End-of-Season Carcass and Reproductive Traits in Original and Replacement Male Broiler Breeders

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Primary Audience: Hatching Egg Producers, Hatchery Specialists and Researchers

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SUMMARY

Reproductive efficiency of male broiler breeders declines in the later part of a production cycle. It is common to add young, replacement males (spiking) to a breeder flock to maintain or increase fertility. To date, no study has reported if there are differences in the carcass and reproductive morphology between original and spiked males at the end of the breeding period. In this study, 327 Hubbard males (237 original and 90 replacement) were killed by cervical dislocation. Body weight, shank length, spur length, keel length, and girth circumference were recorded. Footpad condition was scored on a 3-point scale, and feather condition was scored on a 6-point scale. Breast muscle and testes were dissected and weighed, and presence of abdominal fat visually assessed. The original birds (63 wk of age) had significantly higher BW, breast weight, girth measurement, keel and spur length, and also a higher feather score than the spiked males (47 wk of age). While external indicators of size and fleshing differed between replacement and original roosters, testis weight was not affected by the age of the bird. It was found that BW and breast muscle weight correlated well with average testis weight in birds where testicular regression had not taken place. As original males had a higher BW and were more heavily fleshed than replacement males, their ability to successfully complete matings may be impeded.

DESCRIPTION OF PROBLEM

Broiler stocks have been intensively selected for growth rate, feed efficiency and breast muscle mass. Genetic progress in these traits can impact reproductive fitness (Wilson et al., 1979; Siegel and Dunnington, 1985). Although female effects on a flock with poor fertility cannot be dismissed (Bramwell et al, 1996), the male most strongly influences fertility in the later stages of production. Flock fertility can be maintained with the use of artificial insemination (Brillard and McDaniel,1986). The reduction of fertility seen in naturally-mating flocks may be associated to increased BW of roosters toward the end of lay (Hocking and Duff, 1989) or a decrease in libido of older males (Duncan et al., 1990). It has been suggested that physical impairment of completed copulations due to carcass characteristics such as excessive chest girth can lower flock fertility. There can be considerable variability in reproductive performance between individual males (Reddy and Sajadi, 1990) with some males maintaining high rates of fertility while other males may be sub-fertile or infertile, or may have undergone testicular regression.

The use of external traits such as BW, leg conformation, and secondary sex characteristics as indicators of male fertility in broiler breeders has been reported (McGary et al., 2002). It was found that musculo-skeletal characteristics rather than BW alone, negatively impact a male's ability to copulate successfully. Recent research (McGary et al.,2003) has shown that low fertility toward the end of lay may be a result of poor semen transfer due to males becoming to large to attain full cloacal contact with the hens. Hocking and Duff, (1989) noted that increased male BW, which is common in late production, was negatively correlated to fertility in naturally breeding flocks. Until peak lay, fertility can be maintained by the original males. However, shortly thereafter, fertility tends to decline. Hatching egg producers commonly supplement ('spike') flocks with young, replacement males at 40 to 45 wk of lay (spiking), at this time some poor performing original males may be culled. As a result of the addition of these replacement males, the fertility of a flock can be maintained or even improved at this point.

The primary objective of this study was to determine if replacement males differ from original males in carcass characteristics (chest girth, keel length, shank length, and spur length, BW, and testes weight) at the end of a production cycle. Secondly, external factors such as feather score and foot score of birds were compared within the original and the replacement groups. Birds were sorted into LOW, STD, and HIGH BW categories and all parameters were considered. Data were analyzed to determine if there were correlations between BW, chest girth, keel length, shank length, feather score, foot score, breast weight, and testis weight. It was hypothesized that the original males would have larger testes, and have a higher body weight, and breast weight compared to the younger replacement males.

MATERIALS AND METHODS

Breeder Management

A commercial flock of 4500 Hubbard hens and 327 Hubbard males were managed according standard Western Canadian industry conditions. The original males were reared sex-separate in light-tight housing with an initial photoperiod of 24 h light. On day 4, the day length was reduced to 12.5L:11.5D until week 4, when it was further decreased to 8.5L: 15.5D. At 17 wk of age, 270 original males were co-housed with pullets. The flock was photo stimulated at 23 wk with a single step increase in day length to 14L: 10D. Day length was increased to 15L: 9D at wk 26, and further increased to 16h at wk 28.

At 46 wk of age, 100 replacement males were added to the original flock. The new males were 30 wk old at the time of introduction to the mature breeding flock. The photoperiod that the replacement males were reared with was identical to that of the original males up to 23 wk of age. However, the spiking males were kept in the rearing facility at a photoperiod of 8.5L: 15.5D until 30 wk. Photostimulation (16L:8D) coincided with movement to the laying barn

Both the replacement and original males were feed restricted from 2 wk of age until the end of production in accordance with the Hubbard BW guidelines. Two percent of the males were weighed every 4 d to obtain an average weight of the males then feed allocation was determined. The males were reared on a grower ration with 2,620 kcal/kg ME and 17% CP. The male breeder ration contained 2,660 kcal/kg ME and 16.1% CP. Nipple drinkers provided the males with chlorinated water, available *ad libitum* throughout rearing and breeding. The University of Alberta, Faculty of Agriculture, Forestry and Home Economics, Animal Policy and Welfare Committee approved this experimental protocol, under the guidelines of the Canadian Council of Animal Care (Canadian Council of Animal Care, 1984).

Data Collected

At the time of flock dispersal (63 wk of age), all remaining males (327) were carefully handled and wing-banded for identification. The birds were designated on the basis of history as either original or replacement males by visual observation of spur length and hardness. Original males had longer spurs, which tended to be sharper and pointed when compared to the spurs of younger, replacement males. Older males had developed a callous on the spurs whereas the juvenile males had not.

The girth of the thoracic cavity was measured on each live male using a fabric tape measure using the notch of the keel as a reference point. The males were killed by cervical dislocation. Feather score was determined based on the relative feather cover of the bird's back area. Feather score was evaluated on a six-point scale where a score of '1' indicated a male with no feather cover on its back. A score of '2' indicated a bird which had only a few feathers present on birds back (0 to 5% feather cover), a score of '3' was considered minimal feather cover of birds back (6 to 30% feather cover), a score of '4' equated to partial feather cover of birds back (31 to 65% feather cover), a score of '5' was assigned to birds with adequate feather coverage but may have had one part of back where feather picking occurred (66 to 92% feather cover), a score of '6' was considered complete feather coverage (93 to 100%) no visible signs of bare skin on the back.

Footpad condition was evaluated on a three-point scale where a score of '1' characterized poor footpad condition which had numerous open sores. A score of '2' was considered a good footpad condition characterized by only a few open sores. A score of '3' was an excellent footpad condition characterized by slight to no open sores on the footpad.

Birds were individually weighed, and the length of the shank and spur was recorded. The breast muscle (*Pectoralis major* and *minor*) along with the left and right testes were dissected from each bird and weighed. Any abnormalities such as testicular regression were noted for males and recorded. A bird was considered to have regressed testicles if the average testes weight of the bird was less than 4 g.

The distribution of body weight data were tested for normality using the normal probability plot procedure (Montgomery,1984). The data were analyzed (SAS Institute, Inc. 1999) for differences between the original and the replacement male groups for all the carcass and reproductive traits. Data were then sorted into three BW groups; low (2695 to 4000 g), standard

(4001 to 4900 g), and high (4901 to 6117 g) irrespective of whether the males were replacement or original.

STATISTICS

These data were then analyzed as a one-way analysis of variance (SAS Institute, 1999) to determine the relationship of BW with respect to the carcass and reproductive traits. Pearson correlation coefficients of all parameters were analyzed by SAS to determine if there were any correlations between the parameters measured. Means were considered significantly different at a $P<0.05$.

RESULTS AND DISCUSSION

Body Weight

The mean BW of the 327 males was 4,442 g. From FIGURE 1, it can be seen that the data were determined to be normally distributed around this value. Approximately 80% of the birds were within ± 15% of the mean BW, suggesting that the flock was highly uniform in BW. However, when the total population was sorted into replacement and original groups it was apparent that original males were significantly heavier than replacement males. The number of spiked males that had a BW of less than the population mean BW was 68/90 or 76%. In contrast there were only 40% (94/237) of the original males that had a BW lower than the mean. No spiked birds had a BW of over 5,200 g, whereas 33/237 or 13.9% of original males had a BW of greater than 5,200 g.

The fact that original males were heavier may have negatively contributed to their reproductive fitness. It has been reported that fertility problems are associated with increased male BW (Kondra and Shoffner, 1955; Osgasawara et al., (1963). Other research has related the decrease of fertility in heavier males to an increase in breast fleshing, which impedes the large breasted males from attaining full cloacal contact with females (Soller et al., 1965; Hocking and Duff, 1989). From the data presented in Table 1, it can be seen that the mean BW of the LOW, STD, and HIGH groups of males categories differed significantly (3,712 g, 4,451 g, and 5,264 g respectively).

Breast Muscle Traits

Data presented in TABLE 1 shows that original males had a significantly greater amount of breast muscle than replacement males. Mean breast muscle weight of the original group was 678.4 g while that of the replacement males was 575.9 g. The same trend was apparent when assessing fleshing using external indicators such as keel length and the chest girth. The original group had a mean chest girth of 39.8 cm and a mean keel length of 191.9 mm. Both of these values were greater than what was measured in the replacement males (38.3 cm girth and 190.0 mm keel length). These data indicate that older males tended to have more breast muscle deposition, which may have a negative impact on mating ability. Genetic selection for growth traits has altered body weight and muscle distribution of the broiler breeder, with the frame of the birds also likely changing to carry the redistribution of muscle (McGary et al., 2003). The stance and leg dimensions of the male have been changing as breast muscle mass has increased, which together may affect the ability of the male to achieve cloacal contact during mating.

When the birds were sorted into the three BW categories (TABLE 2), the HIGH BW birds were found to have a significantly greater breast muscle weight (841.0 g) followed by the STD (645.8 g) and LOW birds (499.0 g) (TABLE 2). For the parameters of girth and keel, the same trend was apparent as the HIGH BW birds had a girth of 41.7 cm and a keel length of 197.1 mm which differed from the STD 39.3 cm and 191.4mm and the LOW 37.5 cm and 186.5 cm. While it may be assumed that the heavy birds had excessive breast muscle deposition, the low amount of fleshing seen in the low weight males may also be questioned. It is not known if these males were relatively low weight (and under-fleshed) when they entered the breeding barn, or if their BW and condition deteriorated during the breeding period. When males are subjected to the sperm quality index (SQI) test, those in the lowest quartile also have the lowest BW, while those in the better quartiles are similar in BW (Karaca et al., 2002). While differences in physiological measures male quality have been observed, elevated mating activity in the evening may have a more critical role in optimizing fertilization (Bilcik et al., 2002).

External Carcass Traits

The replacement group had a mean shank length of 140.3 mm, which was significantly greater than the 139.8 mm for the original group (TABLE 1). While these means are significantly different, they are probably not adequately different to negatively impact the ability of the younger replacement males to access the male feeders. The variation seen in shank length due to body weight group was much greater than that seen in original versus replacement males. It is interesting to note from TABLE 2, that heavy males tended to have longer shanks. There were several relatively tall individuals in both the original and replacement groups.

Foot pad condition was better in the replacement group (mean score = 2.13) than in the original group (mean score = 1.92) (TABLE 1). This may be a result of replacement males spending less time in the breeding barn conditions or because they were typically lower in BW than the original males. Previous research has shown that broiler footpad condition could be adversely affected if proper litter, ventilation, and temperatures were not maintained in the barn (Ekstand et al., 1998). Since original males spend more time in breeding barn conditions they may be more likely to develop lesions or sores than new males. If these lesions or sores are severe they may have a negative influence on a males ability to mate. The LOW BW group had a significantly better foot score (2.19) than the STD (1.95) or HIGH (1.80) groups, which, may be a result of lighter males placing less stress on their footpads (TABBLE 2).

Mean feather score for the original males was 6.00 (TABLE 1) which implies that the feather condition of these older birds was excellent. The corresponding score of the replacement males was 5.63. It should also be noted that of the 237 original males observed only one had a feather score of less than 6 where as, 12 of 90 replacement males had a feather score of less than 6. This poorer feathering in the replacement males was apparently the result of increased feather picking, which may have been a consequence of establishment of a new social order from when these males were introduced to the barn. Feather score also demonstrated a role of body size in establishing a competitive advantage. The LOW group of males had a significantly poorer feather score, on average, than either the STD or the HIGH BW groups (TABLE 2).

Original males had a mean spur length of 23.7 mm, which was significantly greater than replacement males, which had a spur length of 13.9 mm (TABLE 1). It is clear that the spurs continue to grow throughout the breeding period. From data shown in Table 2, it can be seen that heavier groups of birds have longer spurs, ranging from 17.5 mm in the LOW weight group to 25.0 mm in the HIGH weight group. The shorter spur length evident in the LOW BW group may be partially explained by the fact that a larger percentage of these birds would have been replacement males. Among just the original males, spur length differed by nearly 3 mm between the HIGH and the LOW weight group (data not shown).

The height of the comb did not differ between male history (TABLE 1) or body weight group (TABLE 2). Comb height was not a good indicator of reproductive status in this study. While comb height can sometimes be an indicator of testes weight and fertility, this may require very diverse population to see the effect, and appears to vary by strain (McGary et al., 2002).

Abdominal Fat Pad Weight

Fat pads were not detectable in the majority of the males. A total of 21.9% of the original males also had fat pads, while only 12.2% of the replacement males did (TABLE 1). This suggests that the older (and heavier) males may have begun to divert nutrients from reproductive traits toward the development of body reserves. There was no effect of body weight grouping on fat pad weight (TABLE 2). To put in the small (approximately 10 g) fat pad weights of males in perspective, the mean fat pad weight of a feed restricted broiler breeder female at 54 weeks of age can be greater than 4.5 % of the mature hen BW (Joseph et al.,2002). Male broiler breeders are feed restricted and have low circulating levels of estrogen, which virtually eliminates the coordinated, dramatic increase in lipid synthesis driven by estrogen that occurs in the hen (Dashti et al., 1983). Without the stimulatory effects of estrogen on lipid deposition, the male remains very lean throughout the first breeding cycle.

Testes Weight

In TABLE 1 it can be seen that mean values of left testis, right testis, and average testis weight did not differ between replacement and original males. When comparing testicular form of males within the replacement and original groups it was observed that 13 of 237 original males had undergone testicular regression whereas only 2 of 90 replacement males had a mean testis weight of less than 4g. The fact that a higher percentage of older males (original males) had undergone testicular regression suggests that age may influence reproductive fitness. It has been observed (Ottinger and Gorham, 1986) that more seminiferous epithelium is atrophied 160-wk old male Japanese quail than in young quail, suggesting an age related decline in sperm output. Hence it may be likely that original BB males were experiencing testicular regression due to advanced age**.** Following testicular regression, blood plasma testosterone concentrations falls as the Leydig cells no longer produce high levels of this sex hormone. This could explain why Duncan et al. (1990) observed a significant decrease in a male libido with age**.** Declines in male fertility are more likely to be due to the loss of effectiveness of specific individuals rather than to widespread declines in reproductive status.

Overall, the left testis was on average 1.8 to 2.3 g heavier than the right in both original and replacement groups (TABLE 1). While this phenomenon has been shown to be true in mammals as well (Duke and Swenson, 1993), an explanation for this observation has not been reported.

Although there was no significant effect on testis weight when the birds were sorted based on age there was a significant effect when males were sorted into the LOW, STD, and HIGH BW groups (TABLE 2). The LOW BW group had a left testis, right testis and average testes weight of 11.9 g, 10.4 g, and 11.1 g which was significantly lower than those values of the the STD (16.3 g, 14.2 g, and 15.3 g) and the HIGH BW group (19.1 g, 17.1 g, and 18.1 g). This suggests that larger birds had larger testes and that testes weight was proportional to BW. However, it has been documented by Brown and McCartney (1983) and Wilson and McDaniel (1987) that birds possessing larger testes did not produce the most semen. Nutrient intake can also be a factor in the maintenance of sperm production. Bramwell et al. (1996) reported that males on reduced energy diets had reduced testes weight in time, and contributed to the production of hatching eggs with reduced fertility. Broiler breeder males maintained on a severe feed restriction program have been found to have a decreased semen volume and sperm concentration per ejaculate (Sexton et al., 1989). If small males are being out-competed for access to feed, there can be direct effects on the testes.

Correlation Analyses

The data in Table 3, illustrate that breast weight, chest girth, and keel length were positively correlated to BW (R^2 = 0.88, 0.68, 0.56, respectively). These findings are in agreement with those of Bjerstedt et al. (1995), who illustrated that breast weight was highly correlated to BW in 62-wk-old laying hens. Average testis weight was positively correlated with BW, indicating that larger males had large absolute testis weight relative to smaller males. This is in agreement with the findings of Wilson et al. (1988) who found that testis weight of males was positively correlated to BW. Keel length was strongly correlated to breast muscle weight (R^2 = 0.52), indicating that a larger keel length in a bird allowed more space for breast muscle deposition, which may be a result of indirect selection for breast muscle mass in broiler offspring. Spur and shank length were also correlated to BW (Table 1). VonSchantz et al. (1995), reported that spur length and testis mass were positively correlated. This is congruent with our findings that spur length was lowly but significantly correlated to average testis weight (0.1095).

CONCLUSIONS AND APPLICATIONS

1. The primary difference between original and replacement males at the end of a breeding cycle is body weight.
2. Small males have less breast muscle mass, determined by live-bird fleshing measurements as well as by necropsy at the end of the laying period.
3. Most male broiler breeders do not have a detectable deposition of abdominal fat at the end of the breeding period.

4. Absolute testis weight did not differ between original and spiking males, however there was a trend to higher incidence of testicular regression in the former.
5. Testes weights were found to be highly correlated to body weight.
6. Research needs to be carried out to determine how variation in juvenile and pre-pubertal growth curve impact the longevity of a male breeder in a commercial flock, as well as the testis and carcass condition at flock dispersal.

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FIGURE LEGENDS

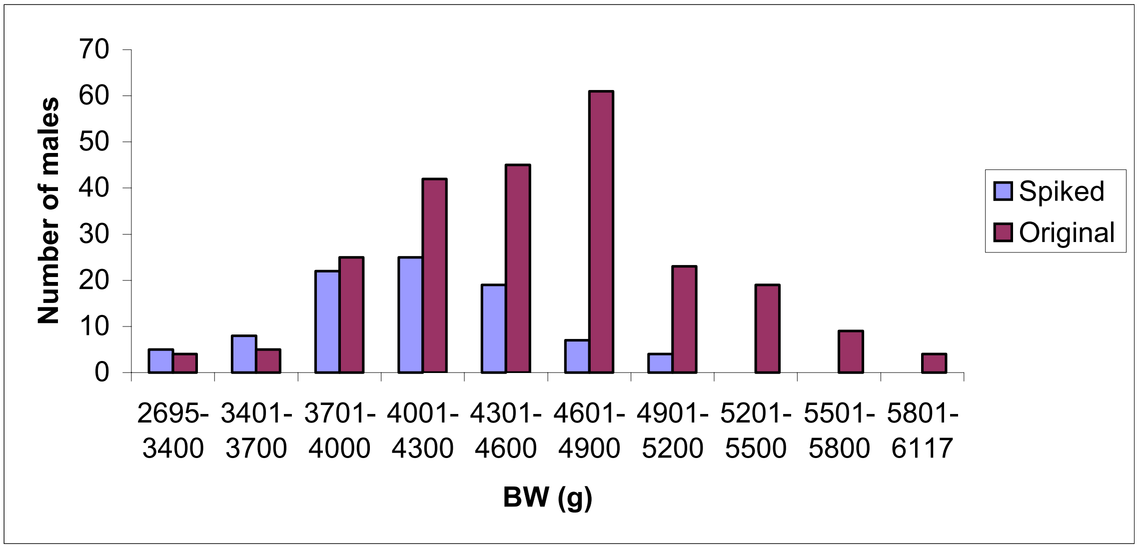

FIGURE 1. Frequency of distribution of 90 replacement and 237 original males at the end of a breeding cycle sorted into ten BW groups.

TABLE 1. Mean values (±SEM) for carcass and reproductive traits of original and replacement broiler breeder males at the end of a breeding cycle.

	Original	Replacement
N	237	90
BW (g)	4573.4±33.5[a]	4095.5±54.4[b]
Breast weight (g)[1]	678.4±8.4[a]	575.9±13.7[b]
Chest girth (cm)[2]	39.8±0.1[a]	38.3±0.2[b]
Keel length (mm)[3]	191.9±0.5[a]	190.0±0.7[b]
Shank length (mm)[4]	139.8±0.4[b]	140.3±0.7[a]
Foot score[5]	1.915±0.050[b]	2.133±0.082[a]
Feather score[6]	5.996±0.033[a]	5.633±0.053[b]
Spur length(mm)	23.7±0.3[a]	13.9±0.5[b]
Comb length (mm)[7]	66.3±0.8[a]	66.2±1.3[a]
Fat pad incidence[8]	21.94±0.03[a]	12.22±0.04[b]
Left testis weight (g)	15.9±0.4[a]	15.9±0.6[a]
Right testis weight (g)	14.1±0.4[a]	13.6±0.6[a]
Average testis weight (g)	15.0±0.4[a]	14.7±0.6[a]

[a-c] Means within a row with different subscripts are significantly different at (p .05)
[1] Breast weight included both P. major and P. minor.
[2] Chest girth was a measure of the birds circumference using notch of keel as reference point.
[3] Keel length was a measure of birds keel from cranial end to the v-joint of the caudal end.
[4] Shank length a measure of birds tibiotarsus length from base of the foot pad to the hock joint.
[5] Foot score was evaluated on a scale of 1-3:

- Score 1 extremely poor foot pad condition characterized by large numbers of open sores or severe lesions.
- Score 2: good footpad condition characterized by few open sores or mild lesions.
- Score 3: excellent footpad condition characterized by little to no open sores.

[6] Feather score was evaluated on a scale of 1-6:

- Score 1: no feathers present on birds back.
- Score 2: only a few feathers present on birds back (0-5% feather cover).
- Score 3: minimal feather cover of birds back (6-30% feather cover).
- Score 4: partial feather cover of birds back (31-65% feather cover).
- Score 5: adequate feather cover but may have one part of back where feather picking has occurred (66-92% feather cover)
- Score 6: complete feather coverage (93-100%) no visible signs of bare skin on the back.

[7] Comb length was measure using a ruler with the height of the third spike as a reference point.
[8] Fat pad incidence was expressed as a percentage of the reference group possessing a discernable abdominal fat pad.

TABLE 2. Mean values (±SEM) for carcass and reproductive traits of original and replacement broiler breeder males sorted on the basis of BW into three groups at the end of a breeding cycle.

	Weight categories		
	Low BW (2695-4000 g)	Standard BW (4001-4900 g)	High BW (4901-6117 g)
N	70	197	60
BW (g)	3712.3±32.2[c]	4450.6±19.2[b]	5264.4±34.8[a]
Breast weight[1] (g)	499.0±10.2[c]	645.8±6.1[b]	841.0±11.1[a]
Chest girth[2] (cm)	37.5±0.2[c]	39.3±0.1[b]	41.7±0.2[a]
Keel length[3] (mm)	186.5±0.7[c]	191.4±0.4[b]	197.1±0.1[a]
Shank length[4] (mm)	137.1±0.8[c]	140.0±0.5[b]	143.1±0.8[a]
Foot score[5]	2.19±0.09[a]	1.95±0.06[b]	1.80±0.10[b]
Feather score[6]	5.74±0.06[b]	5.92±0.04[a]	5.98±0.07[a]
Spur (mm)	17.5±0.7[c]	21.1±0.4[b]	25.0±0.8[a]
Comb 3rd spike[7] (mm)	65.1±1.4[a]	67.2±0.9[a]	64.6±1.6[a]
Fat pad indicence[8]	22.86±0.05[a]	17.26±0.03[a]	21.67±0.05[a]
Left testes weight (g)	11.9±0.7[c]	16.3±0.4[b]	19.1±0.7[a]
Right testes weight (g)	10.4±0.6[c]	14.2±0.4[b]	17.1±0.6[a]
Average testes weight (g)	11.1±0.6[c]	15.3±0.4[b]	18.1±0.7[a]

[a-c] Means within a row with different subscripts are significantly different at (p .05)
[1]Breast weight included both P. major and P. minor.
[2] Chest girth was a measure of the birds circumference using notch of keel as reference point.
[3] Keel length was a measure of birds keel from cranial end to the v-joint of the caudal end.
[4] Shank length a measure of birds tibiotarsus length from base of the foot pad to the hock joint.
[5] Foot score was evaluated on a scale of 1-3:
Score 1 extremely poor foot pad condition characterized by large numbers of open sores or severe lesions.
Score 2: good footpad condition characterized by few open sores or mild lesions.
Score 3: excellent footpad condition characterized by little to no open sores.[6] BW:Shank ratio corrects for the frame size of bird
[6] Feather score was evaluated on a scale of 1-6:
Score 1: no feathers present on birds back.
Score 2: only a few feathers present on birds back (0-5% feather cover).
Score 3: minimal feather cover of birds back (6-30% feather cover).
Score 4: partial feather cover of birds back (31-65% feather cover).
Score 5: adequate feather cover but may have one part of back where feather picking has occurred (66-92% feather cover)
Score 6: complete feather coverage (93-100%) no visible signs of bare skin on the back.
[7] Comb length was measured using a ruler with the height of the third spike as a reference point .
[8] Fat pad incidence was expressed as a percentage of the reference group possessing a discernable abdominal fat pad.

Table 3. Correlation coefficients (and p values) of the relationship of various carcass and reproductive traits for 63 wk male broiler breeders

	Correlation coefficients (P value)							
	Chest[3] girth	Keel[4] length	Shank[5] length	Feather[6] score	Spur length	Foot[7] score	Breast[8] weight	Average testis weight
BW	0.6796[1] (0.0001)[2]	0.5633 (0.0001)	0.3035 (0.0001)	0.1292 (0.0195)	0.4296 (0.0001)	-0.2067 (0.0020)	0.8822 (0.0001)	0.4450 (0.0001)
Chest girth		0.3894 (0.0001)	0.2083 (0.0001)	0.1585 (0.0041)	0.3637 (0.0001)	-0.0984 (0.0760)	0.6616 (0.0001)	0.2589 (0.0001)
Keel length			0.3725 (0.0001)	0.0823 (0.1376)	0.1045 (0.0592)	-0.1864 (0.0007)	0.5247 (0.0001)	0.1631 (0.0031)
Shank length				-0.0108 (0.8458)	0.0404 (0.4672)	-0.2732 (0.0001)	0.2404 (0.0001)	0.0501 (0.3667)
Feather score					0.2222 (0.0001)	-0.0511 (0.3578)	0.1432 (0.0095)	-0.0411 (0.4591)
Spur length						-0.1550 (0.0050)	0.3874 (0.0001)	0.1095 (0.0479)
Foot score							-0.1857 (0.0008)	-0.0916 (0.0986)
Breast weight								0.3147 (0.0001)

[1] Correlation coefficient.
[2] P Value.
[3] Chest girth was a measure of the birds circumference using notch of keel as reference point.
[4] Keel length was a measure of birds keel from cranial end to the v-joint of the caudal end.
[5] Shank length was a measure of birds tibiotarsus from base of the foot pad to the hock joint.
[6] Feather score was evaluated on a scale of 1-6:

Score 1: no feathers present on birds back.
Score 2: only a few feathers present on birds back (0-5% feather cover).
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Score 5: adequate feather cover but may have one part of back where feather picking has occurred (66-92% feather cover)
Score 6: complete feather coverage (93-100%) no visible signs of bare skin on the back.

[7] Foot score was evaluated on a scale of 1-3:

Score 1 extremely poor foot pad condition characterized by large numbers of open sores or severe lesions.
Score 2: good footpad condition characterized by few open sores or mild lesions.
Score 3: excellent footpad condition characterized by little to no open sores.

[8] Breast weight included both P. major and P. minor.