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The Relationship between Body Con Formation, Testicular, Carcass Traits, and Serum Insulin-Like Growth Factor-I Levels in Pubertal Male Boer Goat Crosses

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Abstract **– Body conformation traits (chest girth -CG, height at withers-HTW, body length -BL, body condition scores -BCS, body weight – BW, shoulder width –SW, and hip width - HW), testicular traits (scrotal circumference – SC, testicular weight - TW), several carcass traits, and serum Insulin Growth Factor – I (IGF-I) levels were monitored in twenty-five pubertal male Boer goat crosses at 3 week intervals for 12 weeks to evaluate the relationship among these traits. Overall, serum IGF-I levels have significant and positive correlations with most body conformation but not testicular traits; BL (r = 0.53), BW (r = 0.54), CG (r = 0.38), HTW (r = 0.38), and SW (r = 0.20), TW, r = 0.04, SC (r = 0.21 respectively. However, a negative relationship was observed for BCS (r = -0.02). Carcass traits were recorded as: 37.46 ± 3.43 kg for slaughter weight, 18.00 ± 1.88 kg for warm carcass weight, 17.43 ± 1.92 kg for cold carcass weight, 47.90 ± 2.18% for dressing percentage, 0.069± .02 cm for backfat, 0.099 ± .03 cm for adjusted back fat, 0.411± .16 cm for body wall fat, 36.38± 1.31 cm for leg circumference, and 1.50± 0.22 cm^2 for rib eye area respectively. Correlations between IGF-I levels and carcass traits were either low or negative (adjusted back fat, r = 0.08; back fat, r = 0.19; body wall fat, r = -0.04; chilled carcass weight, r = 0.15, hot carcass weight, r = 0.28; dressing%, r = 0.11; leg circumference, r = 0.40; rib eye area, r = 0.27). Serum IGF-I concentration at pubertal stage of stage of growth was effective for prediction of many body conformation traits, but it was not a reliable physiological predictor of genetic merit of carcass and/or testicular traits in pubertal Boer male goats.**

Keywords **– Boer Goats, Body Conformation, Carcass, IGF-I, Testicular Traits.**

I. INTRODUCTION

In the United States, meat goat production is increasing because of the goats' economic value as efficient converters of low quality forages into quality meat, milk, hide and products for many specialty markets [1]. Meat goat breeds in the U.S. include: South African Boer, the New Zealand Kiko, Myotonic, Savannah, Spanish and the South Kalahari Red [2]. The Boer goat is considered the leading meat breed because of its exceptional carcass yield, high muscle to bone ratio (7:1), high dressing percentage (55-60%) and early maturity [3].

Insulin-like growth factor I (IGF- 1; also known as somatomedin C) is a 70- amino acid, single chain polypeptide [4], and is related to several economically important traits including growth, carcass traits and reproduction in many food animal species [5]. Thus, it is important to determine IGF-I correlations with body conformation, reproductive, and carcass traits in food animal species like the meat goat in order to develop effective breeding and selection strategies to improve productivity. IGF-I is growth-hormone dependent and is related to growth and/or body size in dogs [6], chickens [7], swine [8], sheep [9] and cattle [10, 11]. IGF-I is involved in pre and postnatal growth, lactation, reproduction and immune function [12] through mediating the anabolic actions of growth hormone [13, 14]. One of the ultimate goals of meat goat production is to produce meat with high quality and in high quantity. IGF-I cause hypertrophy in muscle cells and induces changes in expression of the proteins that make up the myofibril, the functional unit of the muscle tissue [15]. Due to its influence on reproductive functions, serum IGF-I concentration is an important candidate for selection to improve reproductive efficiency in meat animals. Several studies have shown a close association between male reproductive traits and IGF-I measurements [16]. [17] Reported that scrotal circumference, sperm motility, and the percentage normal sperm cells are related to blood serum IGF-I concentrations in Angus bulls. Also, IGF-I protects cells in the ovary from apoptosis, increases sperm motility, maintains normal cell morphology [18], and is related to scrotal circumference [19], suggesting that the selection for increased serum IGF-I concentration could result in increased scrotal circumference and sperm motility and, hence, a higher fertility rate.

[20, 21] Suggested that Serum IGF-I concentration is a useful physiological indicator trait in selection programs designed to improve carcass characteristics of beef cattle. In pigs, serum IGF-I concentration at an early stage of growth was effective for prediction of intramuscular fat (IMF), but it was not a reliable physiological predictor of genetic merit of overall meat production traits [22]. [23] Reported that IGF-I was negatively correlated with percentage of carcass fat, carcass fat accretion rate, total carcass fat and fat thickness, and that it was positively correlated with percentage of carcass protein in Simmental crossbred bulls. Most, if not all, of the growth promoting effects of GH are mediated through IGF-I. Responses of cartilage, adipose tissue, and many other tissues to GH are largely enhanced by IGF-I. Therefore, studying growth in relation to some serum IGF-I may have a particular importance for understanding factors controlling muscle growth thus modifying carcass composition through

increasing the rate of lean tissue deposition [24]. [25] Observed that plasma concentrations of IGF-I was highly correlated with empty body fat accretion, empty body weight gain, and protein deposition in steers. [26] Reported that bulls with lower IGF-I concentrations had higher marbling scores and quality grades, but also had higher backfat thickness and yield grades regardless of the slaughter end point. This suggests that Serum IGF-I concentration may be a useful selection criterion when efforts are directed toward improvement of marbling scores and quality grades of beef cattle.

Little is known about the genetic relationships of IGF-I with body conformation, testicular, and/or carcass traits in Boer goats. If IGF-I is moderately or highly heritable, and has moderate to high genetic correlations with growth, reproductive, and carcass traits in meat goats species, it may be used in a selection program to increase rates of genetic change for such traits. Therefore, the objectives of this study were to estimate genetic, phenotypic, and environmental correlations of IGF-I with body conformation, testicular, and/or carcass traits in pubertal male Boer goat crosses.

II. MATERIAL AND METHODS

Animal Management:

Twenty-Five pubertal male Boer goat crosses were used in this study. The Tuskegee University Animal Care and Use Committee approved the animal care, and handling. Upon arrival, animals were quarantined for three weeks at the Tuskegee University's Caprine Research Facility. Animals were given an overall health check by an attending veterinarian at Tuskegee University's School of Veterinary Medicine The animals were treated with Panacur (fenbendezole) to control the development and reproduction of internal parasites. Each animal was housed in individual 1.8 x 2.1m indoor pens for the entire experimental period. Throughout this period animals were maintained on a daily diet that consisted of a high energy concentrate that was given at 2lbs/day. The animals were also allowed *ad libitum* access to hay, water and mineralized salt blocks.

Body Conformation Measurements:

Body conformation traits were recorded at intervals of three weeks for twelve weeks. Body conformation traits recorded in this study included: Body weight, BW, kg (recorded using a standard scale), body condition score, BCS (scored subjectively on scale of 1 = emaciated to 5 = obese), shoulder width, SW, kg (determined with the aid of a measuring tape as the horizontal distance between the processes on the left shoulder to those of the right shoulder blade), chest girth, CG, cm (determined with the aid of a measuring tape as the width around the chest just behind the front legs), body length, BL, cm (determined with the aid of a measuring tape as the distance from the sternum to the aitch bone), hip width, HW, cm (determined with the aid of a measuring tape as the distance between the left and right femur bones) and height at wither, HTW, cm (determined with the aid of a metric ruler as the length, vertically from the thoracic vertebrae to the ground).

Testicular Measurements:

The scrotal circumference, SC, cm, was determined for each animal by pulling the testicles firmly into the lower part of the scrotum, grasping the neck of the scrotum with one hand, squeezing and pulling down. Thereafter, the circumference was measured with the aid of a measuring tape and recorded as the largest diameter of the scrotum. After slaughter, the following testicular measurements were recorded: total testes weight (TWT, kg), left testis weight (LTW, kg), and right test weight (RTW), respectively.

Carcass Evaluation and Fabrication:

Goats were processed according to United States Department of Agriculture (USDA) meat goat slaughter and carcass fabrication guidelines following an overnight period of feed withdrawal. However, water was available *ad libitum* on the day of slaughter. The Institutional Meat Purchase Specifications (IMPS) for fresh goat, series 11, (USDA, 2001) [28] were used by certified USDA graders to report live and carcass selection criteria in this study. According to the IMPS, selection criteria range from No. 1 to No. 3. Hot carcass weight was determined on the day of harvest and carcasses were chilled at 4 ºC. Cold carcass weight (CCW), carcass shrink, fat depth over the midpoint of the LM (Bf; between the 12^{th} and 13^{th} ribs), body wall fat (Bwf; measured at the lower portion of the12^{th} rib), kidney and pelvic fat weight (Kpf), dressing percent (Dp), LM area, hindlimb (measurement taken lateral to the aitch bone) and forelimb (measurement taken midpoint of the foreshank) circumferences were determined by a certified USDA grader 48 h postmortem.

Blood Collection:

Approximately 25 mL of blood was collected into sterile glass tubes at intervals of three weeks from wk0-wk12 for each animal and allowed to clot for 24 h at 40C, and centrifuged. Serum was drawn off and frozen at –200C until it was assayed.

Serum Insulin Growth Factor-I Analysis:

A calibrated IMMULITE 1000 system (developed at Meharry Medical College, Nashville, Tennessee) was used for the quantitative measurement of serum IGF-I. IMMULITE 1000 Total Serum IGF-I is a solid-phase, enzyme-labeled, competitive chemiluminescent immunoassay. The solid-phase, a polystyrene bead enclosed within an IMMULITE Test Unit, is coated with a polyclonal rabbit antibody specific for IGF-I. Serum samples and alkaline phosphatase- labeled IGF-I were simultaneously introduced into the Test Unit, and incubated for approximately 60 minutes at 37°C with intermittent agitation. During this time, IGF-I in the sample competed with alkaline phosphatase labeled IGF-I for antibody-binding sites on the bead. Unbound material was then removed by a centrifugal wash. Substrate is then added, and the Test Unit is incubated for another 10 minutes.

The chemiluminescent substrate, a phosphate ester of adamantyl dioxetane, undergoes hydrolysis in the presence of alkaline phosphatase to yield an unstable intermediate. The continuous production of these intermediate results in the sustained emission of light, thus improving precision

by providing a window for multiple readings. Also the photon output, as measured by the luminometer – is inversely proportional to the concentration of serum IGF-I in the sample.

Statistical Analysis:

Descriptive statistics (*Statistix 7*, 2000) [27] was performed on the data to determined individual buck differences in selected body conformation, testicular and serum IGF-I profiles. Also, data was subjected to analysis of variance using the GLM procedures of *Statistix 7*, (2000), correlation coefficients (r) were established between various body, testicular parameters and serum IGF-I profiles.

III. Results and Discussion

Simple statistics for the relationship between body conformation, testicular, carcass traits and serum insulin-like growth factor-I in pubertal male Boer crosses are shown in Tables 1 and 2 respectively. The average body weight (BW) for week 0 was (27.66 ±2.54kg), with a slight decline into week 3 (27.52±2.20kg). However, BW increased linearly from week 6 to week 12 (31.95±2.64kg, 34.72±2.98kg, and 37.46± 3.44 kg), respectively (Table 1). Growth can be measured in animals by many different means. Rate of gain is usually calculated as the change in weight during a specific time interval. Body mass will change over a period of time as the plane of nutrition changes. Mature weights for bucks and does are 90-130 kg and 80-100 kg, respectively [32]. Body weights measurements obtained in the current study were variable because of influences of genetics, nutrition, health and disease, breeding age and method, and management system. Boer goats are known to have a fast growing rate compared to other goat breeds [26]. Body length (BL) increased linearly throughout the experimental period (58.62±2.41, 61.95±3.21, 63.72±2.26, 65.25±2.34 and 67.13±2.75), respectively. The average chest girth (CG) at week 0 was (66.34±3.22cm), with a slight decline into week 3 (64.37±1.95cm). However, CG increased linearly from week 6 - week 12 (67.82±2.58cm, 68.91±2.21cm and 70.79±2.35cm), respectively. Height at withers (HTW) also increased linearly throughout the experimental period (58.01±1.90cm, 59.97±2.27cm, 61.20±1.86cm, 62.29±2.13 and 64.58±2.39). The average scrotal circumference (SC) at week 0 was (22.87±2.42cm), with a slight decline into week 3 (22.54±1.77cm).

However, Scrotal circumference (SC) increased linearly from week 6 – week 12 (23.22±0.860cm, 24.53±1.43cm and 26.05±1.35cm), respectively. SC is an important trait that is closely associated with the testicular growth and sperm production in males of all meat animals. Thus, selecting breeding males based on their SC would result in larger testes, potentially with the capacity to produce more semen [41]. Being a highly heritable component of fertility, it is important to include SC during animal evaluation for breeding soundness. [42] Reported a highly significant positive relationship between SC and testis weight of West African Dwarf bucks. Testis weight is known to be highly correlated (r = 0.93) with testicular sperm reserves and males with larger testes tend to produce more sperm [43]. It follows that a good measurement of scrotal circumference would be a reliable predictor of sperm producing capacity.

Body condition score (BCS), hip width (HW) and shoulder width (SW) all appeared to fluctuate for weeks 0, 3, 6, 9, and 12, respectively. Mean live weights, carcass weights, and carcass measurements for pubertal Boer meat-type goats are reported presented in Table 2. Briefly, 37.46± 3.43 kg for slaughtering weight 18.00± 1.88 kg for warm carcass weight, 17.43± 1.92 kg for cold carcass weight, 47.90± 2.18% for dressing percentage, 0.113±0.021 kg, 0.069± .02 cm for back fat, 0.099± .03 cm for adjusted back fat, 36.38± 1.31 cm for leg circumference, and 1.50± 0.22 cm^2 for rib eye area. Carcass characteristics of interest were dressing percentage, anatomical distribution of muscle and the ratios of lean:fat:bone. Generally, the dressing percentage of goats is around 45% [32]. As an animal grows, the percentage of fat in the carcass tends to increase; the percentage of bone tends to decrease, whereas the percentage of lean muscle stays about the same. The portions of the carcass with the largest muscle mass are the leg and shoulder. However, percentage wise, these portions tend to decrease as the animal grows. Goats tend to have a lower dressing out percentage than sheep and differ in their carcass proportions. Adipose depots develop in a preferential order. Visceral fat (omental, mesenteric, kidney and pericardial) is the earlier developing depot followed by intermuscular, subcutaneous, and intramuscular fat [29].

Development of fat in goats occurs very late and only reaches appreciable levels when the animals are near or at their mature body weight [30]. The fat content is highly variable and is influenced by such factors as age, sex, nutrition, body weight, growth rate, physiological condition, and physical activity. Most of the fat is deposited in the visceral rather than carcass depots and hence goat carcasses are lean, with a low proportion of subcutaneous fat [32], particularly when compared to sheep [30]. At the same degree of total body fatness (21% of empty body weight), dressed Boer goat carcasses recorded 22% carcass fat with 6.7% in the subcutaneous fat depot while Dorper and South African Mutton Merino carcasses were both 24% fat, with 12.7% and 10.4% subcutaneous fat, respectively [31]. Typically, goat carcasses have more than 60% dissectible lean and 5–14% dissectible fat [32].

As shown in Table 1, IGF-I levels increased linearly from week 0 –week 9 (95.89±42.50ng/ml, 98.05±43.94 ng/ml, 151.96±51.25ng/ml and 196.95±71.04ng/ml) respectively. Serum IGF-I levels declined going into week 12 (172±63.52ng/ml). There was no significant difference ($P > 0.05$) between weeks 0 and 3 IGF-I profiles. However, there was a significant difference for IGF-I between weeks 6, 9, and 12 ($P<0.05$), respectively. [33] Reported IGF-I levels of <500ng/ml (105-300 ng/ml) at the age from birth to weaning (120 days) to expected age of puberty (240 days) before increasing to >500ng/ml, with a temporary drop at day 300 of age in lambs. IGF-I concentrations in

blood have been proven to be highly heritable and phenotypically and genetically associated with many important traits [34]. In addition, it can be accurately and relatively inexpensively measured in the blood of young animals and has been proven to be specifically related to growth rate [30].

Serum IGF-I levels were significantly and positively correlated with most of the body conformation traits measured in the current study. Insulin growth factor-I concentration was significant and positively correlated to BL (r = 0.53), BW (r = 0.54), CG (r = 0.38), HTW (r = 0.38), SC (r = 0.21) and SW (r = 0.20), respectively. However, a negative relationship was observed for BCS (r = –0.02). The correlation coefficients for body conformation, testicular, and carcass traits with IGF-I levels are presented in Table 3. Growth in correlation with IGF-I may provide physiological interpretation of growth feature [35]. Differences in feed conversion rates of cattle are associated with differences in IGF-I concentration [36]. Coefficients for correlation coefficients of average daily gain and feed efficiency with IGF-I concentration were 0.28 (P = 0.001) and 0.16 (P = 0.07), respectively [37]. Cattle with lower IGF-I concentration have greater weights and weight gains [34]. The authors reported genetic correlations of weaning and postweaning weights and weight gains with serum IGF-I concentration that ranged from -0.21 to -0.54.

The correlation coefficients for body conformation, testicular, carcass traits and insulin growth factor-I at slaughter are presented in Table 3. There were positive relationships found between body conformation traits and IGF-I, which include: HTW (r = 0.13), HW (r = 0.41), BCS (r = 0.40), BL (r = 0.15), BW (r = 0.24), CG (r = 0.38) and SW (r = 0.10). However, SC was shown to have a negative correlation with IGF-I (r = -0.21). There were low to negative correlations of IGF-I with testicular and carcass measurements. The obtained correlations include: ADJ (r = 0.08), BF (r = 0.19), BWF (r = -0.04), CCW (r = 0.15), HCW (r = 0.28), DP% (r = 0.11), LTW (r = 0.003), RTW (r = -0.14), LC (r = 0.40), REA (r = 0.27) and TWT (r = 0.04). [35] Reported a high degree of variability of IGF-I measurements, low correlations between IGF-I concentration and BW, that measurement of IGF-I is unlikely to be an effective aid in selection for growth rate in sheep. However, in pigs, [38] reported that phenotypic correlations between IGF-I and fatness traits and measures of size were positive but close to zero. [39] Reported that IGF-I was negatively correlated with growth rate and positively correlated with ultrasonic fat dept at the last rib and feed conversion efficiency. [40] Suggested that selecting animals with lower IGF-I levels would result in leaner, faster growing animals. [34] Reported a low and variable association of IGF-1 serum levels with postweaning weight gains of Angus bulls and heifers. Circulating concentrations of IGF- 1 may be reduced because of increased receptors for IGF- 1 during phases of rapid muscle and bone growth. [38] Reported a correlation of 0.54 (P<0.05) between IGF-I levels and height at 12 months of age in Red Danish bull calves.

Although correlation coefficients of HTW (r = 0.13), HW (r = 0.41), BCS (r = 0.40), BL (r = 0.15), BW (r = 0.24), CG (r = 0.38) and SW (r = 0.10) an estimate of the proportion of phenotypic variance that is genetic in nature, results of the present study indicate that it may be possible to select successfully for serum IGF-1 concentration in meat goats. Because of correlations of serum IGF-1 concentrations at 6 weeks of age with weights at later ages generally ranged from 0.32 to 0.54, the serum concentration of IGF-1, along with other biological indicators of growth, may be a valuable addition to selection indices for improved efficiency of meat goat production.

IV. Conclusions

1. IGF-I concentration increased linearly throughout the study. However, there was a slight decline going into week 12.
2. IGF-I was significant and positively correlated to BL, BW, CG, HTW, SC and SW, respectively, however, a negative relationship was observed for BCS.
3. Serum IGF-I concentration at pubertal stage of stage of growth was effective for prediction of many body conformation traits, but it was not a reliable physiological predictor of genetic merit of carcass and/or testicular traits in pubertal Boer male goats.
4. Further research needs to be conducted in order to explore the feasibility of using serum IGF-I levels as a useful predictor of genetic merits for carcass or reproductive performance in post pubertal Boer meat goats.

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Table 1: The Effect of Week on Body Conformation, Testicular Traits and Serum Insulin-Like Growth Factor-I Levels of Pubertal Male Boer Crosses*

Parameters	Week 0	Week 3	Week 6	Week 9	Week 12**
No. of animals	25	23	23	23	23
Body condition score (BCS, 1-5)	3.40 ± 0.50	3.21± 0.51	3.08± 0.41	2.91± 0.59	3.13± 0.69
Body length (BL, cm)	58.62 ± 2.41	61.95± 3.21	63.72± 2.26	65.25± 2.34	67.13± 2.75
Body weight (BW, kg)	27.66 ± 2.54	27.52± 2.20	31.95± 2.64	34.72± 2.98	37.46± 3.44
Chest girth (CG, cm)	66.34± 3.22	64.37± 1.95	67.82± 2.58	68.91± 2.21	70.79± 2.35
Height at wither (HTW, cm)	58.01± 1.90	59.97± 2.27	61.20± 1.86	62.29± 2.13	64.58± 2.39
Hip width (HW, cm)	42.16± 3.12	41.95± 2.28	43.63± 1.65	42.18± 1.68	45.06± 2.06
Scrotal circumference (SC, cm)	22.87± 2.42	22.54± 1.77	23.22± 0.86	24.53± 1.43	26.05± 1.35
Shoulder width (SW, cm)	41.14± 2.54	40.40± 1.84	41.73± 1.52	41.29± 1.92	44.06± 2.11
Insulin –like growth factor I (IGF-I, ng/ml)	95.89± 42.50	98.05± 43.94	151.96±51.25	196.95±71.04	172±63.52

*Means and standard deviation; **slaughter week
[abcd] means in each row with the same superscript are not significantly different ($p<0.05$).

Table 2: Body Conformation, Testicular and Carcass Traits in Pubertal Male Boer Crosses (Mean± Standard Deviation at Week 12)

Parameter	Mean± Standard Deviation
No. of animals	23
Body condition score (BCS,1-5)	3.13± 0.69
Body length (BL, cm)	67.14± 2.75
Body weight (BW, kg)	37.46± 3.43
Chest girth (CG, cm)	70.79± 2.35
Height at wither (HTW, cm)	64.58± 2.39
Hip width (HW, Cm)	45.06± 2.06
Scrotal circumference (SC, cm)	26.05± 1.35
Shoulder width (SW, cm)	44.06± 2.11
Testes weight (TWT, Kg)	0.418± .04
Left testis weight (LTW, Kg)	0.139± .02
Right testis weight (RTW, Kg)	0.139± .02
Adjusted back fat (cm)	0.099± .03

Back fat (cm)	0.069± .02
Body wall fat (cm)	0.411± .16
Chilled carcass weight(Kg)	17.43± 1.92
Hot carcass weight (Kg)	18.00± 1.88
Leg circumference (cm)	36.38± 1.31
Rib eye area (cm^2)	1.50± 0.22
Dressing %	47.90± 2.18
Insulin Growth Factor-I (IGF-I, ng/ml)	172.04± 63.53

Table 3: The Correlation Coefficient for body Conformation, Testicular, Carcass Traits and Serum Insulin Growth Factor-I in Pubertal Male Boer Crosses at Week 12

Parameter[1]	Correlation coefficient (*r*)
IGF-I vs. BCS	0.38
IGF-I vs. BL	0.14
IGF-I vs. TW	0.04
IGF-I vs. BWF	-0.04
IGF-I vs. SC	0.69**
IGF-I vs. SW	0.22
IGF-I vs. BW	0.24
IGF-I vs. CG	0.38
IGF-I vs. HCW	0.28
IGF-I vs. ABF	0.08
IGF-I vs. BF	0.18
IGF-I vs. CCW	0.15
IGF-I vs. REA	0.0.27
IGF-I vs. LC	0.40
IGF-I vs. DP	0.11

**Significant if P<0.01
[1]BL = Body weight, BW = Body weight, CG = Chest girth, HTW = Height at wither, HW = Hip width, SW = Shoulder width, SC = Scrotal circumference, IGF-I = Insulin Growth Factor-I, ABF = Adjusted back fat, BF = Back fat, BCS = Body condition score, BWF = Body wall fat, CCW = Chilled carcass weight, DP = Dressing percentage, TW = Testis weight, REA = Rib eye area, LC = Leg circumference.