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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 smutsii* 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 ($P < 0.05$) milk fat 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, Andersson and Emanuelson (1993) and Havrevoll, Rajbhandari, Eik 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, Osuji, Umunna, & Crosse, 1994; Malau-Aduli, Eduvie, Lakpini, & Malau-Aduli, 2004; Min, Hart, Sahlu, & Satter, 2005). Gustasfsson *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 (Wangsness & 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

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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 (Otchere *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 authours 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 11º 11′N and Longitude 7º 34′E, and is 640 m above the sea level (Dada, Jibrin, & Ijeoma, 2006).

2.2. Animals, design of experiment and diets

Twenty 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%C, 1.5%C, 2.0%C and 2.5%C, 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%C, 1.5%C, 2.0%C and 2.5%C, respectively.

The feeding time was at 09:00 h after cleaning the pens, and the orts 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. Fortnightly weights of dams and their kids were taken and quantity of feeds offered adjusted accordingly for the dams.

Table 1
Chemical composition of concentrate mixture and grass hay.

Chemical Composition (%DM)	Concentrate mixture	*Digitaria smutsii* hay
Organic matter	85.91	88.73
Crude protein	16.30	5.40
Crude fibre	16.24	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_l MJ/kg DM)[1]	5.80	4.18

[1] NE_l 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 postpartum 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 (-20^0 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 H_2SO_4 saturated with $MgSO_4$ to acidify, de-proteinize and reduce bacteria activity. This mixture was allowed to stand for 10 min and then centrifuged at 3000 rpm for 10 min. Twenty millilitres of the supernatant was then decanted into plastic bottle and kept in a deep freezer (-20° C) until analysed for total volatile fatty acids (VFAs) and rumen ammonia-nitrogen (NH_3-N).

2.6. Chemical analysis

The dried samples of the feeds (concentrates and hay) were ground through 1 mm sieve and further dried at 105° C for two hours to determine the dry matter. The nitrogen in the milk and dried samples of the feeds was determined according to Kjeldahl procedure (AOAC, 1980), while the neutral detergent fibre (NDF) and acid detergent fibre (ADF) of feeds were determined according to the procedure of Goering and Van Soest (1970). The AOAC (1980) procedures were followed to determine the ash content of the feeds and milk samples, and also the crude fibre (CF) and ether extract (EE) for feeds. The samples were ashed by charring in a Muffle furnance at 500° C for about three hours or until a whitish ash remained.

Milk fat was determined according to the method of Gerber (1960). The Gross energy content of the diets was determined using ballistic bomb calorimeter (Gallenkamp). Rumen ammonia nitrogen (NH_3-N) was determined by steam distillation method as described by Markham (1942). Volatile fatty acids (VFAs) were also determined by steam distillation according to the procedure described by AOAC (1980). Blood glucose was determined by the glucose oxidase method as described by Tinder (1969) and blood urea by the method of Marsh, Fingerhut and Miller (1965). Blood cholesterol was determined by the method of Abel, Levy, Brodie and Kendall (1952).

2.7. Calculations and statistical analyses

Four-percent Fat corrected milk (FCM) was calculated according to the equation: 4% FCM = Milk yield (0.3925 + 0.1815% fat in milk) (Gaines and Davidson, 1923).

Non-structural carbohydrate concentrations of the diets was estimated by equation: OM - (CP% + NDF% + ether extract%) (Arieli, Sasson-Rath, Zamwel, & Mabjeesh, 2005).

The procedures of AOAC (1980) and Christian (1980) were followed to derive dilution factors used for determining the concentrations of VFA and ammonia nitrogen in rumen fluid. The titre value of 0.01 M NaOH solution, which was titrated against an aliquot of rumen fluid containing VFAs was used in the equation: 1 ml of 0.01 M NaOH = 0.01 mmoles of VFA, to derive the concentrations of total VFA expressed in millimoles per litre of rumen fluid. Also, the titre value of 0.02 N HCl solution titrated against an aliquot of rumen fluid containing NH_3-N was used in the equation: 1 ml of 0.02 N HCl = 0.28 mg NH_3-N, to derive the concentrations of NH_3-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:

$Y_t = at^be^{-ct}$, where Y_t = 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 Marquardt 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) = $-(b+1)\log_e c$; Peak Production = $a(b/c)^be^{-b}$; 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 GPLOT 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: $Y_{ij} = \mu + t_j + e_{ij}$, where Y_{ij} is the response of animal i in treatment j (i = 1,2,3,4,5), μ is the overall mean, t_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, version 9.0). The statistical model used is: $Y_{ijk} = \mu + t_j + b_i + p_k + tp_{jk} + e_{ijk}$, where, Y_{ijk} is the response of animal i in treatment j at time k, μ is the overall mean, t_j is a fixed effect of the jth treatment (j = 1, 2, 3, 4), b_i is the random effect of the ith animal (i = 1, 2, 3, 4, 5) nested within the jth treatment, p_k is the fixed effect of kth time (k = 1, 2, ……..,20), tp_{jk} is the interaction between the jth treatment and the kth time, e_{ijk} is the random error.

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 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, $Y_i = \beta_0 + \beta_1T_i + \beta_2S_i + \beta_3M_i + \beta_4BW_i + \beta_5T_i{*}BW_i + \beta_6S_i{*}BW_i + \varepsilon_i$, where Y_i is the i^{th} observation for the dependent variable Y (ADG, average daily gain), i = 1,2,3,……,15, T_i is the i^{th} observation for the independent variable T (Type of birth, single or twin), i = 1,2,3,……,15, S_i is the i^{th} observation for the independent variable S (Sex; male or female), i = 1,2,3,……,15, M_i is the i^{th} observation for the independent variable M (Average daily milk yield of dam), i = 1,2,3,……,15, BW_i is the i^{th} observation for the independent variable BW (Birth weight of kids), i = 1,2,3,……,15, $T_i{*}BW_i$ is the i^{th} observation for the interaction between T_i and BW_i, $S_i{*}BW_i$ is the i^{th} observation for the interaction between S_i and $BW_{i,}$ ε_i is the residual error for observation i, and β_0, β_1,….β_6 are regression parameters, and β_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 - 17.38T*BW + 24.84S*BW. The equation resulted in higher estimate of ADG for twin-born kids compared to single-born kids. This was considered unconventional and was attributed to the fact that dams, which kidded twins were 10 in number compared to 5 dams that kidded single kids. Single-born kids are usually heavier than twin-born kids. In fact, the effects of type of birth and sex of the kids were not significant. They were, therefore, dropped from the model and kid ADG regressed only on dams' milk yield using birth weight as a covariate with following model $Y_i = \beta_0 + \beta_1M_i + \beta_2BW_i + \varepsilon_i$, where $Y_{i,}$ M_i,$BW_{i,}$ ε_i, $\beta_{0,}$ β_1 and β_2 are as described above. For this model, the ADG and birth weights of the twin-born kids were each added to get a single ADG or birth weight value for the dam.

3. Results and discussion

3.1. Voluntary feed intake

The daily intakes of dry matter (DM) and water, and concentrate to hay consumption ratio of the goats fed varying levels of concentrate mixture are presented 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 intakes 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 (Dønnem, Randyby, & Eknæs, 2011), Afalfa 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 <		
	1%C	1.5%C	2%C	2.5%C		L	Q	C
Dry matter intake, g/d								
Hay	712..56	637.13	571.04	678.49	57.71	NS	NS	NS
Concentrate	270.87^c	359.69^{bc}	474.00^b	643.77^a	27.89	0.0001	0.0001	0.0001
Total dry matter Intake	983.43^b	996.82^b	1045.04^{ab}	1322.26^a	76.23	0.01	0.01	0.05
Dry matter intake/kgW$^{0.75}$	81.16^b	88.27^b	92.10^b	110.17^a	4.20	0.0003	0.0003	0.001
Dry matter intake as % of BW	3.54^b	3.94^b	4.11^{ab}	4.82^a	0.18	0.0003	0.0003	0.001
Concentrate : hay ratio	0.40^c	0.59^{bc}	0.86^{ab}	1.05^a	0.07	0.0001	0.0001	0.0001
Water intake (l/d)	1.94	2.00	2.50	2.74	0.45	NS	NS	NS

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 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 (Eknæs and Skeie, 2006; Malau - Aduli *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 (Sangaré & 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 (Steinhour & 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 <		
	1%C	1.5%C	2%C	2.5%C		L	Q	C
Milk yield								
Total lactation yield in 20 weeks (L)	57.00^{ab}	54.11^{b}	78.88^{ab}	84.04^{a}	10.40	0.03	0.03	NS
Daily milk yield (ml)	404.09^{b}	386.52^{b}	574.45^{a}	600.31^{a}	62.33	0.02	0.02	NS
4% FCM (ml)	315.51^{b}	362.88^{b}	515.75^{ab}	625.97^{a}	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 composition (%)								
Total Solids	13.06	15.27	14.26	15.91	0.92	NS	NS	NS
Milk fat	2.58^{b}	3.44^{ab}	2.93^{ab}	3.94^{a}	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	9.90^{b}	13.48^{b}	17.31^{ab}	25.10^{a}	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).
₦360 = 1USD. ₦ is Naira, the Nigerian Currency.

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 & Mantzios, 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, & Fernig, 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, & Chanpongsang, 2004; Miller *et al.*, 2006) with

Table 4
Mean milk yield and composition by stage of lactation of Red Sokoto goats fed varying levels of supplementary concentrate mixture .

Parameter	Early lactation (EL = 42 d)					Mid lactation (ML = 42 d)					Late lactation (LL = 56 d)					SEM	Stage of lactation effect		
	1.0%C	1.5%C	2.0%C	2.5%C	ELM	1.0%C	1.5%C	2.0%C	2.5%C	MLM	1.0%C	1.5%C	2.0%C	2.5%C	LLM		ELM vs MLMP <	ELM vs LLM P <	MLM vs LLM P <
Milk yield (ml/d)	510.00	511.33	754.80	795.67	642.95	458.33	442.67	677.40	687.33	566.43	283.97	250.80	422.78	388.53	336.52	37.24	0.05	0.0001	0.0001
4 % FCM (ml/d)	333.69	431.07	615.27	726.52	526.64	357.77	431.83	516.90	743.04	512.38	255.07	225.75	415.06	408.34	326.06	49.41	NS	0.01	0.05
Composition (%)																			
TS %	11.01	14.19	12.11	13.17	12.62	11.52	13.27	12.90	15.26	13.23	16.65	18.34	17.79	19.30	18.02	0.60	NS	0.0001	0.0001
Fat %	1.71	2.98	2.53	3.41	2.66	2.63	3.99	2.62	4.40	3.41	3.41	3.36	3.65	4.01	3.61	0.38	NS	NS	NS
Protein %	5.47	5.02	5.95	4.40	5.21	6.40	6.68	4.87	7.52	6.37	4.87	5.38	4.90	5.05	5.05	0.32	NS	NS	0.05
SNF %	9.30	11.21	9.60	9.76	9.96	8.90	9.30	10.26	10.86	9.82	13.23	14.98	14.14	15.29	14.41	0.63	NS	0.0001	0.0001
Component yield (g/d)																			
Fat yield (g/d)	8.65	15.10	20.83	27.22	17.95	11.63	16.98	16.40	31.21	19.05	9.43	8.40	14.70	16.86	12.34	2.49	NS	0.05	NS
Protein yield (g/d)	28.70	25.45	41.44	35.16	32.69	30.58	28.61	32.83	51.73	35.94	14.00	13.32	19.44	19.31	16.52	2.40	NS	0.0001	0.0001

EL = early lactation, ML = mid-lactation, LL = late lactation, TS = total solids, SNF = solids-not-fat, NS = Not significant ($P > 0.05$), SEM = standard error of mean for lactation stage or period, d = days
ELM = mean of early lactation milk production across treatments
MLM = mean of mid-lactation milk production across treatments
LLM = mean of late lactation milk production across treatments.

attendant lower milk yield (Chaiyabutr et el., 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 (Djibrillou *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 reduced udder 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
Estimates of persistency of milk production and other lactation parameters of Red Sokoto goats fed varying levels of supplementary concentrate mixture .

Concentrate level	a	b	c	s	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
Concentrate Level effect, P <						
L	NS	NS	NS	NS	NS	NS
Q	NS	NS	NS	NS	NS	NS
C	NS	NS	NS	NS	NS	NS

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 week 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; Sölknera & Fuchsb, 1987). According to Sölknera and Fuchsb (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 3).

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 & Huhtanen, 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.

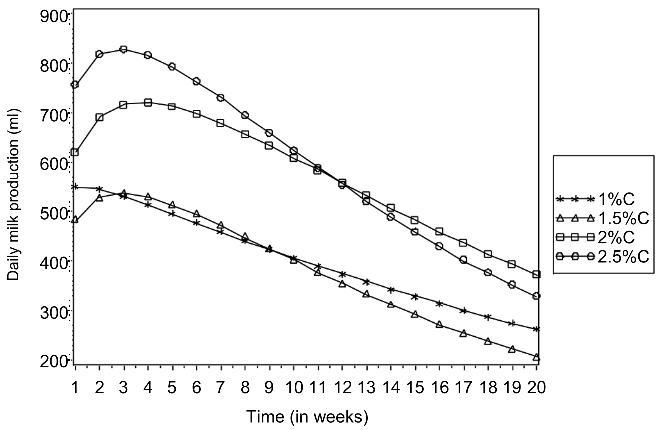

Fig. 1. Lactation curves of Red Sokoto goats fed varying levels of concentrate mixture 1.0%C = Concentrate supplementation at 1% of body weight. 1.5%C = Concentrate supplementation at 1.5% of body weight. 2.0%C = Concentrate supplementation at 2.0% of body weight. 2.5%C = Concentrate supplementation at 2.5 % of body weight.

3.5. Postpartum weight changes of does and pre-weaning growth rate of kids

The least squares means of postpartum liveweight changes of lactating does and the pre-weaning average daily gain of suckled kids are shown in Table 6. The values of liveweight changes for the goats receiving the diet at feeding levels of 1%C, 1.5%C or 2%C were all negative and comparable to each other. Their counterparts in group 2.5%C gained body weight with significant ($P < 0.05$) increase of ADG of 17 g over that of the group (2%C) next in liveweight performance. The post-partum bodyweight change and average daily gain increased linearly with the level of concentrate offered. This finding supports earlier observation on body weight gain of goats (Havrevoll *et al.*, 1995; Malau-Aduli *et al.*, 2004) fed increased level of concentrate. It, however, disagrees with results of similar work on dairy cows (Drackley *et al.*, 2003) and Senegalese Sahel goat (Cissé *et al.*, 2002) where the treatment effect was not significant even though animals offered higher concentrate level exhibited better weight gains. Drackley *et al.* (2003) explained that the Latin square design with 28-d periods used were not sufficiently sensitive to detect diet induced changes in body weight or body condition score. Completely randomized design was used in the present experiment which comparatively lasted for a longer period (20 weeks).

The weaning weights of the kids ranged from 4.30 to 7.26 kg and their corresponding values for pre-weaning ADG were 26.37 to 56.49 g. For both parameters, the kids exhibited significant ($P < 0.01$) linear, quadratic and cubic responses to the concentrate feeding level of the dams. Whereas kids in treatments 1.5% C, 2.0% C and 2.5% C had similar performance, those in treatment 1% C had lower performance than those in treatment 2.5% C ($P < 0.01$) and other treatments ($P < 0.05$). Kids suckling dams which produced the most milk supposedly consumed the most milk and gained the most weight (Tables 3 and 6) despite having the least birth weight. This finding agrees with previous reports on sheep (Purroy & Jaime, 1995) and goats (Malau-Aduli *et al.*, 2004) where diets offered nursing dams significantly affected pre-weaning growth rate of their offspring through marked effect on milk production. However, our observation conflicts with other reports (Al Jassim *et al.*, 1999; Cissé *et al.*, 2002). Al Jassim *et al.* (1999) in particular, found that increased level of concentrate supplementation affected milk yield but did not significantly affect pre-weaning growth rate of lambs.

The regression of kids pre-weaning ADG on dam milk yield with birth weight as a covariate shows that the ADG of kids had significant ($P < 0.01$) dependence on dam yield which accounted for 61% of variation in the ADG of the kids. The regression equation is:-

$Y = -22.58 + 0.123X + 4.44Z + \varepsilon$; ($P < 0.01$; adj. $R^2 = 0.6085$; dependent mean = 59.87 g), where Y = pre-weaning ADG; X = average daily milk yield of dam, and Z = birth weight of kids, and ε = random error. The result of the present study supports the observation of Warmington and Kirton (1990) that growth of suckling kids is highly dependent on milk intake, but disagrees with those of Pralomkarn, Saithanoo, Milton, Praditrungwatana and Kochapakdee (1991) who did not find any significant correlation between milk availability and the growth rate of Thai native goat kids from one to six weeks of age. The proportion of variation in pre-weaning ADG accounted for by dam milk yield in the present study is higher than the range of 22 – 32% earlier reported for the same breed of goat (Ehoche & Buvanendran, 1983).

The range of weaning weight at 98 days and pre-weaning average daily gain obtained in this study are comparable to the corresponding values of 4.01 – 6.25 kg and 33.11 – 53.88 g earlier reported for Red Sokoto goat kids weaned at 90 days (Malau-Aduli *et al.*, 2004) but lower than 7.56 kg and 66.43 g for the same breed of goat kids weaned at 12 weeks (84 days) of age (Ehoche & Buvanendran, 1983). Figure 2 shows the fortnight pre-weaning liveweights of kids. All the kids exhibited consistent weight increase with advancing age up to weaning in a curvilinear manner. The kids of dams supplemented at 2.5% level consistently showed superiority in liveweight gain over other kids, the least of which were the kids of the dams supplemented at 1.0% level. While the kids of treatment groups, 1.5% and 2.0%C, had similar weight response throughout, those of the 1.0% treatment group distinctly had the least response. Generally, the pattern of pre-weaning growth response curve is similar to that reported for Rasa Aragonesa lambs in Spain (Purroy & Jaime, 1995) where diets ensuring two levels of ME intakes with two protein sources (Fish meal and Soya bean cake) enhanced fast pre-weaning growth rate but more so with the fish meal protein source.

Table 6
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<		
	1%C	1.5%C	2%C	2.5%C		L	Q	C
Dams								
Final liveweight (kg)	26.92^b	26.24^b	27.07^b	29.77^a	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^b	-1.82^b	-0.98^b	1.71^a	0.86	0.05	0.05	NS
Average daily gain (ADG) (g)	-7.40^b	-11.81^b	-6.34^b	11.11^a	5.42	0.05	0.05	NS
Kids								
Weaning weight (kg)	4.30^b	5.93^a	6.00^a	7.26^a	0.52	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)	2.58^b	4.21^a	4.28^a	5.54^a	0.52	0.01	0.01	0.01
Pre-weaning ADG (g)	26.37^b	42.92^a	43.68^a	56.49^a	5.31	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 ($P > 0.05$).

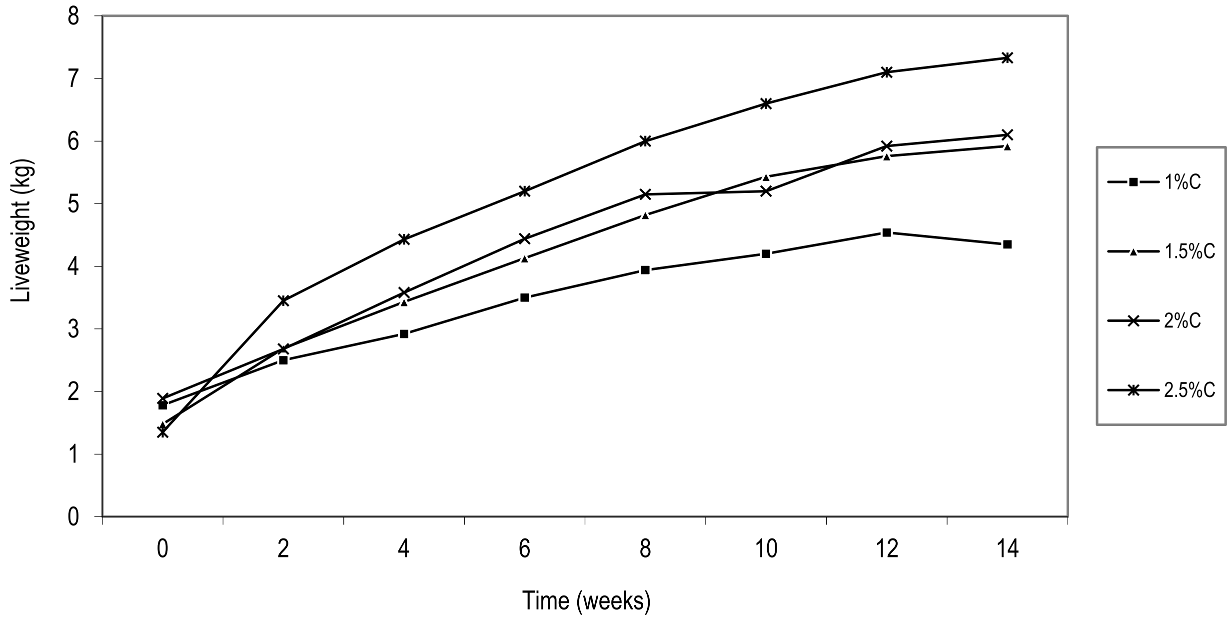

Fig. 2. Pre-weaning fortnight weights of kids of Red Sokoto goats fed varying levels of concentrate mixture 1.0%C = Concentrate supplementation at 1% of body weight 1.5%C = Concentrate supplementation at 1.5% of body weight 2.0%C = Concentrate supplementation at 2.0% of body weight 2.5%C = Concentrate supplementation at 2.5 % of body weight.

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

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^a	110.43^a	70.47^b	71.82^b	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^b	6.95^b	7.30^a	7.28^a	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

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 ($P > 0.05$).

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 at variance with the findings of these authours. 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 (Otaru 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 2.5% of body weight without adverse effect on hay intake while enhancing dry matter intake, postpartum weight gain and higher milk yield with considerable persistency of milk production in Red Sokoto goats. Feeding the concentrate mixture at 2.0 or 2.5% of body weight also enhanced the support or influence of dam's milk yield on pre-weaning growth rate of the kids. However, it is recommended that for the efficiency of milk production and the least cost per kilogramme of milk produced, the concentrate mixture used in this study should be fed at the 2.0% of bodyweight to lactating Red Sokoto goats.

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

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