Influence of levels of supplementary concentrate mixture on lactation performance of Red Sokoto does and the pre-weaning growth rate of their kids

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ABSTRACT
Twenty pregnant Red Sokoto goats (liveweight, 28 ± 1.30 kg) were used in a completely randomized design to determine the effect of varying levels of concentrate on lactation performance. The concentrate, which contained 4% palm oil, was fed at levels of 1.0, 1.5, 2.0 and 2.5% of body weight of the does in addition to a basal diet of Digitaria smutisi hay offered ad libitum. The corresponding dietary treatments were designated as 1.0%C, 1.5%C, 2.0%C and 2.5%C, respectively. The goats were balanced for parity and randomly allocated to give five animals per treatment, and stall-fed individually.

The intake of dry matter and daily milk production linearly and quadratically increased (P<0.05) to the levels of concentrate supplementation. Increase in level of concentrate mixture supplementation affected (P<0.05) milkfat content and milk fat yield, but not other milk constituents. Persistency of milk production was numerically higher at higher levels of concentrate supplementation. Whereas 1.0%C, 1.5%C and 2.0%C could not prevent weight loss in the does, the 2.5%C significantly (P<0.05) promoted average daily gain (11.11 g/head/day) during lactation. The dam milk yield significantly (P<0.01) accounted for 61% of variation in kids pre-weaning average daily gain (ADG). It is concluded that concentrate mixture containing 4% palm oil can be fed at 2.5% of body weight without adverse effect on total dry matter intake, while enhancing postpartum weight gains, higher milk yield, persistency of milk production, pre-weaning growth of kids in Red Sokoto goats.

1. Introduction

Increase in energy intake of farm animals is achieved by either increasing the amount of concentrate fed or increasing the energy density by adding soluble carbohydrate (e.g. grain) or a fat source. Reports of studies on these two approaches as regards milk production in ruminants are conflicting. For example, while Gustafsson, Anderson and Emanuelsson (1993) and Havrevoll, Rajbhandari, Elk and Nedkvitne (1995) reported that increased levels of dietary concentrate decreased milk yield in cows and dairy goats, respectively, others reported increase in milk yield as levels of concentrate were increased (Eknæs & Skeie, 2006; Khalili, Osugi, Umunna, & Crosse, 1994; Malau-Aduli, Eduvie, Lakpini, & Malau-Aduli, 2004; Min, Hart, Sahlu, & Satter, 2005). Gustafsson et al. (1993) concluded from their studies that to achieve higher milk yield in Swedish dairy cows, it was preferable to increase dietary energy density rather than increase dietary concentrate level. Subsequent studies by Vazquez-Anon, Bertics and Grummer (1997) and Drackley, Cicela and LaCount, (2003) agreed with this conclusion. On the other hand, the study by Canale, Burgess, Muller and Varga (1990) showed that greater milk yield response was achieved by increasing the proportion of concentrate in the diet rather than iso-caloric addition of dietary fat.

It is a desirable feeding strategy to increase dietary levels of concentrate when low quality roughages are fed to lactating animals (Al Jassim, Aziz, Zorah, & Black, 1999; Morand-Fehr & Sauvant, 1978), or grower sheep (Liu, Wang, & Lee, 2005), but when concentrate proportion is beyond 50 – 60% in the diet, rumen pH decreases (Goncalves et al., 2001a, 2001b; Morand-Fehr, 2005) leading to off-feed problems (Wangness & Muller, 1981) and impaired digestibility (Llano & Depeters, 1985). In goats, in particular, if the lowering of rumen pH last several hours symptoms of acidosis can appear as diarrhea and fall in feed intake (Morand-Fehr, 2005). Therefore, the need to have optimum forage: concentrate ratio in the diets of ruminants was further emphasized by the study of Liu et al. (2005). Related works have shown the importance of dietary levels of neutral detergent fibre (NDF) to milk yield and composition. High levels of dietary NDF can decrease milk yield (Ruiz, Bernal, Staples, Sollenberger, & Gallaher, 1995) but the...
reported optimum dietary proportion for maximum dry matter intake (DMI) and fat-corrected milk production in dairy cows was 35% (Mertens, 1983 as cited in West, Hill, Gates, & Mullinix, 1997), 60% of which must come from forage (Sarwar, Firkins, & Eastridge, 1992).

The population of goats in Nigeria was estimated to be 72.5 million (FMARD, 2016), with the Red Sokoto goats constituting about 65% of the population. The coat colour and ecological distribution of Red Sokoto goats had earlier been reported (Otaru, Adamu, Ehoche, & Makun, 2011). Although the Red Sokoto goats is valued internationally for the quality of its skin (Wilson, 1991; RIRDC, 2003), it faces major challenges of poor management, inadequate nutrition and high pre-weaning mortality (32.8%), especially in the traditional farming system (Ottchere et al., 1987). Mba, Bassey and Oyenuga (1980) noted that the Red Sokoto goat has great potential for milk production, which should be exploited through intensive nutritional studies. In a study using Red Sokoto goats fed at the rate of 1.6% of body weight with concentrate mixtures containing varying levels of palm oil, it was observed that the goats fed 470 g/head/day of the concentrate mixture containing 4% of palm oil recorded the most (29%) improvement in milk yield with the least cost compared with the control group (without palm oil inclusion), while all the treatment diets could not prevent postpartum weight loss in the lactating goats (Otaru et al., 2011). Similar results were earlier reported for the same breed of goats in Niger Republic (Djibrillou, Pandey, Gouro, & Verhulst, 1998). The level of concentrate to offer is sometimes influenced by the quality of forage fed. It would seem the level of concentrate fed to the goats in the study by Otaru et al. (2011) was not adequate enough to enhance higher milk yield and better postpartum weight gains. Further evaluation of the effect of increasing the feeding level of the concentrate mixture containing 4% palm oil in the diets of male Red Sokoto goats fed basal diet of Digitaria smutsii hay showed that supplementation at 2% of body weight enhanced consumption of hay, total DMI and digestibility of nutrients and nitrogen retention (Otaru, Adamu, Ehoche, & Lakpini, 2016). Beyond 2% of body weight, the authors observed greater consumption of concentrate mixture compared to the amount of hay consumed.

Concentrate containing both glucogenic precursor and a fat source has been reported to increase milk yield in dairy cows (Patton, Sorenson, & Hippen, 2004) as energy is the critical nutrient for milk production (Morand-Fehr & Sauvant, 1978). However, there is a paucity of information on the optimum level of feeding such concentrate to lactating goats in Nigeria with native pastures characterized by C4 type of grasses which grow and lignify so rapidly with concomitant low soluble carbohydrates and crude protein contents. The objective of this study therefore was to determine the effect of increasing the level of maize-based concentrate (containing 4% palm oil) on lactation performance of Red Sokoto goats and pre-weaning growth rate of suckled kids. We hypothesized that supplementation of Red Sokoto goats fed basal diet of D. smutsii hay with greater quantities of concentrate mixtures containing 4% palm oil will enhance milk production, postpartum weight gains and pre-weaning growth rate of their kids.

2. Materials and methods

The protocol and procedures used in this study were in accordance with the guidelines given by the Committee On Animal Use and Care of the Ahmadu Bello University, Zaria, Nigeria (Approval No: ABUCAUC/2020/007).

2.1. Location of the study

The study was carried out at the Goat Project of the Small Ruminant Research Programme, National Animal Production Research Institute (NAPRI), Ahmadu Bello University, Shika – Zaria, Nigeria. Shika is located within the Northern Guinea Savannah Zone at Latitude 11° 11′ N and Longitude 7° 34′ E, and is 640 m above the sea level (Dada, Jibrin, & Ijeoma, 2006).

2.2. Animals, design of experiment and diets

202 pregnant Red Sokoto goats of average weight of 28.01 ± 1.30 kg, which were either in the first, second, third, fourth or fifth parity and in the last one month of pregnancy, were obtained from the flock of Red Sokoto goats at the Small Ruminant Research Programme, National Animal Production Research Institute, Ahmadu Bello University, Shika-Zaria, and used for this trial. The goats were balanced for parity and randomly assigned to the concentrate feeding levels of 1.0, 1.5, 2.0 and 2.5% of body weights designated as treatment 1%, 1.5%, 2.0% and 2.5%, respectively. The design of the experiment was a completely randomized design comprising four treatment groups and five replicates or animals per treatment group.

The concentrate mixture fed to the goats was composed of 33.87% ground maize, 18.94% maize offal, 4% palm oil, 39.04% cotton seed cake, 0.15% urea, 2.5% bone meal and 1.5% common salt. The basal diet was Wooly finger grass (Digitaria smutsii Stent) hay fed to the animals ad libitum. The concentrate was compounded to contain 16% crude protein and 11.98 ME MJ/kg DM. The procedure for mixing the concentrate ingredients with a pre-determined quantity of palm oil was as earlier described (Otaru et al., 2011). Table 1 shows the nutrient concentrations of the concentrate mixture and Digitaria smutsii grass hay.

2.3. Management of animals

Before the commencement of the trial, the goats were dipped in acaricide (Amitix®) solution (with amitraz as an active ingredient) to control ecto-parasities. The animals were thereafter weighed on two consecutive days and the weights averaged to get the initial weights of the animals. They were subsequently housed in individual feeding pens and the concentrate mixture offered at the rate of 1.0, 1.5, 2.0 or 2.5% of body weight of the animals in accordance with treatment groups 1%, 1.5%, 2.0% and 2.5%, respectively.

The feeding time was at 09:00 h after cleaning the pens, and the ors or refusals of the previous day’s feeding had been collected and weighed. During feeding, the animals were first given the concentrate mixture and allowed 30–45 minutes to eat it before the Digitaria smutsii hay was offered ad libitum in a separate trough provided in the pens. Water was offered in a 13-litre capacity plastic buckets, to allow ad libitum water consumption, and changed every morning. Every fortnight water intake (in litres) was determined for two consecutive days and values averaged to get the volume of water consumed.

After adjustment period of 14 days, daily records were taken of the quantity of feeds offered and refused in order to determine voluntary feed intake. Forthnightly weights of dams and their kids were taken and quantity of feeds offered adjusted accordingly for the dams.

Table 1

| Chemical Composition (%DM) | Concentrate mixture | Digitaria smutsii hay |
|----------------------------|---------------------|-----------------------|
| Organic matter             | 85.91               | 88.73                 |
| Crude protein              | 16.30               | 5.40                  |
| Crude fibre                | 26.24               | 46.48                 |
| Ether extract              | 14.52               | 5.10                  |
| Neutral detergent fibre    | 36.37               | 68.34                 |
| Acid detergent fibre       | 25.00               | 45.20                 |
| Ash                        | 9.00                | 8.22                  |
| Non-structural carbohydrate (calculated) | 18.72 | 9.90 |
| Gross energy (GE, MJ/kg DM) | 16.08 | 17.66 |
| Net Energy Lactation (NE, MJ/kg DM) | 5.80 | 4.18 |

1 NEl values were calculated according to the NRC (1981) equations.
2.4. Milking of animals

After kidding, as soon as possible, the dams and kids were weighed to know the parturition weight and birth weight, respectively. The parturition weights were taken as the initial weights of the dams. Milk yield measurement was commenced after the kids were allowed to suckle the dams for the first seven days postpartum to consume colostrum and to establish strong dam-kid relationship to forestall rejection of kids by their dams after overnight separation to measure milk yield. Hand milking of the animals was done between 06:00 h and 07:00 h for two consecutive days in a week. The kids were separated from their dams for 12 h overnight (18:00 h – 06:00 h) and only re-introduced to their dams after milking. The milk was collected into 500 ml graduated plastic beaker and weighed thereafter. Values obtained were multiplied by a factor of 2 to get the milk yield for 24 h because according to Bencini, Knight and Hartmann (2003) milk secretion rates are the same for milking intervals of 8, 12, 16 and 20 hrs. This approach was continued for 12 weeks postparturum after which the kids were weaned and the dams were milked twice daily (morning and evening) for eight weeks. The morning and evening milk yields were added together to get the daily milk yield. Milking was terminated when it was discovered that daily yield was, on the average, 48% (a range 26 – 65% of individual animal’s peak yield) of mean peak yield of 755 ml. Only one animal was producing below 150 ml per day at the 20th week, the quantity below which a lactating non-dairy goat was considered dry (Sangaré & Pandey, 2000).

2.5. Measurement of blood and rumen metabolites

Blood samples were collected from three animals from each treatment monthly at days 28, 56 and 84 post-partum and at the termination of the experiment. The blood samples were collected before morning feeding. During each sampling time, 10 ml of blood was collected from each animal by jugular veni-puncture into test-tube. The test tubes and their contents were allowed to stand for about six hours, and the serum which had separated from cells was carefully decanted into serum vials. Serum samples were stored in a deep freezer (-20° C) before being analysed for glucose, urea and cholesterol within 10 days of collection.

During the last week of the feeding trial, rumen fluid was collected before and at 3½ h after feeding from all the 20 goats by aspiration method using stomach tube. The rumen fluid was collected into plastic containers, and the pH of the fluid was immediately taken. The fluid was strained through muslin cloth before 15 ml aliquot of the filtrate was taken and mixed with an equal volume of 1 N H₂SO₄ saturated with NH₃ solution titrated against an aliquot of rumen fluid containing NH₃-N was used in the equation: 1 ml of 0.02 N HCl = 0.28 mg NH₃-N, to derive the concentrations of NH₃-N expressed in milligrammes per litre of rumen fluid. Also, the titre value of 0.02 N HCl solution titrated against an aliquot of rumen fluid containing NH₃-N was used in the equation: 1 ml of 0.02 N HCl = 0.28 mg NH₃-N, to derive the concentrations of NH₃-N expressed in milligrammes per litre of rumen fluid.

The lactation curve parameters of the goats were estimated by using the Wood (1967) incomplete gamma function: 

\[ Y_n = e^{-(b+1) \log(c)} \]

where \( Y_n = \) daily milk yield in the period of t of the lactation; \( a = \) general level of production or the beginning yield or the intercept; \( b = \) rate of rise in milk yield to peak and \( c = \) rate of decline in milk yield to drying up; \( e = \) base of the natural logarithm. The equation was fitted by non-linear regression to the milk production data of the goats using the PROC NLIN procedure of SAS (2002, Version 9.0) with Markgaard as the iteration method. The parameters \( a \), \( b \) and \( c \) generated were used to further estimate other parameters of lactation curve namely, persistency, peak production and peak time as defined by the following equations by Wood (1967):

Persistency (S) = -(b+1)logc; Peak Production = a/(b/c)e^{b}; Peak time = b/c; where a, b, c and e are as defined before. Lactation curve parameters generated and output were subjected to the analysis of variance using PROC GLM of SAS (2002) to know the effect of the treatment on the parameters. Least squares means were separated using the PDIFF OPTION of SAS (2002). The parameters generated from the PROC NLIN procedure were used to plot the lactation curves of the goats using PROC GPLET procedure of SAS (2002).

Data on average daily gain (ADG), total live weight change, initial and final liveweights, rumen metabolites and pH, total lactation yield (for 20 weeks), estimated persistency of lactation, peak yield and peak time of the lactating goats, pre-weaning ADG, weight change, birth weights and weaning weights of suckled kids were analysed by ANOVA using the General Linear Model (GLM) procedures of the statistical Analysis Systems (SAS, 2002, version 9.0) according to the following statistical model: \( Y_{ij} = \mu + \tau_j + e_{ij} \), where \( Y_{ij} \) is the response of animal i in treatment j (\( j = 1, 2, 3, 4 \)), \( \mu \) is the overall mean, \( \tau_j \) is a fixed effect of the jth treatment (\( j = 1, 2, 3, 4 \)), \( e_{ij} \) is the random error. After significant F-test, least squares means were separated using the PDIFF OPTION of SAS (SAS, 2002) and differences between least squares means were declared significant at P < 0.05. Data on daily voluntary feed intake, water intake, daily milk yield, milk composition, efficiency of milk production and blood metabolites of dams whose values were correlated because of repeated measure, were subjected to analysis of variance for repeated measure analysis according to Littell, Henry and Ammerman (1998) using PROC MIXED procedure of SAS (SAS 2002, 2008).
The statistical model used is: $Y_{ijk} = \mu + T_j + B_i + \beta_4 M_i + \beta_5 B_{Wi} + e_{ijk}$, where $Y_{ijk}$ is the $i$th observation for the dependent variable $Y$ (ADG, average daily gain), $i = 1, 2, 3, \ldots, 15$, $T_j$ is the $j$th observation for the independent variable $T$ (Type of birth, single or twin), $B_i$ is the $i$th observation for the independent variable $B$ (Birth weight of kids), $i = 1, 2, 3, \ldots, 15$, $M_i$ is the $i$th observation for the independent variable $M$ (Average daily milk yield of dam), $i = 1, 2, 3, \ldots, 15$, $B_{Wi}$ is the $i$th observation for the independent variable $W$ (Birth weight of kids), $i = 1, 2, 3, \ldots, 15$. $T_i*B_i$ is the $i$th observation for the interaction between $T_i$ and $B_i$, $S_i$ is the $i$th observation for the independent variable $S$ (Sex; male or female), $i = 1, 2, 3, \ldots, 15$, $M_i$ is the $i$th observation for the independent variable $M$ (Average daily milk yield of dam), $i = 1, 2, 3, \ldots, 15$, $B_{Wi}$ is the $i$th observation for the independent variable $W$ (Birth weight of kids), $i = 1, 2, 3, \ldots, 15$, $T_i*B_i$ is the $i$th observation for the interaction between $T_i$ and $B_i$, $S_i$ is the $i$th observation for the interaction between $S_i$ and $B_i$, $e_i$ is the residual error for observation $i$, and $\beta_0$, $\beta_1$, $\ldots$, $\beta_6$ are regression parameters, and $\beta_0$ is the intercept. The resulting parameters estimates are as shown in the equation below:

$$Y = 34.38 + 40.12T - 21.36S + 0.021 M - 13.90BW - 0.024 S^2 + 0.004 M^2 + 0.001 BW^2 + 0.000 S^3 + 0.000 M^3 + 0.000 BW^3 + e_i$$

where $\mu$ is the overall mean, $T$ is a fixed effect of the $j$th treatment ($j = 1, 2, 3, 4$), $B_i$ is a random effect of the $i$th animal ($i = 1, 2, 3, 4$), $e_{ijk}$ is the residual error for observation $i$, and $\beta_0, \beta_1, \ldots, \beta_6$ are regression parameters, and $\beta_0$ is the intercept. For each variable analysed under this model, animal as a subject nested within treatment was subjected to five covariance structures: Compound symmetry (CS), unstructured (UN), autoregressive order [AR(1)], heterogeneous autoregressive [ARH (1)] and spatial power (SP (POW)). The covariance structure that yielded the smallest Akaike’s Information Criterion (AIC) and met the convergence criteria was used. Autoregressive order (AR (1)) was used for total dry matter intake; ARH (1) for daily hay dry matter intake, total dry matter intake on metabolic weight basis, daily milk yield, milk protein percent, milk fat percent, milk total solids percent and milk fat yield; CS for solids-not-fat; UN for daily dry matter intake for the concentrate, total dry matter intake as a percentage of body weight, concentrate intake to hay intake ratio and water intake, fat-corrected milk yield for the entire lactation and by stage of lactation, efficiency of milk production; SP(POW) for the blood metabolites. When effect of treatment was significant, Bonferroni multiple comparisons test was used to determine differences among at least squares means. Orthogonal polynomial contrast was run in accordance with the procedures of SAS (2002) to establish the response relationship between the variables and dietary concentrate level.

A total of 31 kids were kidded, but 10 kids died before reaching weaning age (i.e. 32% mortality recorded) and 21 kids were successfully weaned. Regression of kids’ pre-weaning average daily gain (ADG) on type of birth, sex and dam’s milk yield was done with birth weight as a covariate using PROC REG procedure of SAS (2002) with the following model, $Y_i = \beta_0 + \beta_1 T_i + \beta_2 S_i + \beta_3 M_i + \beta_4 B_{Wi} + \beta_5 T_i*B_{Wi} + \beta_6 S_i^2 + \beta_7 B_{Wi}^2 + e_i$, where $Y_i$ is the $i$th observation for the dependent variable $Y$ (ADG, average daily gain), $i = 1, 2, 3, \ldots, 15$, $T_i$ is the $i$th observation for the independent variable $T$ (Type of birth, single or twin), $S_i$ is the $i$th observation for the independent variable $S$ (Sex; male or female), $i = 1, 2, 3, \ldots, 15$, $M_i$ is the $i$th observation for the independent variable $M$ (Average daily milk yield of dam), $i = 1, 2, 3, \ldots, 15$, $B_{Wi}$ is the $i$th observation for the independent variable $W$ (Birth weight of kids), $i = 1, 2, 3, \ldots, 15$, $T_i*B_{Wi}$ is the $i$th observation for the interaction between $T_i$ and $B_{Wi}$, $S_i$ is the $i$th observation for the interaction between $S_i$ and $B_{Wi}$, $e_i$ is the residual error for observation $i$, and $\beta_0$, $\beta_1$, $\ldots$, $\beta_6$ are regression parameters, and $\beta_0$ is the intercept. The resulting parameters estimates are as shown in Table 2. Total dry matter intake by the goats, and their dry matter intake on metabolic weight basis increased with linear, quadratic and cubic responses (P<0.05) to the levels of concentrate fed. The goats fed concentrate at 2.5% level had significant (P<0.05) increase of 33% to 35% in total dry matter intake over the takes of the goats fed at lower level of 1.0% or 1.5% of body weight. When the total dry matter intake was expressed on metabolic weight basis, a significant (P<0.05) increase of 20% to 36% in intake was observed for goats fed at 2.5% level compared to goats in other treatments. The linear increase of dry matter intake to increasing level of concentrate mixture in the diet may be due to increased consumption of protein and energy from the concentrate mixture, which in synergism, facilitated rumen microbial growth to enhance digestion and intake by the goats (Otaru et al., 2016). Calculated crude protein intakes from concentrate component of the diets (not shown in the Table) were 44.15, 58.63, 77.26 and 104.93 g, respectively for goats in the treatment groups 1%C to 2.5% and they correspondingly represented 5.6, 7 and 8% of total DMI. The present observation on DMI is consistent with earlier reports of increased DMI by goats fed grass silage (Dennem, Randyby, & Eknæs, 2011), Alfalfa hay and oat hay (Tufarelli, Dario, & Laudadio, 2009) or grass hay (Otaru et al., 2016) with varied levels of concentrate mixture. Similar response was observed in sheep fed different levels of concentrate as supplement to corn stalk (Liu et al., 2005) and barley hay (Cherif, Ben Salem, & Abidi, 2018). Nitrogen intake has been shown to account for 56% of the variation in DMI (Lallo, 1996) because the total DMI appears to increase with level of crude protein intake from the concentrate component of the diet. The effect of concentrate level on DMI as observed in this study is however in contrast to the report by Mele et al. (2008) where different concentrate levels offered to goats receiving basal roughage diet had similar dry matter intakes. The difference between the observation in this study and that of Mele et al. (2008) may be due to forage quality. According to Matejovsky and Sanson (1995), the response of lambs to increasing level of energy source (supplemental corn) is dependent on forage quality. They found that when lambs were fed low quality forage (5.2% CP) and supplemented with corn, total dry matter and hay dry matter intakes were significantly affected with

### Table 2

Mean daily dry matter intake, water consumption and body weight changes of Red Sokoto goats fed varying levels of supplementary concentrate mixture.

| Parameter                  | Concentrate mixture Level (g/kg LW) | SEM  | Concentrate level effect, P< |
|----------------------------|-------------------------------------|------|-----------------------------|
| Dry matter intake, g/d     |                                     |      |                            |
| Hay                        | 712.56                              | 637.13 | 571.04                     |
| Concentrate                | 270.87b                             | 359.69bc | 474.00b                    |
| Total dry matter Intake    | 983.43b                             | 996.82b | 1045.04b                    |
| Dry matter intake/kgW0.75  | 81.16b                              | 88.72b  | 92.10b                      |
| Dry matter intake as % of BW| 3.54b                               | 3.94b   | 4.11b                       |
| Concentrate : hay ratio    | 0.40b                               | 0.59bc  | 0.86abc                     |
| Water intake (l/d)         | 1.94                                | 2.00    | 2.50                        |

a,b,c Means within the same row bearing different superscript letters differ significantly (P<0.05). BW = Body weight, L=Linear, Q=Quadratic, C=Cubic, NS=Not Significant (P > 0.05).
quadratic response, whereas with medium quality (10.2% CP) and high quality (14.2% CP) hay supplemented with the same levels of corn, no significant effect on total dry matter intake was observed but hay dry matter intake response was linear.

The concentrate to hay consumption ratio increased with linear, quadratic and cubic responses (P<0.0001) up to a unity at 2.5%C where the concentrate to hay intake ratio was 50:50. The hay intake was not (P>0.05) affected by the treatments. Water consumption was not significantly (P>0.05) different among treatment groups but there was a consistent numerical increase in the amount of water consumed with increase in the amount of concentrate intake. The consistent increase in the concentrate to hay consumption ratio across levels of supplementation reflected increase in concentrate consumption at the expense of hay consumption. The calculated substitution rates of 0.21, 0.30 and 0.05 g DM decrease in grass hay consumption per 1 g DM increase in concentrate intake by the goats in the treatments 1.5%C, 2.0%C and 2.5%C, respectively, show that there was substitution effect consistent with similar observation by Doyle (1987). However, the rates are comparable to the modest rates ranging from 0.1 to 0.5 earlier reported for cattle fed varying levels of concentrate supplements (Quang et al., 2015). The fact that the substitution was not pronounced is reflected in the comparable mean values of hay DM consumption among the treatments where relative to 1.0%C, only a depression of 5% was observed in hay consumption at 2.5%C where the consumption of concentrate mixture was the most. Since the ratio of concentrate to hay consumption reached unity (1.0) at 2.5%C, it means that further increase in level of concentrate offered could markedly affect hay consumption.

3.2. Milk yield and composition

The goats exhibited significant (P<0.05) linear and quadratic responses in terms of mean daily milk production to the levels of concentrate supplementation. The highest yield was 600.31 mL/d for the 2.5% level followed by 574.45 mL/d for the 2.0% level (Table 3). Both values were statistically similar but were 48 - 55% higher (P<0.05) than values recorded at lower levels of supplementation. The fat-corrected milk yield followed similar pattern of response to the level of concentrate supplementation with goats in treatment 2.5%C with the rected milk yield followed similar pattern of response to the level of concentrate supplementation with goats in treatment 2.5%C with the most yield. The mean total lactation yield, which ranged from 54 to 84 L during the 20-week lactation, showed that at levels beyond 1.5%C, milk yield improved by 40 - 55% over and above the values recorded for goats supplemented at lower levels. This observation is consistent with results of previous studies on goats (Eknaes and Skeie, 2006; Malau - Adulri et al., 2004; Min et al., 2005; Shen, Yang, Chen, Xu, & Wang, 2017) and sheep (Al-Jassim et al., 1999) where treatment groups given high levels of concentrate produced significantly more milk than those given low levels of concentrate supplement. The lactation length of 20-weeks or 140 days recorded in this study is longer than 12 weeks earlier reported by Ehoche and Buvanendran (1983) for the breed probably due to better nutrition of the goats in our study. Ehoche and Buvanendran (1983) did not impose any nutritional treatment apart from routine feeding with proprietary diet while the goats were milked. In the present study, milking of the goats was stopped at the 20th week of lactation when, on the average, the daily yield was 48% of the mean peak yield of 755 mL and only one animal was producing below 150 mL per day, the quantity below which a lactating non-dairy goat was considered dry (Sangare & Pandey, 2000). From Table 2, the goats in 2%C and 2.5%C treatment groups consumed more concentrate DM and total DM. Since the concentrate was maize-based (33.87%), the 2%C and 2.5%C goats would have consumed more maize and by implication more dietary starch. Starch-containing concentrates enhance more production of propionate in the rumen which is converted to glucose in the liver via gluconeogenesis (Steinbour & Bauman, 1988). The mammary gland uptake of glucose from the blood is not insulin dependent and the corollary is that as more glucose is produced from gluconeogenesis, more of it is also converted to lactose in the mammary glands (Hills, Wales, Dunshea, Garcia, & Roche, 2015). The production of lactose elicits the need to keep milk and blood isotonic, thus triggering increased water movement into the mammary secretory cells and resulting ultimately in greater volume of milk (Hills et al., 2015).

The significant treatment effect observed in this study contradicts the findings of other workers (Gustafsson et al., 1993; Havrevoll et al., 1995) who found that increased levels of concentrate feeding decreased milk yield in cows and dairy goats, respectively, when compared to low levels of concentrate feeding. Concentrate supplementation generally increases milk yield, but the difference between the observation (increased yield) in this study and that (decreased yield) of Havrevoll et al (1995) might be due to quality of roughage used as basal diet. It has been suggested that roughage quality was one of the factors that affect animal responses to supplementation (Nsahlai, 1991 as cited in Umunna, Osuji, Nsahlai, Khalili, & Mohammed-Saleem, 1995). Havrevoll et al (1995) used good quality grass hay and grass silage of about 10% DCP; the grass hay we used in the present study had 6% CP. The effect of concentrate supplementation is more dramatic in animals on poor quality forage compared to those on moderate to high quality forage because the latter forage type alone would have supplied or met substantially the energy and protein requirements of the animal, thus requiring from supplementation, a small complementary quantity or supply beyond which further increase can be counterproductive.

Table 3
Mean milk yield, milk composition and economic efficiency of Red Sokoto goats fed varying levels of supplementary concentrate mixture.

| Parameter | Concentrate mixture level (g/kg LW) | SEM | Concentrate level effect, P< | L | Q | C |
|-----------|----------------------------------|-----|-------------------------|---|---|---|
|           | 1%C | 1.5%C | 2%C | 2.5%C | | | |
| Milk yield Total lactation yield in 20 weeks (L) | 57.00ab | 54.11b | 78.88ab | 84.04a | 10.40 | 0.03 | 0.03 | NS |
| Daily milk yield (ml) | 404.09b | 386.52b | 574.45b | 600.31a | 62.33 | 0.02 | 0.02 | NS |
| 4% FCM (ml) | 315.51b | 362.88b | 415.25b | 625.97a | 75.61 | 0.01 | 0.01 | 0.04 |
| Efficiency of milk production (milk yield, ml/kg DM) | 408.40 | 385.92 | 34.72 | 464.92 | 59.69 | NS | NS | NS |
| Cost of total DM intake (%) | 55.78 | 58.88 | 61.73 | 78.10 | | | | |
| Cost,₦/litre of milk produced | 138.02 | 152.33 | 107.45 | 130.10 | | | | |
| Milk component yield (g/d) | | | | | | | | |
| Total Solids | 13.06 | 15.27 | 14.26 | 15.91 | 0.92 | NS | NS | NS |
| Milk fat | 2.58b | 3.44b | 2.93b | 3.94b | 0.40 | NS | NS | 0.03 |
| Milk protein | 5.58 | 5.69 | 5.24 | 5.65 | 0.37 | NS | NS | NS |
| Solids-not-fat | 10.47 | 11.82 | 11.33 | 11.97 | 0.82 | NS | NS | NS |
| Milk component yield (g/d) | | | | | | | | |
| Fat | 9.90b | 13.48b | 17.31b | 25.10a | 3.27 | 0.01 | 0.01 | 0.02 |
| Protein | 24.42 | 22.46 | 31.24 | 35.69 | 3.80 | NS | NS | NS |

a,b Means within the same row bearing different superscript letters differ significantly (P<0.05).
L = Linear, Q = Quadratic, C = Cubic, NS = Not Significant (P>0.05).
₦ = Naira, the Nigerian Currency.

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Efficiency of milk production was comparable between concentrate levels but the 2%C was the most efficient numerically as intake of 1 kg DM of the diet elicited milk yield of 535 mL per goat per day. The cost of total DM consumed increased linearly with the level of concentrate supplementation, but the cost of the feed per liter of milk produced was cheaper at the higher levels of concentrate supplementation, the cheapest being at 2%C. It thus implies that achieving high production occasioned by feeding expensive quality feed with high feed efficiency, ultimately results in reducing the cost of feed per unit of product.

Increasing level of concentrate supplementation only affected (P<0.05) percent milk fat, which showed cubic response (P<0.05). Other milk constituents were not significantly affected (P>0.05) by the treatments. Milk fat yield was also affected (P<0.05) by the treatment with linear, quadratic and cubic effects (P<0.05). The marked increase in milk fat percent and milk fat yield with increase in concentrate supplementation is not in agreement with the findings of Eknæs and Skeie (2006) on goats where high concentrate to forage ratio decreased milk fat concentration. High concentrate to forage ratio usually leads to high consumption of concentrate which reduces the concentration of rumen acetic acid (Zervas, Zarkadas, Koutsotolis, Goulas & Mantziou, 1999) and thus causes milk fat depression (Morand-Fehr & Sauvant, 1978) since acetic acid and butyric acids are lipogenic (Mietinen & Huhtanen, 1996). In the present study, increased concentrate supplementation increased milk fat percent and yield because of two main reasons. Firstly, the concentrate supplement contained 4% palm oil, which upon consumption enhanced milk fat level in agreement with other studies where concentrate mixtures containing fat source or vegetable oil gave higher milk fat percent in goats (Bernard et al., 2005; Schmidely, Morand-Fehr & Sauvant, 2005). It has been stated that milk fatty acids originate from two main origins – synthesis de novo in the mammary gland or extraction from the arterial blood into mammary gland from mobilized body fat or after ingestion, digestion and absorption of dietary fat (Bernard et al., 2005; Chilliard & Ferlay, 2004; Clegg et al., 2001). Secondly, the concentrate consumption was not to the detriment of hay consumption since the highest level of concentrate supplementation (2.5 % of body weight) gave concentrate to hay intake ratio of 50:50. The fibre intake may have been enough as not to affect the rumen pH and VFA concentrations as evident in Table 7, and ultimately not affecting acetic acid which ruminal molar ratio has been reported to be positively and significantly correlated with milk fat percent (Li, Wang, Li, & Lin, 2007).

3.3. Stage of lactation effect on milk yield and composition

Table 4 shows dietary treatment means by stage of lactation for milk yield and composition. There was significant (P<0.05) effect of stage of lactation on milk yield and composition. No effect (P>0.05) of interaction between treatment and stage of lactation on milk yield and composition was observed. Therefore, values of yield and composition were averaged across treatments to obtain means for early lactation (EL), mid-lactation (ML) and late lactation (LL). The daily milk yield significantly declined (P<0.05) with advancing lactation, with EL value accounting for 42% of the total lactation yield while ML value was 68% more (P<0.001) than the 337 mL recorded for LL. Four percent Fat-corrected milk followed similar pattern, but significant differences were only observed between the values of EL and LL (P<0.01) and ML and LL (P<0.05). The attendant decrease in milk and fat – corrected milk yield with advancing lactation is consistent with previous findings on goats (Otaru et al., 2011). The effect of stage of lactation is mediated through apoptosis (programmed cell death of mammary gland secretory cells) (Capuco, Wood, Baldwin, Mcleod, & Paape, 2001; Wilde, Addey, Li, & Fennig, 1997) and growth hormone and prolactin both of which are lactogenic hormones with galactopoietic effects (Capuco et al., 2003). The concentrations of these hormones decrease with advancing lactation (Chaiyabutr, Komolvanich, Thammacharoen, & Chanponsang, 2004; Miller et al., 2006) with
attendant lower milk yield (Chaiyabutr et al., 2004). Given the influence of interplay of hormones, nutritional influences on stages of lactation may, in most cases, not be too obvious.

Although percent milk fat increased with advancing lactation, the successive increase was not significant (P > 0.05). Percent milk protein showed a significant (P < 0.05) decline at LL after an increase at ML. This agrees with previous reports where irrespective of the diets fed, milk protein content was higher at the first two weeks (Dijibrilou et al., 1998) or five weeks (Brown-Crowder, Hart, Cameron, Sahlu, & Goetsch, 2001; Otaru et al., 2011) of lactation compared to subsequent weeks.

From the review by Hanigan, Bequette, Crompton and France (2001), the reduction in percent milk protein with advancing lactation weeks may be attributable to reduced enzymatic capacity as lactation advances, negative correlation between uptake of essential amino acids (especially arginine, lysine and methionine) and advancing lactation, and reducedudder protein mass with progressing lactation. The nature of response of percent milk protein in this study disagrees with the earlier observation on goats (Mba, Boyo, & Oyenuga, 1975), ewes (Casals, Caja, Such, Torre, & Calsamiglia, 1999) and cows (Socha et al., 2008) where percent milk protein increased with advancing lactation. Total solids percent increased with advancing lactation with the value at LL having at least 36% significant (P < 0.0001) increase over the other two stages of lactation. The observed increase in percentages of total solids with advancing lactation is consistent with similar observation on Red Sokoto (Otaru et al., 2011) and Sahel goats (Sangaré & Pandey, 2000). The milk fat yield, a derivative of milk yield and milk fat content, was lowest at LL and differed (P < 0.05) only from EL value and not different from the highest value at MM with which it had wider mean disparity (12.34 Vs 19.05). The reason for not detecting significant difference between ML and LL was because of too wide individual variation of 72 g amongst goats during ML compared to the variation of 43 g for EL and 27 g for LL among the goats. Milk protein yield showed a significant (P < 0.05) decline at LL after an increase at ML.

3.4. Persistency of milk production

The estimated values for persistency (s), the beginning production (a), rate of rise to peak (b), rate of decline from peak (c), peak week and peak production were all comparable among treatments (Table 5). The persistency of production was numerically higher with 12 – 18% increase or improvement in goats fed at higher concentrate supplementation levels. The 2% C group, which had second to the least rate of decline after peak, was also with the highest persistency value.

Table 5

| Concentrate level | a   | b   | c   | Peak week | Peak production |
|------------------|-----|-----|-----|-----------|-----------------|
| 1% C             | 566.46 | 0.19 | 0.0644 | 3.39 | 4.21 | 507.10 |
| 1.5% C           | 531.75 | 0.27 | 0.0871 | 3.11 | 2.93 | 548.88 |
| 2.0% C           | 665.72 | 0.31 | 0.0714 | 3.60 | 4.63 | 743.11 |
| 2.5% C           | 823.23 | 0.18 | 0.0734 | 3.51 | 3.10 | 936.10 |
| SEM              | 114.10 | 0.15 | 0.0228 | 0.33 | 1.12 | 145.67 |

ab Means within the same column bearing different superscript letters differ significantly (P < 0.05).

a = general level of production or the beginning yield or the intercept.
b = rate of rise in milk yield to peak.
c = rate of decline in milk yield to drying up.
s = persistency.
L = Linear, Q = Quadratic, C = Cubic, NS = Not Significant (P > 0.05).

Estimates of peak production showed that the 2.0% level concentrate had the highest peak week of 4.63 (approximately 5) but was non-significantly (P > 0.05) different from the 1.5% level concentrate with the least value of 2.93 (approximately 3). The observed greater persistency of milk production in goats fed higher levels of concentrate mixture compared to those fed at lower levels is in tandem with similar pattern of observation by Horan, Dillon, Berry, O’Connor and Rath (2005) and Min et al. (2005) who, however, noted significant effect of level of concentrate supplementation. In this study, 2.0% level of concentrate appeared to be the best because it numerically had the highest persistency and reached peak production at the longest week (5 weeks) postpartum (Table 5). The benefits of high persistency as they relate to feed cost, health and fertility of the animal has been described (Dekkers, Ten Hag, & Weersink, 1998, Lin & Togashi, 2002; Sölkner & Fuchs, 1987). According to Sölkner and Fuchs (1987), highly persistent cows required between 69 and 161 kg less concentrate than low persistent cows to produce 5500 kg of milk. In the present study, it is therefore not surprising that goats fed the 2.0%C diet with higher persistency had least cost of producing one litre of milk (Table 5).

Persistency of lactation is defined as the rate of decline in production after peak milk production has been reached (Cole & Null, 2009) or the ability of an animal to maintain a more or less constant yield during lactation after peak production (Gengler, 1996). Goats fed higher levels of concentrate consumed quantitatively more critical nutrients (protein and energy) which provided numerically higher blood metabolites – urea-nitrogen and glucose – to support persistent milk production during lactation. Although, glucose uptake by mammary gland is controlled homeostatically and does not depend only on arterial concentrations (Lykos & Varga, 1997), several studies had established a strong link between serum glucose and mammary uptake of glucose on one hand, and lactose increase and milk production on the other (Hills et al., 2015; Kronfeld, Raggi, & Ramberg, 1968; Lemosquet, Rigout, Bach, Rulquin, & Blum, 2004; Lykos & Varga, 1997; Miettinen & Hultanan, 1996; Rigout, Lemosquet, Van Eys, Blum, & Rulquin, 2002).

Estimated peak production value increased with increase in the levels of concentrate supplementation, but the increase was not significant (P > 0.05). The beginning production (a) was not significantly affected (P > 0.05) by treatment, but a numerical increase of 45 – 55% was observed in the goats fed at higher level of supplementation (2% C or 2.5% C) compared to the goats fed at lower levels. This observation is at variance with previous reports (Horan et al., 2005 and Min et al., 2005) where the beginning production and peak production were significantly affected by the level of concentrate supplementation.

Fig 1 shows the fitted lactation curve of the goats using the parameters generated from the Wood’s model. From the Figure, the milk production levels of goats in treatments 2% C and 2.5% C were, all throughout the 20-week lactation period, higher than those of animals in 1% C and 1.5% C treatments. It was goats in groups 1.5% C, 2% C and 2.5% C that had noticeable peak period at week 3, 4 and 3.5, respectively, with corresponding daily peak production values of 540 mL, 720 mL and 830 mL. Whereas the goats in the rest of the treatments showed typical lactation curve shape, the ones in 1% C group showed atypical lactation curve as there was no peak period in that the peak production was also the production at beginning of lactation at week 1. The ability of nutrition to affect the shape of lactation curve has been demonstrated in this study. The goats which received 2% C appeared to be more persistent with a relatively flatter curve. Goats receiving concentrate mixture at 1% level leading to lower intake of critical nutrients (Otaru et al., 2016) had atypical lactation curve with steep slope owing to two of the goats in the 1% C treatment group having negative values of ‘b’, the rate of rise to the peak yield, which resulted in the beginning production being also the peak yield. The present result is in agreement with the report of Wahome, Carles, & Schwartz (1994) who observed that Small East African goats on poor vegetation had flat or straight curve where the values of ‘b’ approached 0 and ‘c’ large and negative, compared to those on better vegetation with typical lactation curves.
Mean daily weight gain of pre-weaning suckled kids and their dams fed varying levels of supplementary concentrate mixture .

| Parameter                  | Concentrate mixture level (g/kg LW) | SEM | Concentrate level effect, P<0.05 |
|----------------------------|-------------------------------------|-----|----------------------------------|
| **Dams**                   |                                     |     |                                  |
| Final liveweight (kg)      | 26.92<sub>a</sub> 26.24<sub>b</sub> 27.07<sub>b</sub> 29.77<sub>b</sub> | 0.86 | 0.05 0.05 NS                  |
| Initial liveweight (kg)    | 31.13 27.10 27.13 27.30 | 2.28 | NS NS NS                     |
| Total weight change (kg)   | -1.14<sub>a</sub> -1.82<sub>b</sub> -0.98<sub>b</sub> 1.71<sub>a</sub> | 0.86 | 0.05 0.05 NS                  |
| Average daily gain (ADG) (g) | -7.40<sub>b</sub> -11.81<sub>a</sub> -6.34<sub>b</sub> 11.11<sub>a</sub> | 5.42 | 0.05 0.05 NS                  |
| **Kids**                   |                                     |     |                                  |
| Weaning weight (kg)        | 4.30<sub>a</sub> 5.93<sub>b</sub> 6.00<sub>b</sub> 7.26<sub>a</sub> | 0.52 | 0.01 0.01 0.01 0.01            |
| Birth weight (kg)          | 1.83 1.52 2.02 1.48 | 0.20 | NS NS NS                     |
| Total weight change (kg)   | 2.59<sub>a</sub> 4.21<sub>a</sub> 4.28<sub>a</sub> 5.54<sub>a</sub> | 0.52 | 0.01 0.01 0.01 0.01            |
| Pre-weaning ADG (g)        | 26.37<sub>a</sub> 42.92<sub>b</sub> 43.68<sub>b</sub> 56.49<sub>a</sub> | 5.31 | 0.01 0.01 0.01 0.01            |

a,b Means within the same row bearing different superscript letters differ significantly (P<0.05).

LW = Liveweight, L = Linear, Q = Quadratic, C = Cubic, NS = Not Significant (P>0.05).
3.6. Rumen and blood metabolites

The least squares means of rumen ammonia nitrogen, total volatile fatty acids (VFA), ruminal pH and monthly serum concentrations of glucose, urea-nitrogen and cholesterol are presented in Table 7. Increasing the level of concentrate supplementation did not significantly (P>0.05) affect the postprandial (after feeding) concentrations of rumen ammonia nitrogen, total VFA and pH values (Table 7). However, goats fed at higher concentrate levels exhibited numerically lower concentrations of the metabolites. The postprandial rumen ammonia concentrations obtained in this study fall within the range of 61 to 347 mg/L earlier reported for Alpine and Saanen goats (Archimède, Sauvant, Hervieu, Ternois, & Poncet, 1996; Fernandez, Sahlu, Lu, Ivey, & Potchoiba, 1997). Total VFA concentrations postprandial are comparable to the range of 67 to 109 mM/L reported for Alpine and Saanen goats (Archimède et al., 1996; Serment, Schmidely, Giger-Reverdin, Chapoulot, & Sauvant, 2011).

Total volatile fatty acids concentration before feeding (preprandial) was significantly (P<0.05) lower in goats fed at higher levels of supplementation compared with those fed at lower levels, whereas the associated pH values were significantly (P<0.05) higher in goats receiving concentrate at 2.0 and 2.5% levels than their counterparts at 1.0 and 1.5% levels. The explanation for higher levels of VFA at lower levels of concentrate supplementation is that those animals exposed to higher concentrate supplementation for about 5 months would have had more developed ruminal papillae and large surface area to absorb more volatile fatty acids soon after they were produced. It has been reported that lambs exposed to high concentrate diet developed more ruminal papillae than those not exposed (Ortega-Reyes, Provenza, Parker, & Hatfield, 1992) and this takes 4 – 7 weeks in adult cows to develop fully following ingestion of high starchy concentrates (Dirksen, Liebich, & Mayer, 1985; Mayer, 1986). The apparent linear decrease in the postprandial pH values with increase in concentrate level consumed attest to higher amounts of fermentable carbohydrate (starch) degraded at 2.0%C and 2.5%C diets. Zervas et al. (1999) observed non-significant decrease in ruminal pH values with increased consumption of starchy concentrate.

Levels of concentrate supplementation did not have significant (P>0.05) effect on the concentrations of blood metabolites. However, glucose concentration, numerically, showed a consistent increase from

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### Table 7

Mean rumen and blood metabolites of lactating Red Sokoto goats fed varying levels of supplementary concentrate mixture .

| Parameter                        | Concentrate mixture level (g/kg LW) | SEM | Concentrate level effect, P< |
|----------------------------------|-------------------------------------|-----|------------------------------|
|                                  | 1%C | 1.5%C | 2%C | 2.5%C | L | Q | C |
| **Rumen metabolites and pH**     |      |        |      |        |   |   |   |
| Rumen ammonia nitrogen (mg/L)    |      |        |      |        |   |   |   |
| Before feeding                   | 188.17 | 197.13 | 156.80 | 138.88 | 36.27 | NS | NS | NS |
| After feeding                    | 264.32 | 264.32 | 255.36 | 228.29 | 17.06 | NS | NS | NS |
| Volatile fatty acids (Mmol/L)    |      |        |      |        |   |   |   |
| Before feeding                   | 102.69<sup>a</sup> | 110.43<sup>a</sup> | 70.47<sup>b</sup> | 71.82<sup>b</sup> | 7.91 | 0.05 | 0.05 | NS |
| After feeding                    | 112.87 | 107.06 | 90.19 | 103.15 | 12.40 | NS | NS | NS |
| Rumen pH values                  |      |        |      |        |   |   |   |
| Before feeding                   | 7.03<sup>b</sup> | 6.95<sup>b</sup> | 7.30<sup>a</sup> | 7.28<sup>a</sup> | 0.07 | 0.05 | 0.05 | NS |
| After feeding                    | 6.93 | 6.63 | 6.65 | 6.50 | 0.13 | NS | NS | NS |
| **Blood metabolites (Mmol/L)**   |      |        |      |        |   |   |   |
| Glucose                          | 3.06 | 3.20 |      |      | 0.18 | NS | NS | NS |
| Urea-nitrogen                    | 3.12 | 2.96 | 4.67 | 3.68 | 0.43 | NS | NS | NS |
| Cholesterol                      | 3.95 | 3.05 | 3.96 | 3.57 | 0.28 | NS | NS | NS |

<sup>a,b</sup> Means within the same row bearing different superscript letters differ significantly (P<0.05).

L = Linear, Q = Quadratic, C = Cubic, NS = Not Significant (P>0.05).
3.06 to 3.26 mM/L with the level of supplementation while the urea-nitrogen and cholesterol concentrations did not follow any definite pattern (Table 7). The non-significant increase in glucose concentration as the level of concentrate fed increased, contradicts previous reports on goats ([Mba et al., 1980; Min et al., 2000; Serment et al., 2011]) where increase in level of concentrate fed significantly increased serum glucose concentrations. The values of serum glucose concentrations of 3.06 – 3.26 mM/L (55.08 – 58.68 mg/dL) recorded in this experiment are higher than 26.6 to 50.92 mg/100 mL recorded for the Red Sokoto goats (Mba et al., 1980), but comparable to 51.9 to 62.7 mg/dL recorded for Italian goats (Rubino, Moioli, Fedele, Pizzillo, & Morand-Fehr, 1995).

It was expected that increased consumption of concentrate leading to increased consumption of energy would significantly reduce serum urea nitrogen concentrations as reported for lambs (Daura & Reid, 1991), dairy goats (Min et al., 2005) and dairy cows (Lykos, Varga, & Casper, 1997), but the result of this study is in variance with the findings of these authors. Serum urea-nitrogen concentrations were instead non-significantly increased at higher levels of supplementation compared to lower levels. Reist et al. (2003) and Loor et al. (2005) increased the level of concentrate fed to lactating dairy cows and did not observe any significant effect on serum total cholesterol concentrations. This was confirmed by the present study on lactating goats. The diet fed to the goats contained 4% palm oil. It was expected that goats offered high amount of concentrate would consume more of the palm oil or fat that would result in elevated serum level of cholesterol (Oturu et al 2011; Tudisco et al., 2019), but the goats in all the four groups had similar cholesterol levels.

4. Conclusion

It is concluded that concentrate mixture containing 4% palm oil can be fed at 2.0% of body weight to lactating Red Sokoto goats. The diet fed to the goats contained 4% palm oil. It was expected that goats offered high amount of concentrate would consume more of the palm oil or fat that would result in elevated serum level of cholesterol (Oturu et al 2011; Tudisco et al., 2019), but the goats in all the four groups had similar cholesterol levels.

5. Ethical statement

The protocol and procedures used in this study were in accordance with the guidelines given by the committee on Animal Use and Care of the Ahmadu Bello University, Zaria, Nigeria (with an Approval No: ABUCAUC/2020/007).

Declaration of Competing Interest

The authors declare that there are no conflicts of interests in the study carried out and being reported in this paper.

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