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Effects of Low Plane of Nutrition on the Development of Lean Muscle, Bone and Fat in the West African Dwarf Goats of Nigeria

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Keywords: Dwarf goat - Under nutrition - Muscle - Bone - Fat.

Summary

Thirty West African Dwarf goat kids were raised on low plane of nutrition from 5 days old to 52 weeks of age. They were serially slaughtered at 2, 8, 12, 24 and 52 weeks old to study changes in liveweight and the development of lean muscle, bone and fat.

Lean muscle and fat expressed as the percentage of empty body weight (E.B.W.) increased from 32.5% and 3.5% at 2 weeks to 42.0% and 9.4% at 52 weeks respectively. These increases at 52 weeks old represented about 544.9% and 1093.3% over their respective weights at 2 weeks old. The bone tissue increased to about 307.3% at 52 weeks old over its weight at 2 weeks of age, but decreased from 15.4% E.B.W. at 2 weeks to 10.9% E.B.W. at 52 weeks of age.

Lean muscle was consistently the largest carcass tissue from 2 weeks to 52 weeks of age followed by the bone tissue, while fat was the least.

Female goat kids entered the rapid fattening phase at about 38 weeks of age (6.9 kg liveweight), but the males did not enter the rapid fattening phase, even at 52 weeks of age (11.8 kg. liveweight).

Résumé

Trente chevreaux de race naine d'Afrique occidentale ont été soumis à un régime pauvre depuis l'âge de 5 jours jusqu'à 52 semaines. Ils ont été abattus par lots à 2, 8, 12, 24 et 52 semaines afin de suivre les variations du poids vif et du développement des muscles maigres, des os et de la graisse.

Les muscles maigres et la graisse en pourcentage du poids du corps vide a respectivement augmenté de 32,5 % et 3,5 % à 2 semaines et jusqu'à 97,8 % et 9,4 % à 52 semaines. Les poids observés à 52 semaines représentaient à peu près 544,9 % et 1093,3 % du poids à 2 semaines. Le poids de l'os augmentait de 307,3 % entre 2 et 52 semaines mais diminuait en pourcent du poids vide de 15,4 % à 2 semaines à 10,9 % à 52 semaines.

L'augmentation du poids du muscle maigre de 2 à 52 semaines était la plus importante suivie par celle de l'os, puis celle de la graisse.

L'âge d'engraissement des chevrettes commençait à peu près dès l'âge de 30 semaines (6,9 kg de poids vif) tandis que les chevreaux n'entraient pas en phase d'engraissement rapide même à 52 semaines (11,8 kg de poids vif).

Introduction

In studies of meat animals. the Scientist is primarily concerned with the growth of the major tissues of the carcass which are lean muscle, bone and fat and with the proportions of these three major tissues in the carcass. Carcass weight as an end point for growth in meat animals is therefore more useful than liveweight since the later includes non-soleable components of the animal and its gut contents. The main problem with carcass weight is one of assessing its yield of high value tissues and cuts. Age. weight. breed. sex, nutritional history and other factors influence the proportions of muscle, bone and fat at any particular stage of weight increase (2, 3, 4, 5, 9,). Because goats are mostly kept under traditional husbandry system in Nigeria, information on their economic returns as meat animals are limited.

In a previous study (1), some information were gained on the development of lean muscle, bone and fat in the West African Dwarf (WAD) goats of Nigeria maintained on good plane of nutrition. The period the carcass had a maximum of lean muscle. a minimum of

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bone and optimum amount of fat occurred later in the life of male goat kids and at heavier liveweight than the female goat kids.

Very little attention had been hitherto devoted to investigations on the merits or limitations of WAD goats for meat production in a well defined set of conditions. The present paper reports a further study on the development of lean muscle, bone and fat in the WAD goats maintained on low plane of nutrition from 5 days old to 52 weeks of age.

Material and methods

Thirty WAD goat kids were obtained from the University of Ibadan Teaching and Research farm at 5 days of age after they had suckled their dams to obtain colostrum.

They were separated into two groups consisting of 15 males and 15 females to avoid indiscriminate mating at later age. The management of the two groups of the experimental animals was the same.

From 5 days to 2 weeks of age, the kids were fed with fresh cow milk warmed to 37° C at half appetite level (1) thrice daily at 08.00, 13.00 and 18.00 hours. The centesimal and proximate chemical composition of solid feeds fed to the animals are presented in Table 1. From 2 weeks of age the milk diet was supplemented with pre-weaning creep feed at half appetite level (1) and chopped giant star grass (*Cynodon nlemfuensis* var Robustus) *ad libitum*. A gradual withdrawal of milk from the diet of the kids was embarked upon during the 5th week of life. This was accomplished by feeding the kids with warmed milk twice daily (08.00 and 13.00 hrs) for the first 4 days and once daily for the last 3 days of week five. By the end of the 5th week, milk feeding was completely stopped and all kids were on pre-weaning creep feed and chopped grass. From the 13th week of age, the pre-weaning creep feed was replaced with post-weaning feed at half appetite (1). All animals had free access to salt lick and fresh water supply.

Six animals (3 males and 3 females) were serially slaughtered at 2, 8, 12, 24 and 52 weeks of age to study the growth of lean muscle, bone and fat in the carcass.

Slaughter method

A day prior to slaughter. all animals to be slaughtered were weighed to obtain their liveweight. They were then subjected to an 18-hr. fast, weighed and then slaughtered, dressed, chilled and then dissected according to the standard muscle groups (4). Briefly. this involved separation of the right side of the carcass into its individual muscle groups, associated bones and four major fat depots (intermuscular, subcutaneous. kidney and channel).

Analytical procedure

All dissected lean muscle, bones and fat were weighed according to their anatomical locations, then combined, weighed and multiplied by two for subsequent calculations of total lean muscle, bone and fat.

TABLE 1
Centesimal and chemical composition of pre-and post-weaning creep feeds and *Cynodon nlemfuensis*.
(a) Centesimal composition

Ingredient (%)	Pre-weaning feed	Post-weaning feed	*Cynodon nlemfuensis* (grass)**
Cassava flour	31.5	39.0	-
Dried bewers grain (milled)	20.0	20.0	-
Soya bean (meal)	40.0	40.0	-
Sucrose	2.5	-	-
Glucose	5.0	-	-
Dicalcium phosphate	0.5	05.	-
Mineral/vitamin mixture*	0.5	0.5	-
	100.0	100.0	

* Mineral/vitamin mixture :
Content in g/kg . Manganese 16.0 ; Zinc 12.0 ; Iron 6.0 ; Copper 4.0 ; Cobalt 0.30 ; Iodine 1.20 ; Magnesium 200.0 , Vitamin A. 0.50 IU and vitamin D. 0.25 IU.

(b) Chemical composition

Constituent on a DM basis			
Fresh weight dry matter	-	-	43.4
Residual dry matter (DM)	94.5	95.0	93.4
Organic matter	91.0	91.5	87.2
Crude protein (N x 6.25)	19.7	18.8	4.9
Crude fibre	7.4	8.0	32.10
Ether extract	7.0	9.0	1.0
Nitrogen free extractives	56.9	55.7	49.4
Ash	3.5	3.5	6.1
Gross energy (Kj/100 g)	384.1	410.4	451.4

** *Cynodon nlemfuensis*
Chemical composition on a DM basis , each value is mean for 52 determinations from January to December

The growth coefficients for lean muscle, bone and fat were estimated by the use of the allometric growth equation, $Y = aX^b$(2). Where Y = the respective tissue weight (or part); X = the corresponding weights of muscle plus bone (or whole); a = intercept; b = the growth coefficient of the respective tissues.

Data obtained from this study were subjected to analysis of variance. Significant differences were estimated by the use of Duncan's multiple range test (11).

Results

The growth of the WAD goats at the five stages is presented in Table 2. The mean liveweight at 52 weeks of age was 10.20+0.92 kg. The empty body weight (E.B.W.), the dressing out percentage and all the carcass tissues studied increased with advancing age.

The dressing out percentage increased only slightly from 44.4 ± 0.47% at 2 weeks old to 45.2 ± 0.11% at 52 weeks of age. Lean muscle increased from.538.9 ± 39.96 g. (32.5 ± 0.04% E.B.W.) at 2 weeks old to 2936.3 ± 283.6 g. (42.0 ± 0.28% E.B.W.) at 52 weeks of age. Total dissectible carcass fat increased from 58.8 ± 6.89 g. (3.5 ± 0.22% E.B.W.) at 2 weeks old to 642.3 ± 31.08 g. (9.4+0.89% E.B.W.) at 52 weeks of age. Total carcass bones also increased with advancing age from 247.5±11.62 g. at 2 weeks old to 760.6 ± 67.26 g. at 52 weeks of age.

Lean muscle was consistently the largest of the three carcass tissues from 2 weeks to 52 weeks of age, followed by the bone tissue, while fat was the least.

TABLE 2
Live weight and weights of certain body components of the West African Dwarf goat as affected by age.

Parameters	2 weeks	8 weeks	12 weeks	24 weeks	52 weeks
Live weight at slaughter (kg)	1.75±0.12	3.28±0.19	4.08±0.34	5.33±0.34	10.20±0.92
Empty body weight (E.B.W.) (kg)*	1.65±0.13	1.68±0.19	3.04±0.25	3.88± 0.23	6.98±0.63
E.B.W. as % of liveweight (%)	94.29	81.70	74.51	72.80	68.43
Total dry matter intake g/day	30.98±4.43	75.39±6.51	115.69±19.57	143.18±4.06	260.48±7.16
Dresing out percentage (%)	44.42±0.47	44.49±0.65	44.52±0.09	44.61±0.27	45.22±0.11
Total lean muscle (side tissue x 2) (g)	538.90±39.96	1046.28±74.14	1221.70±106.91	1611.57±115.51	2936.33±283.56
As % of E.B.W. (%)	32.50±0.04	39.10±0.07	40.12±0.37	41.50±0.51	42.03±0.28
Total carcass bone (side tissue x 2) (g)	247.52±11.62	375.39±21.62	398.52±29.79	464.41±29.20	760.55±67.26
As % of E.B.W.	15.38±0.45	14.07±0.21	13.13±0.08	11.92±0.04	10.92±0.20
Total dissectible fat (side tissue x 2) (g)	58.75±6.89	113.86±10.02	146.31±5.67	299.86±5.78	642.32±31.08
As % of E.B.W. (%)	3.53±0.22	4.25±0.18	4.87±0.28	7.82±0.47	9.42±0.89
Muscle : Bone ratio	2.17±0.17	2.63±0.24	3.06±0.08	3.46±0.05	3.86±0.12

*Empty body weight (E.B.W.) = Live weight at slaughter minus the gut contents.

These increases at 52 weeks old represented about 544.0%, 307.3% and 1093.3% over the respective weights of lean muscle bone and fat at 2 weeks of age. The ratio of muscle to bone was about 2:1 at 2 weeks old. The ratio increased to about 4:1 at 52 weeks of age.

Table 3 shows the effect of sex on the liveweight and growth of carcass tissues in the WAD goat kids. Male goat kids weighed significantly ($P < 0.05$) heavier than the females from 12 weeks of age. They also had consistently heavier carcass muscle weight than the females and the difference was significant from the 12th week of age. Carcass bones of male goat kids were heavier than those of the females, but the difference was only significant ($P < 0.05$) at 52 weeks of age. The weight of fat in the carcasses of both sexes was similar ($P > 0.05$). Extrapolations of tissue weight (lean muscles, bone, fat) on liveweight or age, indicated that the weight of fat in the carcass of the female goats equalled those of the bones at about 6.9 kg liveweight (about 38 weeks of age) and thereafter exceeded the bones. Fat in the carcasses of the male goats never equalled the weight of the bones. even at 52 weeks of age.

The growth coefficients of the three major carcass tissues, lean muscle, bone and fat are presented in Table 4. The growth coefficient for the bones was less than one (0.87), intermediate for lean muscle (1.04) and high for fat (1.48).

TABLE 3
Sex effect on the liveweight and weights of muscle, bone and fat (side tissue x 2) of the West African Dwarf goat as affected by age.

Age of goat kids	Liveweight at slaughter (kg)		Total lean muscle		Total carcass bones (g)		Total dissectible fat (g)	
	Male	Female	Male	Female	Male	Female	Male	Femal
2 weeks	1.83 ±0.28	1.68 ±0.03	574.49 ±83.18	503.31 ±11.45	245.61 ±28.19	249.43 ±2.85	61.46 ±14.79	56.04 ±7.11
8 weeks	3.60 ±0.10	2.97 ±0.04	1171.74 ±24.30	920.82 ±30.21	411.12 ±5.52	339.65 ±14.85	128.90 ±3.23	98.82 ±11.80
12 weeks	4.65 ±0.15	3.50 ±0.10	1403.06 ±52.83	1040.33 ±19.90	448.26 ±19.12	348.77 ±2.91	153.02 ±7.96	139.60 ±6.29
24 weeks	5.90 ±0.10	4.75 ±0.05	2414.24 ±25.66	1808.89 ±38.97	514.13 ±11.94	414.68 ±5.50	301.15 ±0.70	298.58 ±14.04
52 weeks	11.75 ±0.55	8.70 ±0.40	3395.14 ±213.82	2477.50 ±125.28	873.61 ±18.19	646.63 ±35.54	633.81 ±54.97	650.84 ±51.29

TABLE 4
Growth coefficients (b) of component tissues (Y) from the relationship $\log_{10} Y = a + b \log_{10} X$; Where X = Muscle plus bone, from dissection data for West African Dwarf goats maintained on low plane of nutrition.

Dependent variable (Y)	Intercept (a)	Regression coefficient (b)	Standard error (SE)	Correlation coefficient (r)
muscle	-0.694	1.040	0.059	99**
bone	-0.701	0.869	0.033	99**
fat	-1.989	1.476	0.074	96**

** ($P< 0.01$).

Discussion

The fastest growth rate of about 36 g/day by the WAD goats was obtained at between 2 and 8 weeks of age. This was in good agreement with the period of fastest growth rate (about 79 g./day) obtained for WAD goats maintained on good plane of nutrition (1). Early postnatal period has been shown to be the period a calf doubles its birth weight (5).

Results obtained with the WAD goats in the two sets of experiments not only confirmed the above statement, but also indicated clearly that plane of nutrition

merely affected the rate of weight gain per day, but did not alter the pattern of early post-natal growth. Values on the rate of gain after birth for goats are extremely limited. A range from 18 g/day for native breeds to over 200 g/day post-weaning for improved breeds on high plane of nutrition had been reported (9). Differences among breeds in size at maturity as well as other factors are known to affect rate of growth. The WAD goat a part from being small in size even at maturity, is a slow growing animal (6), reaching a mean liveweight of about 14kg in the humid forest areas of Nigeria in 12 months (1)* The WAD goats in the present study attained a mean liveweight of about 10 kg in 12 months of age.

The dressing out percentage changed very little from 2 weeks to 52 weeks of age, representing only about 1.8% increase as against 3.4% increase over the same period of time for WAD goats maintained on good plane of nutrition. The E.B.W. increased progressively with age, but when the E.B.W. was expressed as the percentage of liveweight, decreased consistently from 92.2% at 2 weeks old to 68.4% at 52 weeks of age. In comparison the E.B.W. of the group of WAD goats maintained on good plane of nutrition also decreased as the percentage of liveweight from 91.3% at 2 weeks to 73.6% at 52 weeks of age. This is indicative of the fact that the digestive tract and its contents were in both cases increasing at faster rate than the liveweight.

The mean proportion of lean muscle. bone and fat relative to total carcass weight at both 2 and 52 weeks of age were lean muscle, the largest (544.9% increase), followed by the bone tissue (307.3% increase) and fat, the least (1093.3% increase). This contrasts sharply with earlier results obtained with the WAD goats maintained on good plane of nutrition at 52 weeks of age, where the proportion of the carcass tissues were, lean muscle, the largest (673.2% increase) followed by fat tissue (2090.8% increase) and the bone tissue, the least (220.7% Increase). Information in the literature, mostly from sheep and cattle show that lean muscle comprised the highest percentage of the carcass at birth. then followed by fat and that bone tissue at no stage exerted a dominant role in the determination of the relative proportions of the three major carcass tissues (4). The results obtained with the WAD goats of Nigeria in the two sets of experiments at 2 weeks of age is at variance with the above statements. However, interpretation of data on the relative growth of tissues in meat animals must be made to the exclusion of confounding factors that tend to shroud clear vision of intrinsic and extrensic causes and effects. For example, it has been demonstrated that goats lay more fat in the visceral organs than sheep and cattle (8,9) and that goats are characterized by sparse fat covering over the external body surface and a large accumulation of fat around the kidneys even feral goats (10). Thus species difference in fattening pattern has well been documented in the literature. The low fat accretion in the carcasses of the WAD goats in the present experiment, even at 52 weeks of age, could be attributed to the animal species on one hand and to effects of low plane of nutrition on the other hand.

Similar to other domestic species of livestock, the male WAD goats gained faster than the females both in the present experiment and in the previous ones maintained on good plane of nutrition. Male goats usually gain faster in the earlier months of life, but as they reach sexual maturity they become temperamental, feed intake is reduced and gain slowed (9). The influence of sex on the relative growth of lean muscle, bone and fat showed that male goats had significantly ($P < 0.05$) heaver lean muscle than the females even from 12 weeks of age and significantly ($P < 0.05$) heavier bones only at 52 weeks of age.

Although the amounts of fat accretion in the carcasses of both sexes of goats in the present study was similar ($P > 0.05$) even at 52 weeks of age, yet the female goats entered the rapid fattening phase at about 38 weeks of age (about 6.9 kg liveweight), while the males did not enter the rapid fattening phase even at 52 weeks of age (11.8 kg liveweight). The rapid fattening phase refers to the period when the growth of carcass fat equalls the bone tissue in weight. Results from the previous study, showed that female WAD goats maintained on good plane of nutrition entered the rapid fattening phase at about 28 weeks of age (9.0 kg liveweight) and the males at about 43 weeks of age (12.1kg liveweight). This is indicative of the fact that good plane of nutrition not only increased the rate of liveweight gain, but also enhanced the onset of rapid fattening phase in both sexes. Predisposition to fattening is inversely related to gonadal androgen levels» and the androgenic effect of the male hormones consequently are necessary to complete a full pattern of muscle development (3).

Due to early development of bone and later development of muscle, the ratio of lean muscle to bone at 2 weeks of age was about two parts of lean muscle to one part of bone. During subsequent growth, bone tissue grew at a steady but slow rate and muscle at a relatively fast rate, so that at 52 weeks of age, the ratio increased to about four parts of lean muscle to one part of bone. Results of the application of the allometric growth equation, $= aX^{b}$(2), further substantiated the above statements. Thus, the growth coefficient for the bone was less than one (0.87), indicating that the bone tissue was growing at a low impetus rate, intermediate for muscle (1.04), which was growing at an intermediate impetus rate and high for fat (1.48), which was growing at high impetus rate. The above observations were again in good agreement with the lean muscle: bone ratio and the growth coefficients obtained for the WAD goats maintained on good plane of nutrition (1). Thus, plane of nutrition affected the rate of growth of the three major carcass tissues, but did not alter the muscle: bone ratio and the growth coefficients of the tissues.

This could be explained in part by the fact that undernutrition of young growing animals results in continued growth (even if the undernutrition is severe enough to cause a decrease in body weight) and also a homeostatic mechanism of body organs adjust cellular activity to systemic demand thus limiting organs size or restore this size after tissue had been lost (4,7).

The WAD goat farmer in this country manages his flock under traditional system of animal husbandry, resulting in poor growth and finished animals for the market at much longer time and lower liveweight. For greater economic advantage, the WAD goat farmer can thus utilize the growth advantages of improved nutrition and management practices to manage his flock in order to produce animals for the market at relatively shorter period of time and at heavier liveweight.

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