) lower bone and ash manganese contents. Bone and ash phosphorus or magnesium contents were not influenced by castration. Why the capon had lower bone manganese content is presently unclear.

The results from this study showed that the calcium: phosphorus ratio was nearly 2.1:1 and the ash was made up of calcium, 36%; phosphorus, 17.4%; magnesium, 0.71%, and manganese, 4.9 ppm. Similarly, Hegsted (1973) reported that the calcium:phosphorus ratio was nearly constant and somewhat greater than 2:1. He reported that the ash was made up of calcium, 36%; phosphorus, 17%; and magnesium, 0.8% in mammals. The reduced bone and ash calcium contents in capons may have been due to increased bone calcium loss and decreased kinetic markers in the bone calcium deposition (Mauras et al., 1999).

In view of the results from this study on bone traits, the androgens clearly have significant skeletal effects; the paracrine mediators of androgen action on bone are include suppression of osteoblast interleukin-6 production (Hofbauer et al., 1999), an antiresorptive effect on bone (Hofbauer et al., 1999), reduction in bone remodeling (Katznelson et al., 1996), and increased β-transforming growth factor production and bone deposition (Gill et al., 1998; Pederson et al., 1999).

## CONCLUSION

These findings support the hypothesis that androgenic effects on secondary sexual characteristics are stronger than anabolic growth promoting response. Androgens can directly influence calcium fluxes in male chickens. Caponized caused a reduction in the bone percentage, stress, cortical thickness and bone calcium content.

## REFERENCES

Association Official Analytical Chemists. 1984. Official methods of analysis. 14th ed. Washington, DC:Association Official Analytical Chemists.

Burke, W. H. and H. M. Edwards. 1994. Effect of early castration on body weight, muscle growth, and bone characteristics of male Nicholas strain turkeys. Poult. Sci. 73:457-463.

Chen, K. L., C. P. Wu and Y. M. Hong. 2000. Meat quality and carcass traits of capon in comparison with intact male and female Taiwan country chicken. J. Chin. Soc. Anim. Sci. 29:77-88. (in Chinese)

Crenshaw, T. D., E. R. Peo, Jr. A. J. Lewis and B. D. Moser. 1981. Bone strength as a trait for assessing mineralization in swine : a critical review of techniques involved. J. Anim. Sci. 53:827-835.

Crenshaw, T. D.1986. Reliability of dietary Ca and P levels and bone minerals content as predictors of bone mechanical properties at various time periods in growing swine. J. Nutr. 116:2155-2170.

Dahlberg, E., M. Snochowski and J. A. Gustafson. 1981. Regulation of the androgen and glucocorticoid receptors in rat and mouse skeletal muscle cytosol. Endocrinology 108:1431-1440.

Deyhim, F., R. E. Moreng and E. W. Kienholz. 1992. The effect of testosterone propionate on growth of broiler chickens. Poult. Sci. 71:1921-1926.

Fennell, M. J. and C. G. Scanes. 1992a. Inhibition of growth in chickens by testosterone, 5α-dihydrotestosterone, and 19-nortestosterone. Poult. Sci. 71:357-366.

Fennell, M. J. and C. G. Scanes. 1992b. Effect of androgen (testosterone, 5α-dihydrotestosterone, and 19-nortestosterone) administration on growth in turkey. Poult. Sci. 71:539-547.

Fennell, M. J., S. V. Radecki, J. A. Proudman and C. G. Scanes. 1996. The suppressive effects of testosterone on growth in young chickens appears to be mediated via a peripheral androgen receptor : Studies of the anti-androgen ICI 176,334. Poult. Sci. 75:763-766.

Gan, M. T. 1986. The effects of rearing methods and perch on the daily activity, agonistic behavior, sexual behavior and economic traits of Taiwan Country Chicken. Master thesis, Department of Animal Science, National Chung-Hsing University, Taiwan, ROC. (in Chinese)

Gill, R. K., R. T. Turner, T. J. Wronski and N. H. Bell. 1998. Orchiectomy markedly reduces the concentration of the three isoforms of transforming growth factor beta in rat bone, and reduction is prevented by testosterone. Endocrinology 139:546-550.

Greendale, G. A., S. Edelstein and E. Barrett-Connor. 1997. Endogenous sex steroids and bone mineral density in older women and men : The rancho bernardo study. J. Bone Miner. Res. 12:1833-1843.

Griggs, R. C., W. Kingston, R. F. Jozefowicz, B. E. Herr, G. Forbes and D. Halliday. 1989. Effect of testosterone muscle mass and muscle protein synthesis. J. Appl. Physiol. 66:498-503.

Hanssler, I. And R. Prinzinger. 1979. The effects of male sex hormone testosterone on body temperature and energy metabolism in male Japanese quail (*Coturnix japonica*). Comp. Biochem. Physiol. 70A:247-250.

Hegsted, D. M. 1973. *In* : R. S. Goodhart and M. E. Shils, (eds.): Modern nutrition in health and disease, pp. 268. 5th ed. Lea and Febiger, Philadelphia, Pennsylvania.

Hofbauer, L. C., R. M. Ten and S. Khosla. 1999. The anti-androgen hydroxyflutamide and androgens inhibit interleukin-6 production by an androgen-responsive human osteoblastic cell line. J. Bone Miner. Res. 14:1330-1337.

Hutt, F. B. 1929. Sex dimorphism and variability in the appendicular skeleton of the Leghorn fowl. Poult. Sci. 8:202-218.

Jaap, R. C. and R. Penquite. 1938. Criteria of conformation in market poultry. Poult. Sci. 17:425-430.

Johnson, N. E., B. F. Harland, E. Ross, L. Gautz and M. A. Dunn. 1992. Effects of dietary aluminum and niacin on chick tibiae. Poult. Sci. 71:1188-1195.

Jones, D. G. and W. F. Lamoreux. 1943. Estimation of the size of comb live fowl. Endocrinology 32:356-360.

Katznelson, L., J. S. Finkelstein, D. A. Schoenfeld, D. I. Rosenthal, E. J. Anderson and A. Klibanski. 1996. Increase in bone density and lean body mass during testosterone administration in men with acquired. J. Clin. Endocrinol. Metab. 81:4359-4365.

Koch, T. and E. Rossa. 1973. Antaomy of the chicken and domestic birds. P. 12. Humbaldt University, West Germany.

Landauer, W. 1937. Studies on the creeper fowl. XI. Castration and length of bones of the appendicular skeleton in normal and creeper fowl. Anat. Rec. 69:247-253.

Lilburn, M. S., K. Ngiam-Rilling and J. H. Smith. 1987. Relationships between dietary protein, dietary energy, rearing environment, and nutrient utilization by broiler breeder pullets. Poult. Sci. 66:1111-1118.

Lilburn, M. S., K. Ngiam-Rilling and D. J. Myers-Miller. 1989. Growth and development of broiler breeds. 2. Independent effects of dietary formulation versus body on skeletal and muscle growth. Poult. Sci. 68:1274-1281.

Lin, C. C. 1999. Effects of different age of injecting estradiol into Taiwan country chicken on the agonistic behavior, sexual behavior, social status, economic traits and texture properties of breast meat in the later period of growing and the maturate. Master thesis, Department of Animal Science, Nationial Chung-Hsing University, Taiwan, ROC. (in Chinese)

Lin, C. Y. and J. C. Hsu. 2002. Effects of surgical caponization on growth performance, fiber diameter and some physical properties of muscles in Taiwan country chicken cockerels. Asian-Aust. J. Anim. Sci. 15:401-405.

Mast, M. G., H. C. Jordan and J. H. Macneil. 1981. The effect of partial and complete caponization on growth rate, yield, and selected physical and sensory attributes of cockerels. Poult. Sci. 60:1827-1833.

Mauras, N., S. Q. Doi and J. R. Shapiro. 1996. Recombinant human insulin-like growth factor I, recombinant human growth hormone, and sex steroids : Effects on markers of bone turnover in humans. J. Clin. Endocrinol. Metab. 81:2222-2226.

Mauras, N., V. Y. Hayes, N. E. Vieira, A. L. Yergey and K. O. O'Brien. 1999. Profound hypogonadism has significant negative effects on calcium balance in males: A calcium kinetic study. J. Bone Miner. Res. 14:577-582.

Moghetti, P., R. Castello, N. Zamberlan, M. Rossini, D. Gatti, C. Negri, F. Tosi, M. Muggeo and S. Adami. 1999. Spironolactone, but not flutamide, administration prevents bone loss in hyperandrogenic women treated with gonadotropin-releasing hormone agonist. J. Clin. Endocrinol. Metab. 84:1250-1254.

Pearce, J. 1977. Effect of testosterone on hepatic lipid metabolism in the mature female domestic fowl. J. Endocrinpl. 75:343-344.

Pederson, L., M. Kremer, J. Judd, D. Pascoe, T. C. Spelsberg and B. L. Riggs. 1999. Androgens regulate bone resorption activity of isolated osteoclasts *in vitro*. Proceedings of the National Academy of Sci., USA 96:505-510.

Peh, H. C. and Y. P. Lee. 1985. The cockerels serum testosterone and it's relationships with daily activities, carcass traits and meat qualities. J. Chin. Soc. Anim. Sci. 14:91-98. (in Chinese)

Pierson, F. W., P. Y. Hester and E. K. Wilson. 1981. The effect of caponization and dietary 17α-methyltestosterone on the incidence of leg abnormalities in turkeys. Poult. Sci. 60:2144-2149.

Prescott, J. H. D. and G. E. Lamming. 1964. The effects of castration on meat production in cattle, sheep and pigs. J. Agric. Sci. 63:341-357.

Puche, R. C. and M. C. Romano. 1968. The effect of dehydroepiandrosterone sulfate and testosterone on the development of chick embryo frontal bones *in vitro*. Calcify. Tiss. Res. 2:133-144.

Puche, R. C. and M. C. Romano. 1969. The effect of dehydroepiandrosterone sulfate on the mineral accretion of chick embryo frontal bones cultivated *in vitro*. Calcify. Tiss. Res. 4:39-47.

SAS. 1988. SAS user guide : Statistics. SAS Inst., Cary, NC.

Stewart, P. A. and K. W. Washburn. 1983. Wariation in growth hormone, triiodthyroxine and lipogenic enzyme activity in broiler strains differing in growth and fatness. Growth 47:411-425.

Turner, R. T., K. S. Hannon, L. M. Demers, J. Buchanan and N. H. Bell. 1989. The effects of fluoride on bone and implant histomorphometry in growing rats. J. Bone Miner. Res. 4:477-484.

Vandeschueren, D., E. Van Herck, A. M. H. Suiker, W. J. Visser, L. P. C. Schot and R. Bouillon. 1992. Bone and mineral metabolism in aged male rats : short and long term effects of androgen deficiency. Endocrinology 130:2906-2916.

Vandeschueren, D. and R. Bouillon. 1995. Androgens and bone. Calcif. Tissue Int. 56:341-346.

Wakley, G. K., H. D. Schritte, K. S. Hannon and R. T. Turner. 1991. Androgen treatment prevents loss of cancellous bone in the orchiectomized rat. J. Bone Miner. Res. 6:325-330.

Wang, H. T. 2001. Effects of surgical caponization and administration of estradiol to chicken embryos on daily activity, agonistic behavior, growth performance, carcass traits and sensory evaluation of male Taiwan country chickens. Master thesis. Department of Animal Science, National Chung-Hsing University, Taiwan, ROC (in Chinese)

Yeh, L. T. 1990. Effects of declawing, perch, and separating two sexes during rearing period on daily activity, agonistic, behavior, sexual behavior in the puberty period and economic traits of Country Chickens. Master thesis. Department of Animal Science National Chung-Hsing University, Taiwan, ROC. (in Chinese).