ORIGINAL ARTICLE

# Scrotal circumference, bodyweight and serum testosterone concentration of Red Sokoto weaner bucks as influenced by dry season crop-residue supplementation

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## ABSTRACT

The effect of dry season supplementation with crop-residue-based rations on bodyweight, scrotal circumference and serum testosterone concentrations in Red Sokoto weaner bucks at 5, 6 and 7 months of age was investigated in the present study. There were 7 treatment groups which were fed a positive control ration (conventional concentrate) fed at 1 and 2% of the bucks' bodyweights (Rations 1A and 2A), two crop-residue-based test rations each fed at 1 and 2% of bodyweight (1B, 2B, 1C and 2C), and a negative control that was unsupplemented (Ration D). All treatment groups had ad libitum access to natural pastures and *Digitaria smutsii* hay as a basal diet. Bodyweight and scrotal circumference of the bucks significantly increased ($P < 0.05$) with age from 5.9 kg to 10.2 kg, and 4.40 cm to 6.95 cm, at 5 and 7 months of age, respectively. Bucks on Ration D (unsupplemented group) had the lowest bodyweight and scrotal circumference. Bucks on Ration 2A showed a significant increase in basal testosterone concentration from 0.32 ng/mL at 5 months of age to 0.65 ng/mL at 7 months of age. Peak testosterone concentration also increased from 1.0 ng/mL at 5 months to 2.8 ng/mL at 7 months of age. Bucks on test Ration 2C had higher bodyweights (6.75, 8.00 and 10.00 kg at 5, 6 and 7 months of age, respectively) than bucks on the other test Ration B (6.20, 7.20 and 8.50 kg, respectively). There were no significant differences between the two test rations with regard to scrotal circumferences of the bucks at all ages. However, at 7 months of age, bucks on test Ration 2C had significantly higher peak testosterone concentration (1.80 ng/mL) than their counterparts on test Ration 2B (1.30 ng/mL). The secretory patterns of testosterone were episodic and pulsatile in nature. It was concluded that crop-residue supplementation in prepubertal Red Sokoto bucks has a significant influence on their bodyweight, scrotal circumference and testosterone production. Test Ration C was a cheap, affordable and better crop-residue-based ration for optimal reproductive performance than test Ration B.

**KEYWORDS:** bodyweight, crop-residue, Red Sokoto bucks, scrotal circumference, testosterone.

## INTRODUCTION

The Red Sokoto goat is found throughout the subhumid and semiarid zones of Nigeria. It is a medium-sized breed with reddish-brown coat color with a mature average liveweight of 30 kg and is kept for its milk, meat and skin. Detailed descriptions of its herd size (Gefu & Adu 1982), production (Mathewman 1980; Otchere *et al.* 1987), lactation (Ehoche & Buvanendran 1983) and reproductive performance (Adu *et al.* 1979) have been documented. The dry season is a critical period for small ruminant farmers in the subhumid zone of Nigeria because of feed scarcity.

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Smallholder goat farmers resort to crop residues from postharvest farm operations to feed their animals. However, these crop residues are limiting in nutrients necessary for maintenance and production. Therefore, supplementary feeding to boost the nutritional status of the animals has been recommended (Alawa & Umunna 1993). However, feed supplementation packages for improving reproductive performance of small ruminants during the long dry periods of the year are currently not available in Nigeria.

The purpose of proper management of a young male animal is to improve growth rate and to enable it to produce optimum levels of good quality semen at the earliest possible age. However, the onset of puberty is more closely related to bodyweight than to age (Setchell *et al.* 1965). The effect of improving protein intake on age at onset of puberty in Zebu bulls under range conditions has been reported (Oyedipe *et al.* 1981; Rekwot *et al.* 1987). The concentrations of serum testosterone have been shown to increase linearly with advancing age in bulls (Lunstra *et al.* 1978). Furthermore, *Bos indicus* bulls have been reported to have lower fertility than *Bos taurus* bulls (Fields *et al.* 1982) and this is attributed to smaller testis size (Oyedipe *et al.* 1981). Strategic intervention with supplementary feeding in the dry season of the year is likely to have a great impact on the nutritional deficiencies observed in tropical animals during this period. Vital information on testosterone profiles for monitoring reproductive performance in Red Sokoto bucks is lacking. Therefore, this present study was designed to investigate the influence of dry season crop-residue supplementation on bodyweight, scrotal circumference and testosterone concentrations of Red Sokoto weaner bucks in order to recommend to smallholder goat farmers a cheap, affordable and better crop-residue-based ration for optimal reproductive performance.

## MATERIALS AND METHODS

### Location and climatic conditions

The experiment was conducted in the Goat Experimental Unit of the Small Ruminant Research Programme at the National Animal Production Research Institute, Shika, Zaria, Nigeria. Shika falls between latitudes 11 and 12°N and between longitudes 7 and 8°E, with an altitude of 640 m above sea level. Shika is located within the Northern Guinea Savannah Zone and average annual rainfall and temperature are 1107 mm and 24.4°C, respectively. The seasonal distribution of the annual rainfall is approximately 0.1% (11.0 mm) in the late dry season (January–March), 25.8% (285.6 mm) in the early wet season (April–June), 69.6% (770.4 mm) in the late wet season (July–September) and 4.5% (40.0 mm) in the early dry season (October–December). The experiments were conducted during the dry seasons (from October to March). The animals were routinely dewormed with anthelmintic drugs and dipped in an acaricide (Asuntol, Bayer Nigeria, Essex, UK) solution against ectoparasites. The animals were housed in well-ventilated pens during the night after grazing during the day.

### Experimental animals

Twenty-eight Red Sokoto weaner bucks approximately 4 months of age were balanced for weight and blocked into 7 treatment groups of 4 animals per group (Table 1). They were group-fed for 2 hours each day between 08.00 and 10.00 hours with the appropriate ration. Thereafter, they were released into a specified paddock to graze natural pastures and *Digitaria smutsii* hay ad libitum, under the supervision of a herdsman, until 18.00 hours. An initial adjustment period of 3 weeks was allowed so that the animals could get used to their respective feeds and pens before measurements. The present study lasted for 3 months. Just before the commencement of the study (i.e. at 4 months of age), measurements of bodyweight and scrotal circumference for all the treatment groups were taken. Subsequently, these parameters were measured at 5, 6 and 7 months of age in the experimental animals. The component ingredients and chemical composition of the experimental rations are shown in Tables 2 and 3, respectively.

### Hormonal assay

Blood samples from the bucks in each treatment group were collected every 30 min for 6 h (from 06.00 to 12.00 hours) at 5, 6 and 7 months of age by jugular venipuncture. Serum samples were harvested and stored at −20°C until analyzed. Thus, a total of 273 blood samples were collected and the serum was analyzed for testosterone concentration. Serum testosterone concentrations were determined using a non-extraction, 'Coat-A-Count' solid phase testosterone radio-immunoassay kit (Diagnostic Products Corporation, Los Angeles, CA, USA). Human serum-based standards with testosterone concentrations of 0, 0.3, 1.0, 3.0, 10.0 and 30.0 ng/mL were used. The assay

**Table 1** Component ingredients in the experimental rations

| Ration | Ingredients | % inclusion (dry matter) | Remarks |
|---|---|---|---|
| 1A + Basal diet | Maize | 40.00 | Positive control (conventional concentrate) offered at 1% of bodyweight |
| | Wheat offal | 35.00 | |
| | Cottonseed cake | 20.00 | |
| | Bone meal | 3.00 | |
| | Salt | 2.00 | |
| 2A + Basal diet | Maize | 40.00 | Positive control (conventional concentrate) offered at 2% of bodyweight |
| | Wheat offal | 35.00 | |
| | Cottonseed cake | 20.00 | |
| | Bone meal | 3.00 | |
| | Salt | 2.00 | |
| 1B + Basal diet | Guinea-corn bran | 39.50 | Test Ration 1 offered at 1% of bodyweight |
| | Cowpea husk | 30.00 | |
| | Groundnut haulms | 30.00 | |
| | Salt | 0.50 | |
| 2B + Basal diet | Guinea-corn bran | 39.50 | Test Ration 1 offered at 2% of bodyweight |
| | Cowpea husk | 30.00 | |
| | Groundnut haulms | 30.00 | |
| | Salt | 0.50 | |
| 1C + Basal diet | Maize offal | 49.50 | Test Ration 2 offered at 1% of bodyweight |
| | Groundnut shells | 20.00 | |
| | Groundnut haulms | 30.00 | |
| | Salt | 0.50 | |
| 2C + Basal diet | Maize offal | 49.50 | Test Ration 2 offered at 2% of bodyweight |
| | Groundnut shells | 20.00 | |
| | Groundnut haulms | 30.00 | |
| | Salt | 0.50 | |
| D (Basal Diet) | *Digitaria* hay and natural grazed pasture | Ad libitum | Negative control (unsupplemented) |

procedure was as follows: to antibody coated tubes, 25 µL of standard (0, 0.3, 1.0, 3.0, 10.0 and 30.0 ng/mL) or serum sample and 1 mL buffered [$^{125}$I]-labeled testosterone solution were added. The mixture was vortexed, incubated for 3 h at 37°C and decanted to remove all visible moisture and to separate bound from free testosterone. The tubes were placed in a gamma counter (Beckmann 4000, Beckmann Instruments Inc., Manchester, UK) and the potencies of the samples estimated using a linear logit log dose–response curve. The antisera were highly specific for testosterone, the cross reactivities with androsteredione and dihydrotestosterone were 3.0 and 8.1%, respectively, while the cross reactivity with other C19 steroids was <3%. The sensitivity of the assay was 0.081 ng/mL, while intra and interassay coefficients of variation were 8.5 and 9.5%, respectively. Mean basal testosterone levels were defined as the mean of the 6 lowest values observed during the 6 h sampling, while peak testosterone concentrations were defined as each single or series of values two-fold higher than mean basal concentration (Renaville *et al.* 1983).

## Digestibility trial

Each buck was individually offered its appropriate corresponding ration to evaluate the digestibility of the diets. The animals used for the digestibility trial were 5 months old on average. The present study comprised a 2 week preliminary period of realimentation and adjustment, and one week of sample collection. The animals were housed in individual metabolism cages with facilities for separate collection of feces and urine. The animals were weighed at the beginning and end of the present study. Feces were collected each morning just before feeding. Ten percent of each daily fecal output was collected for chemical analyses. Samples of the different rations fed were taken daily and bulked, from which subsamples were taken for laboratory analysis. Also, samples of the individual feed ingredients were analyzed in the laboratory. Water was made available

**Table 2** Chemical composition of the major feed ingredients (dry matter basis, %)

| Feedstuff | Dry matter | Crude protein | Crude fiber | Ash | Ether extract | Nitrogen-free extract |
|---|---|---|---|---|---|---|
| Maize | 90.73 | 9.56 | 2.20 | 9.67 | 4.05 | 74.52 |
| Wheat offal | 87.60 | 16.90 | 11.30 | 6.40 | 3.80 | 61.60 |
| Cottonseed cake | 93.60 | 29.94 | 23.50 | 5.16 | 5.76 | 35.64 |
| Bone meal | 75.00 | 36.00 | 3.00 | 49.00 | 4.00 | 8.00 |
| Guinea corn bran | 93.33 | 7.60 | 24.80 | 6.95 | 3.01 | 59.90 |
| Cowpea husks | 91.41 | 7.10 | 33.40 | 7.14 | 0.65 | 58.91 |
| Groundnut haulms | 93.65 | 15.63 | 23.26 | 8.00 | 2.43 | 51.00 |
| Maize offal | 89.07 | 10.08 | 1.50 | 0.80 | 1.70 | 60.30 |
| Groundnut shells | 96.05 | 5.90 | 31.80 | 8.50 | 1.31 | 50.30 |

**Table 3** Chemical composition of the experimental diets (dry matter basis, %)

| Ration | Dry matter | Crude protein | Ash | Ether extract | Acid detergent fiber | Neutral detergent fiber | Lignin |
|---|---|---|---|---|---|---|---|
| Ration A | 93.87 | 17.19 | 13.85 | 14.08 | 20.00 | 40.01 | 4.64 |
| Ration B | 94.97 | 9.54 | 10.55 | 10.43 | 38.10 | 68.42 | 8.94 |
| Ration C | 95.94 | 10.38 | 11.97 | 12.45 | 36.65 | 54.74 | 8.23 |
| Ration D, Hay | 94.78 | 4.75 | 8.47 | 2.40 | 49.14 | 74.73 | 9.49 |
| Ration D, Natural pastures | 96.26 | 2.76 | 7.02 | 0.78 | 50.29 | 80.27 | 11.50 |

Calculated analysis of the experimental rations

| | Ration A | Ration B | Ration C |
|---|---|---|---|
| CP (%) | 17.05 | 9.82 | 10.85 |
| ME (MJ /kg DM) | 11.17 | 10.29 | 10.17 |

The metabolizable energy (ME) values of the experimental rations were calculated as per Alderman (1985) as follows: ME (MJ/kg DM) = $11.78 + 0.00654CP + (0.000665EE)^2 - CF(0.00414EE) - 0.0118A$, where CP, Crude Protein; EE, Ether Extract; CF, Crude Fibre; A, Ash.

to the animals ad libitum. The inventory, abundance and palatability of the plant species in the grazed paddock was recorded as described by Lakpini *et al.* (1997).

## Proximate analyses

Proximate analyses of feed and fecal samples were carried out by the AOAC (1980) methods. Dry matter of samples was determined in an oven at 105°C for 48 h. Nitrogen determination was by the Micro Kjedahl method, while the Soxhlet extraction procedure was used for ether extraction. Crude fiber was determined by alternate refluxing with weak solutions of $H_2SO_4$ and KOH. The detergent fiber fractions (neutral detergent fiber, acid detergent fiber and lignin) were determined according to Goering and Van Soest (1970).

## Statistical analysis

Statistical analysis was carried out using the general linear model procedure of SAS (1987) in a $3 \times 2$ factorial ANOVA to test the effects of ration and feeding level on bodyweight, scrotal circumference and testosterone concentrations. Duncan's multiple range test was used in separating differences between significant means.

# RESULTS

## Experimental rations

The chemical composition of the individual feed ingredients and the experimental diets are shown in Tables 2 and 3, respectively. Table 3 shows that all the rations had high dry matter (DM) contents with a mean value of approximately 95%. Ration A had the highest crude protein (CP) value of 17.19% followed by Rations B and C with 9.54 and 10.38%, respectively. The CP value of the grazed pastures (dry season) was the lowest (2.76%), while that of *Digitaria* hay was 4.75%. The least ash content value was obtained in Ration D with the hay having 8.47% and the grazed pasture having 7.02%. The highest ash content value of 13.85% was obtained in Ration A. Ration A also had the highest ether extract (EE) value of 14.08% and Ration D, the least (0.78 and 2.40% for grazed pasture and *Digitaria* hay, respectively). Acid

**Table 4** Mean nutrient intake, apparent digestibility coefficients and cost of the experimental diets

| Ration | 1A | 2A | 1B | 2B | 1C | 2C | D | SEM |
|---|---|---|---|---|---|---|---|---|
| Nutrient intake (kg/day) | | | | | | | | |
| Dry matter intake | $0.24^{b}$ | $0.47^{a}$ | $0.21^{bc}$ | $0.30^{ab}$ | $0.23^{b}$ | $0.42^{a}$ | $0.15^{c}$ | ±0.02 |
| Crude protein intake | $0.044^{a}$ | $0.087^{a}$ | $0.012^{b}$ | $0.017^{b}$ | $0.032^{a}$ | $0.072^{a}$ | $0.009^{b}$ | ±0.01 |
| Apparent digestibility of nutrients (%) | | | | | | | | |
| Dry matter | $84.3^{a}$ | $83.0^{a}$ | $62.5^{d}$ | $60.5^{e}$ | $75.8^{b}$ | $67.8^{c}$ | $56.4^{f}$ | ±2.84 |
| Crude protein | $90.6^{a}$ | $89.2^{a}$ | $69.5^{d}$ | $65.5^{e}$ | $82.7^{b}$ | $78.1^{c}$ | $48.4^{f}$ | ±3.07 |
| Neutral detergent fiber | $69.5^{a}$ | $66.6^{b}$ | 62.1c$^{d}$ | $61.9^{d}$ | $65.9^{b}$ | $63.7^{c}$ | $60.1^{e}$ | ±3.23 |
| Acid detergent fiber | $51.7^{a}$ | $49.8^{a}$ | $43.9^{bc}$ | $42.8^{c}$ | $46.1^{b}$ | $44.4^{bc}$ | $42.3^{bc}$ | ±5.01 |
| Economic analysis of the feeds | | | | | | | | |
| Cost of feed consumed per animal per day (Naira)* | $2.19^{b}$ | $4.42^{a}$ | $0.50^{e}$ | $1.06^{d}$ | 0.83d$^{e}$ | $1.55^{c}$ | – | ±0.15 |

$^{a,b,c,d,e,f}$Means within the same row bearing different superscript letters differ significantly ($P < 0.05$). *Naira, Nigerian currency (100 kobo make 1 Naira and current exchange rate is US$1 = 140 Naira).

detergent fiber (ADF), neutral detergent fiber (NDF) and lignin contents were least in Ration A with values of 20.00%, 40.01% and 4.64%, respectively. Ration D however, contained the highest ADF, NDF and lignin values of 49.14%, 74.73% and 9.49% for hay and 50.29, 80.27 and 11.5% for grazed pasture, respectively. The calculated chemical analysis of the experimental rations (Table 3) reveals that Ration A had a CP content of 17.05% while the test Rations B and C had 9.82 and 10.85%, respectively. Ration A also had a metabolizable energy (ME) of 11.17 MJ/kg DM, while Rations B and C had 10.29 and 10.17 MJ/kg DM, respectively. Table 4 shows the DM and CP intakes and digestibilities of the nutrients. The table shows that generally, the supplemented groups had significantly higher ($P < 0.05$) DM and CP intakes and digestibilities than the unsupplemented group except animals on Ration B that had similar values to the unsupplemented group. It was also evident that increasing the level of supplementation also resulted in increased DM and CP intakes of all the experimental rations, with these increases being significant ($P < 0.05$) and similar for Rations A and C. It was also observed that supplementation increased the digestibility of all the nutrients. However, animals on Ration B recorded very poor digestibility values and their counterparts in the unsupplemented group had the lowest. Even though the digestibility of nutrients decreased with increasing levels of supplementation, these decreases were not significant ($P > 0.05$). Ration 1A (the conventional concentrate at 1% of bodyweight) gave the highest digestibility values. A comparison of the unsupplemented animals with all the other treatment groups reveals that DM digestibility improved by a range of 4.1–27.9 points and CP digestibility by 17.1–42.2 points, the highest being in animals on Ration A at 1% level. Similar improvement trends were also noticeable for neutral detergent fiber (NDF) and acid detergent fiber (ADF). A simple economic analysis (Table 4) revealed that the conventional concentrate feed was the most expensive for supplementation particularly, at the 2% level (4.42 naira per animal per day). Of the two tested crop-residue rations, Ration 1B was significantly cheaper ($P < 0.05$) than Rations 2B and 2C, but similar to Ration 1C.

## Bodyweight, scrotal circumference and testosterone concentration

The means ± SE of prestudy measurements of bodyweight and scrotal circumference of the experimental animals were 5.8 ± 0.3 kg and 4.0 ± 0.2 cm, respectively. The results of the present study showed that there were significant ($P < 0.05$) bodyweight differences among bucks fed different rations and at the different ages (Table 5). At 5 months of age, bucks on Rations 2A and 2C were significantly heavier (6.80 and 6.75 kg, respectively) than bucks on all other rations, except for Ration 1A (6.50 kg). Bucks on Ration D had the lowest weight (5.90 kg) but it was not significantly different from Rations 1A, 1B, 1C and 2B. At 6 and 7 months of age, the trends were similar, with bucks on Rations 2A and 2C weighing more than the others and those on Ration D ranking the lowest in weight (Table 5). Within treatments, there were significant age effects in that all the bucks increased in weight as their ages increased from 5 to 7 months. At 5 and 6 months of age, there were no significant differences between bucks on different rations in terms of scrotal circumference, but at 7 months of age, bucks

**Table 5** Effect of ration supplementation on bodyweight and scrotal circumference at 5, 6 and 7 months of age

| Ration | 1A | 2A | 1B | 2B | 1C | 2C | D |
|---|---|---|---|---|---|---|---|
| Bodyweight (kg) at: | | | | | | | |
| 5 months | $6.50^{ab}$ | $6.80^{a}$ | $6.00^{b}$ | $6.20^{b}$ | $6.20^{b}$ | $6.75^{a}$ | $5.90^{b}$ |
| 6 months | $7.80^{a}$ | $8.00^{a}$ | $6.70^{c}$ | $7.20^{bc}$ | $7.75^{ab}$ | $8.00^{a}$ | $6.20^{d}$ |
| 7 months | $9.50^{b}$ | $10.20^{a}$ | $8.20^{c}$ | $8.50^{c}$ | $9.50^{b}$ | $10.00^{ab}$ | $7.50^{d}$ |
| Scrotal circumference (cm) at: | | | | | | | |
| 5 months | 4.60 | 4.40 | 4.40 | 4.70 | 4.60 | 4.50 | 4.40 |
| 6 months | 4.90 | 4.70 | 4.65 | 4.90 | 4.85 | 4.85 | 4.75 |
| 7 months | $6.20^{b}$ | $6.95^{a}$ | $6.35^{b}$ | $6.20^{b}$ | $6.30^{b}$ | $6.30^{b}$ | $6.25^{b}$ |

$^{a,b,c,d}$Means within rows bearing different superscripts are significantly different ($P < 0.05$).

**Table 6** Effect of ration supplementation on basal and peak testosterone concentrations at 5,6 and 7 months of age

| Ration | 1A | 2A | 1B | 2B | 1C | 2C | D |
|---|---|---|---|---|---|---|---|
| Basal testosterone concentration (ng/mL) at: | | | | | | | |
| 5 months | 0.30 | 0.32 | 0.30 | 0.33 | 0.30 | 0.32 | 0.31 |
| 6 months | 0.30 | 0.33 | 0.31 | 0.34 | 0.31 | 0.32 | 0.33 |
| 7 months | $0.32^{b}$ | $0.65^{a}$ | $0.31^{b}$ | $0.34^{b}$ | $0.33^{b}$ | $0.34^{b}$ | $0.34^{b}$ |
| Peak testosterone concentration (ng/mL) at: | | | | | | | |
| 5 months | 1.00 | 1.00 | 1.10 | 1.00 | 1.20 | 1.20 | 1.10 |
| 6 months | 1.00 | 1.10 | 1.20 | 1.20 | 1.20 | 1.30 | 1.10 |
| 7 months | $1.30^{b}$ | $2.80^{a}$ | $1.30^{b}$ | $1.30^{b}$ | $1.50^{b}$ | $1.80^{b}$ | $1.30^{b}$ |

$^{a,b}$Means within rows bearing different superscripts are significantly different ($P < 0.05$).

on Ration 2A had significantly larger scrotal circumferences (6.95 cm) than all the other groups.

Table 6 shows the episodic peaks in testosterone concentration of the experimental animals. The trend was similar for both the basal and peak testosterone concentrations. In this regard, there were no significant differences between all the treatment groups at 5 and 6 months of age, but at 7 months, bucks on Ration 2A recorded significantly higher values than all the others. The fluctuations in testosterone concentrations in bucks at 7 months of age during a 6 h period at 30 minute intervals are presented in Fig. 1. Bucks on Ration 2A had significantly ($P < 0.05$) higher peak testosterone concentrations (2.8 ng/mL) than the other bucks (1.3–1.8 ng/mL).

## DISCUSSION

The quantity and type of ingredients used in formulating the rations influenced their chemical compositions. In Ration A, the inclusion of wheat offal and cottonseed cake boosted the protein level of the ration, giving it a value of 17.19%. This value is higher than the recommended CP level of 15% for optimum maintenance of production by Nuru (1985) and 8.9–16.0% by NRC (1975). The metabolizable energy (ME) value of Ration A (11.17 MJ/kg DM) is also higher than the 9.5 MJ/kg DM recommended for maintenance by INRA (1988). Rations B and C had similar CP and ME values indicating that they are isocaloric and isonitrogenous rations. The preponderance of crop residues in Rations B and C was responsible for their high crude fiber and lignin levels. The current study showed that in spite of Rations B and C being isocaloric and isonitrogenous, animals on Ration C had better intakes and digestibilities than those on Ration B, possibly because of the low palatability, hence low voluntary intake, and poor digestibility of Ration B.

The observed higher digestibilities of DM, CP, NDF and ADF at the 1% level in comparison to the 2% level can be attributed to the higher feed intake at the 2% level of inclusion. It has been established that higher feed intake results in a faster rate of passage of digesta from the reticulo-rumen (Swan & Lamming 1967). This does not allow for effective degradation, hence lowering the digestibility of feed. Increasing the level of crop residue inclusion in the diet also increases the amount of lignin, which depresses the digestibility of the ration (McDonald *et al.* 1988), because the rate of microbial colonization of a feed with high fiber

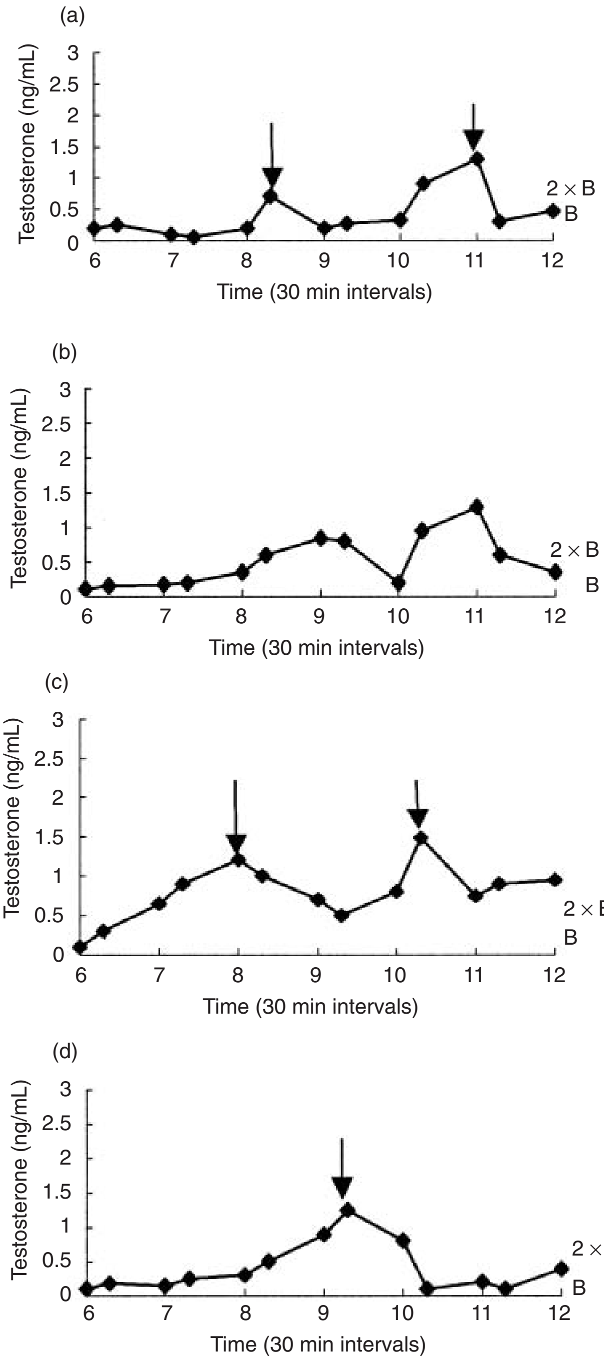


**Fig. 1** Testosterone profiles of Red Sokoto weaner bucks at 7 months of age showing basal (B) and episodic peaks (arrows) in different treatment groups, fed at 1% of bodyweight. Fig. 1d is the unsupplemented group.

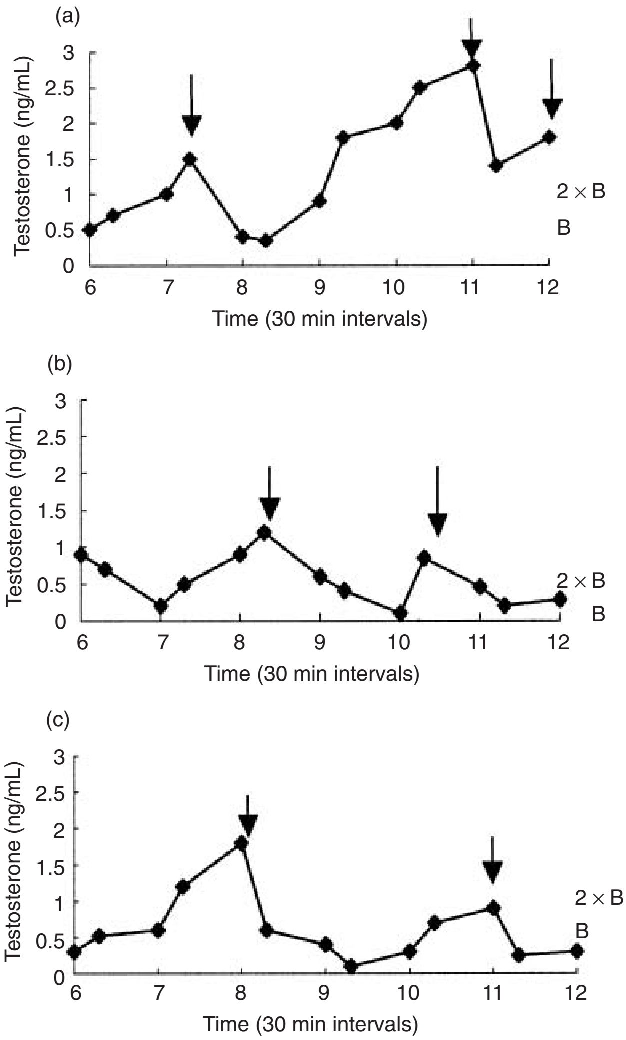


**Fig. 2** Testosterone profiles of Red Sokoto weaner bucks at 7 months of age showing basal (B) and episodic peaks (arrows) in different treatment groups, fed at 2% of bodyweight.

content is comparatively lower (Silva & Orskov 1988). The poor intake and digestibility values obtained for the unsupplemented animals is a result of the fact that Ration D had crude protein levels that are below the recommended minimum values for maintenance. This shows that there is a need for dry season supplementation in goats because the available feeds at that time are limiting in crude protein.

Of the two tested rations, Ration C seemed to have produced better intakes and digestibilities in the animals, possibly because of the composition of the rations. It contained maize offal which has very low fiber content (Alawa & Umunna 1993), groundnut haulms which have been demonstrated to be better quality roughage than *Digitaria smutsii* hay and contain adequate protein to maintain ruminants without any form of supplementation during periods of feed scarcity (Ikhatua & Adu 1984). The groundnut shells fed to the animals were also crushed before inclusion into the ration as suggested by Alawa and Umunna (1993). This must have helped to improve their consumption and digestibility. Even though Ration B contained groundnut haulms, the combination of Guinea corn bran and cowpea husk which had low crude protein percentages, must have reduced the intake and digestibility of the ration. Alhassan *et al.* (1984) observed lower digestibility values in sheep and goats (48.8 and 56.3%, respectively) compared with cattle (73.6%) when they were fed cowpea vines. This might imply that cattle do better on cowpea residues than do small ruminants. From the economic analysis, the high cost of the conventional concentrate ration shows that it is beyond the reach of a typical smallholder goat farmer, whereas the crop-residue-based rations seem quite affordable. Even though Ration B had the lowest cost, it was obvious that it had lower intake and digestibility compared to Ration C, meaning, in essence, that Ration C had a better efficiency of utilization.

The results from the present study have shown the significance of supplementation on bodyweight gain, scrotal circumference and testosterone concentration. Dyrmundsson (1973) reported that supplementation enhanced the ability of lambs to reach puberty and the results from the present study substantiate his observations. Bodyweight, scrotal circumference and testosterone concentrations have all been observed to increase with age in bulls (Karg *et al.* 1976; Lunstra *et al.* 1978; Rekwot *et al.* 1987). The observation in the present study that testosterone concentrations increased gradually as the bucks approached puberty supports the hypothalamic desensitization theory of sexual maturation (Odell & Swedloff 1974; Lacroix & Pelletier 1979). Nutritional imbalances may primarily affect the anterior pituitary or hypothalamus, thus interfering with normal luteinizing hormone and follicle-stimulating hormone production (Gerioff 1986).

The peak and basal testosterone concentrations reported in this present study are lower in value than those reported by Rekwot *et al.* (1997) in Bunaji bulls. This may be a result of species differences and also the duration of the present study (3 months) being less than the present study (7 months). However, the testosterone concentrations of the bucks showed fluctuations, with one to three distinct episodic peaks, in agreement with the findings of Sanwal *et al.* (1974), Agarwal *et al.* (1983) and Rekwot *et al.* (1987) in bulls. The exact significance of these episodic peaks is not clear but may be related to the sexual and behavioral states of the animals or adjustments to photoperiodicity, temperature and postural states of the animals (Sanwal *et al.* 1974). The testosterone profiles observed were episodic, pulsatile or temporal in nature and this agrees with the results obtained in bulls (Agarwal *et al.* 1983; Rekwot *et al.* 1987).

In conclusion, the present study demonstrates that supplementation aids bodyweight gain and peak testosterone concentration, with bucks on Ration 2A recording the highest bodyweights and testosterone concentrations (especially at 7 months of age) in agreement with studies in sheep by Orji (1976) and Osinowo and Abubakar (1988). Furthermore, Ration C also recorded some positive results compared to the other test ration (Ration B) in that bucks fed on Ration 2C had heavier bodyweights and higher peak testosterone concentrations. From the economic and biological analyses reported herein, it can be recommended to smallholder goat farmers that test Ration C is a cheap, affordable and better crop-residue-based ration for optimal reproductive performance than test Ration B, and a good alternative to the expensive conventional concentrate Ration A.

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