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Performance of Yankasa Weaner Rams Fed Roughage and Concentrate Supplement at Different Sequences and Intervals

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Abstract

The production and productivity of small ruminant in humid West Africa is being limited by feed constraints, which are largely due to non-strategic utilization and combination of available feed resources to develop an efficient production feeding system, rather than absolute non availability. Farmers under semi-intensive system commonly offer feed supplements to their animals in the morning before grazing fibrous grasses all day. However, results of rumen degradability studies suggested that this system should be the opposite. This study was designed to investigate the effect of changing the sequence and interval of feeding concentrate supplement (CS) and roughage on performance of Yankasa weaner rams. A 90-day feeding trial was conducted using twenty eight 5-6 months old Yankasa weaner rams with average body weight of 14.96 ± 1.10 kg. The rams were randomly assigned to four treatments (CB1: CS fed 1 h prior to feeding grass hay (GH); CB2: CS fed 2 h prior to feeding GH; GB1: GH fed 1 h before feeding CS; and GB2: GH fed 2 h before feeding CS) using a 2x2 factorial arrangement in a randomized complete block design (RCBD). The rams were fed woolly finger grass (Digitaria smutsii Stent) hay and CS at the rate of 2.4% and 1.6% of body weight, respectively, and offered water ad libitum. **.** *Blood collection was done at four weeks interval pre- feeding and 4 h post- second feeding. Rumen fluid was collected pre- feeding and 3 h post-second feeding during the last week of feeding trial. Parameters measured include dry matter intake (DMI), total weight change, Average daily gains (ADG), Total volatile fatty acids (VFAs), ruminal pH values, and Blood creatinine levels. DMI was significantly ($P < 0.05$) affected by the interval of the feeding. The total weight change of GB2 and CB2 rams was significantly ($P < 0.01$) higher than that of CB1 and GB1 rams. ADG among treatments were affected ($P < 0.05$) by feeding interval. VFAs and ruminal pH values of the rams 3 h post-feeding were affected ($P < 0.05$) by the interval of feeding CS and GH. Pre-feeding blood creatinine levels and 4 h post-feeding, were also significantly ($P < 0.05$) affected by interval of feeding GH and CS. It is concluded that, even though, feed intake and growth rate of Yankasa rams were not markedly affected by the sequence as much as interval of feeding CS and GH, the GB2 rams had higher ADG and better feed efficiency.*

Key words: sequence, interval, concentrate supplement, roughage, rams

Performance de Yankasa Weaner Rams a nourri un brouillage et un supplément de concentré à différentes séquences et intervalles

Résumé

La production et la productivité des petits ruminants en Afrique de l'Ouest humide sont limitées par des contraintes alimentaires, qui sont en grande partie dues à une utilisation non stratégique et à une combinaison des ressources alimentaires disponibles pour développer *un système d'alimentation de production efficace, plutôt qu'à une indisponibilité absolue. Les éleveurs sous système semi-intensif offrent couramment des compléments alimentaires à leurs animaux le matin avant de faire paître des herbes fibreuses toute la journée. Cependant, les résultats des études de dégradabilité dans le rumen suggèrent que ce système devrait être le contraire. Cette étude a été conçue pour étudier l'effet de la modification de la séquence et de l'intervalle d'alimentation du supplément concentré (SC) et du fourrage grossier sur les performances des béliers sevrés Yankasa. Un essai d'alimentation de 90 jours a été mené sur vingt-huit béliers sevrés Yankasa âgés de 5 à 6 mois et pesant en moyenne 14,96 ± 1,10 kg. Les béliers ont été assignés au hasard à quatre traitements (CB1 : SC nourris 1 h avant l'alimentation avec du foin d'herbe (GH) ; CB2 : CS alimentés 2 h avant l'alimentation avec GH ; GB1 : GH nourris 1 h avant l'alimentation avec CS ; et GB2 : GH nourris 2 h avant d'alimenter SC) en utilisant un arrangement factoriel 2x2 dans une conception en bloc complet randomisé (CBCR). Les béliers ont été nourris avec du foin et du SC à raison de 2,4 % et 1,6 % du poids corporel, respectivement, et ont reçu de l'eau à volonté. La collecte de sang a été effectuée à quatre semaines d'intervalle avant l'alimentation et 4 heures après la deuxième alimentation. Le liquide du rumen a été recueilli avant l'alimentation et 3 h après la deuxième alimentation au cours de la dernière semaine de l'essai d'alimentation. Les paramètres mesurés comprennent l'apport en matière sèche (AMS), le changement de poids total, les gains quotidiens moyens (GQM), les acides gras volatils totaux (GVT), les valeurs de pH ruminal et les niveaux de créatinine sanguine. Le DMI était significativement (P < 0,05) affecté par l'intervalle d'alimentation. Le changement de poids total des béliers GB2 et CB2 était significativement (P < 0,01) supérieur à celui des béliers CB1 et GB1. Le GQM parmi les traitements a été affecté (P < 0,05) par l'intervalle d'alimentation. Les valeurs de GQM et de pH ruminal des béliers 3 h après l'alimentation ont été affectées (P < 0,05) par l'intervalle d'alimentation de CS et de GH. Les niveaux de créatinine sanguine avant l'alimentation et 4 h après l'alimentation ont également été significativement (P < 0,05) affectés par l'intervalle d'alimentation GH et CS. Il est conclu que, même si la prise alimentaire et le taux de croissance des béliers Yankasa n'étaient pas nettement affectés par la séquence autant que par l'intervalle d'alimentation CS et GH, les béliers GB2 avaient un GQM plus élevé et une meilleure efficacité alimentaire.*

Mots-clés : séquence, intervalle, supplément de concentré, fourrage grossier, béliers

Introduction

Productivity of small ruminants in many tropical areas is often poor because they are subjected to various kinds of diseases, feeding and housing management techniques. Several survey reports (Ademosun, 1994; Aliyu *et al*., 2005; Shiawoya and Tsado, 2011) indicated that small holder farmers that own over 70% of the livestock population in sub-Saharan Africa offer their stocks little or no supplementary feed. Several works had shown that young animals raised on forages alone had lower daily gains, dressing percentage and carcass quality than those supplemented with concentrate (Warmington and Kirton 1990; Johnson and McGowan 1998; Kosum *et al*., 2003; Johson *et al*., 2005). Concentrate feeds promote rapid growth of sheep and cattle (McDonald *et al*.,1996), increase propionate production and reduce ruminal methane production, thereby lowering energy losses and contributing to higher overall efficiency of utilization of dietary energy for body weight gain, and enhance milk production in lactating dairy cows under grazing conditions (Kolver *et al*., 1998; Mandebvu and Galbraith, 1999).

Increase in level of dietary concentrate was observed to cause increase in milk production in ewes (Zervas *etal*., 1999) and Red Sokoto goats (Otaru, 2009). However, high level of concentrate feeding can cause low ruminal pH (Mould *et al*., 1983; Carro *et al*., 2000), which can decrease forage degradability (Mould *et al.,* 1983; Allen, 1997) and induce clinical ruminal acidosis. The appropriate ratio of concentrate to roughage to be fed to ruminants had been studied (Zervas *et al*., 1999). A ratio of 40:60% concentrate to hay had been recommended (Liu *et al*., 2005). Concentrate supplements by nature are more easily degraded than roughages. Consequently, concentrate supplements fed before feeding roughage degrade rapidly and lower the rumen pH before the buffering effect of roughage fermentation that occurs afterwards sets in.

According to Smith (1992), feed constraints currently limiting small ruminant production and productivity in humid West Africa were, to a large extent, due to a non-strategic utilization and combination of available feed resources, to develop an efficient production feeding system, rather than absolute quantitative and qualitative shortages. It is a common practice that farmers, under semi-intensive system in the forest belt of humid West Africa, offer feed supplements to their animals first thing in the morning before turning them out to graze fibrous grasses all day. However, results of rumen degradability studies suggested that this system should be the opposite, with the rapidly degraded feeds fed late in the afternoon and at night, to better synchronize the release of the energy and nitrogen they contain with those of the less rapidly degraded grasses. There is a need to verify this premise on-farm (Smith, 1992).

Feeding of concentrate supplements subsequent to feeding roughage had been suggested to enhance higher intake of roughages, and increase productivity of animals (Robinson, 1989; Beauchemin, 1992). Nevertheless, work by Robinson (1994) showed that changing the sequence of feeding supplemental grain relative to forage-based mixed ration did not improve or modify the productivity of primiparous cows. Earlier experiments investigated the influence of changing the sequence of feeding concentrate supplements and roughages on the performance of ruminants fed supplement either 1 h (Robinson, 1994; Carro *et al*., 1994) or less than 1 h (Morita and Nishino, 1993; Zeyner *et al*., 2004) before or after feeding the roughage. The time intervals were probably too short for effective degradation of basal ration; hence there is a need for extended time intervals. In addition, there is paucity of information on similar studies with our indigenous small ruminants using the compounded concentrate supplement. Therefore, this study was designed to evaluate the effects of changing the sequence and interval of feeding concentrate supplement and grass hay on performance of Yankasa weaner rams.

Materials and methods

Location of the study

A study, which lasted for 90 days, after two weeks adjustment period, was conducted at the Experimental Unit of the Small Ruminants Research Programme of National Animal Production Research Institute (NAPRI), Ahmadu Bello

University, Shika, Zaria, Nigeria. Shika is located within the Northern Guinea Savannah Zone on latitude 11^0 11'N and longitude $7^0$34'E, and is 640 m above the sea level (Macmillan Nigeria, 2006). Annual rainfall is 1100-1200 mm while mean temperature is about 24.4 ℃ (14.5-39.3 ℃) with the lowest temperature occurring during the early dry season (October-December) while the higher temperatures are experienced during the late dry season (January-March). Drought or dry spells occur occasionally (Osinowo *et al*., 1991; Kallah, 2004; Aregheore, 2009).

Animals and experimental design

Twenty-eight Yankasa weaner rams of average live weight of 14.96 ± 1.10 kg (5-6 months old) were separated from the sheep flock of the Small Ruminant Research Programme, National Animal Production Research Institute. The design was in a randomized complete block with a 2 x 2 factorial arrangement of treatments to evaluate the sequence and interval of feeding concentrate supplement (CS) and roughage on intake and performance. The rams were blocked according to weight and randomly allocated to four treatments to give a total of seven rams per treatment group. The CB1 rams were offered CS 1 h before feeding GH, while CB2 rams were offered CS 2 h before feeding GH. The GB1 rams were given GH 1 h prior to feeding CS, and GB2 rams were given GH 2 h prior to feeding CS.

Experimental diets and management of animals

The experimental diets consisted of woolly finger grass (*Digitaria smutsii*, Stent) hay, and the concentrate mixture compounded to contain 15% CP. The concentrate mixture was composed of maize offal, cottonseed cake, bone meal, and common salt as shown in Table 1. Before the commencement of the trial, the rams were dipped in acaricide solution to control ecto-parasites. The rams were dewormed with a broad spectrum antihelminth (Zambezole®) to control internal parasites. Thereafter, the rams were weighed, and subsequently blocked for weight and randomly assigned to each of the treatment groups.

The rams were housed in individual feeding pens and offered feed. The diets were offered to the rams daily at about 0900 h after the previous day's refusal had been collected and weighed. The hay and CS diets were separately offered at the rate of 2.4 % and 1.6 % of body weight, respectively, to correspond to a ratio of 60% hay: 40% CS. During each feeding time, the CB1 and CB2 rams were offered CS at 1 & 2 h, respectively, before feeding the GH, while the GB1 and GB2 rams were given the GH at 1 &2 h, respectively, before offering the CS. Water was offered *ad libitum* and changed every morning.After an initial adjustment period of 14 d, records were taken of the quantity of feeds offered and refused in order to determine the voluntary feed intake. Fortnightly, weights of the rams were taken and the quantity of feeds offered adjusted accordingly. Initial and final weights of the rams were taken at the beginning and end of the experiment, respectively.

Collection of blood and rumen metabolites

Samples of blood from five rams from each treatment were collected before the commencement of the experiment, and every four weeks after the commencement up to the end of the experiment. Blood collection was done pre-feeding and 4 h post-second feeding. During each collection time, 5 ml of blood was collected from each ram by jugular veni-puncture into test-tube and centrifuged immediately at 3000 rpm for 10 min using MSE minor centrifuge. The serum which had separated from cells was carefully decanted into serum vials. Serum samples were stored in deep freezer (-4°C) before analysis for glucose, urea nitrogen, protein and creatinine within 10 d of collection.

During the last week of the feeding trial, rumen fluid was collected from the rams pre-feeding and 3 h post-second feeding by aspiration method using stomach tube. The rumen fluid was collected into plastic containers, and the pH of the fluid was taken immediately. The collected fluid was strained through muslin cloth before 25 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 and de-proteinize as well as reduce bacteria activity, respectively. This mixture was allowed to stand for 10 minutes and then centrifuged at 6000 rpm for 5 min. Thirty millilitres of the supernatant was then decanted into plastic bottle and kept in deep freezer (-4°C) until analyzed for total volatile fatty acids (VFAs) and rumen ammonia-nitrogen (NH_3-N).

Chemical analysis

The nitrogen in the feed was determined according to AOAC (2000). The feed samples were analyzed for dry matter (DM), crude fibre (CF), ether extract (EE), crude protein (CP) and ash according to standard methods (AOAC, 2000). Analysis of neutral detergent fibre (NDF) and acid detergent fibre (ADF) were done following the procedures of Van Soest *et al*. (1984). Rumen ammonia-nitrogen (NH_3-N) was determined by steam distillation method (Markham, 1942). Volatile fatty acids (VFAs) were also determined by steam distillation according to procedure described by AOAC (2000). Blood metabolites were analyzed using Roche Hitachi 902 Auto-analyzer according to the technique of Leonard (1957).

Calculations and statistical analyses

Non-structural carbohydrate (NSC) concentrations of the diets were estimated using the equation: OM – (CP% + NDF% + ether extract %) (Ariel *et al*., 2005 cited by Otaru *et al*., 2013). The energy contents of the diets were calculated using the method of Alderman (1985); $\text{ME (MJ/kg DM)} = 11.78 + 0.00654\,\text{CP} + (0.000665\,\text{EE})^2 - \text{CF}\,(0.00414\,\text{EE}) - 0.0118\,\text{Ash}$.

Data on daily intake of nutrients, DM, weight gain and blood metabolites, whose values were correlated because of repeated measures, were subjected to analysis of variance (ANOVA) for repeated measure analysis using PROC MIXED procedure of SAS (SAS, 2002). The variables analyzed were subjected to four covariance structures: Compound symmetry (CS), unstructured (UN), first order autoregressive [AR (1)] and autoregressive heterogeneous [ARH (1)]. The covariance that yielded the smallest Akaike's Information Criterion (AIC) was used. The blood parameters before experiment were used as covariates in the analyses. Kenward-Roger correction for degree of freedom was used because the standard errors are linear combinations of variances which cannot be estimated by a single mean square. Moreover, it was used to reduce the probability of type I error.

Data on feed efficiency, rumen metabolites, and pH were analyzed with ANOVA using the General Linear Model (GLM) procedures of the Statistical Analysis systems (SAS, 2002). The treatments means were separated using PDIFF OPTION of SAS with Tukey - Kramer adjustment. Differences between treatment were declared at P<0.05. *The general statistical model* for the analyses is shown below:

$Y_{ijk} = \mu + B_i + S_j + H_k + (SH)_{jk} + E_{ijk}$

Where:

Y_{ijk} = individual observation
μ = overall mean
B_i = effect of the blocks
S_j = effect of i^{th} sequence (before, after)
H_k = effect of j^{th} hour (one hour, two hours)
$(SH)_{jk}$ = Effect of interaction of i^{th} sequence with j^{th} hour
E_{ijk} = Random error

Results

Composition of the diet

The ingredients composition of the concentrate diet is presented in Table 1, while Table 2 shows the chemical composition and metabolizable energy (ME) content of the Woolly finger grass (*Digitaria smutsii*, Stent) hay and the concentrate supplement fed in the study.

Table 1: Ingredient composition of concentrate supplement (%)

Ingredients	Composition (%)
Maize offal	65.60
Cottonseed cake	32.40
Bone meal	1.50
Common salt	0.50
Total	100.00

Table 2: Chemical composition and energy content of the experimental feeds

Parameters (%)	Concentrate supplement	Hay (*D.smutsii*)
Dry matter	92.00	93.50
Crude protein	15.00	7.50
Ether extract	3.14	1.52
Neutral detergent fibre	44.00	68.00
Acid detergent fibre	13.00	45.50
Ash	11.00	7.00
Nitrogen free extract	50.76	35.41
Non-structural carbohydrate	22.36	6.83
Metabolizable energy (ME, MJ/kg DM)	11.09	10.78

ME (MJ/kg DM) = $11.78 + 0.00654CP + (0.000665EE)^2 - CF\ (0.00414EE) - 0.0118A$, where CP = Crude Protein, EE = Ether Extract, CF = Crude Fibre, A = Ash (Alderman, 1985).

Voluntary feed intake

The interval of feeding concentrates and the grass hay had significant (P<0.05) effects on the consumption of the supplement and the hay, while the sequence of feeding did not have any effect (Table 3). The concentrate intake by the rams in CB2 group was significantly (P<0.001) improved by 16% compared to the intake by the rams in CB1 group. The intake of concentrates by rams fed hay 2 h before offering concentrate supplement (GB2) was 3% significantly (P<0.01) less than the intake by rams on hay 1 h before concentrate supplement (GB1). The effect of interval of feeding on hay intake was only observed between GB1 and GB2 rams where the latter group had significantly

($P<0.01$) lower intake by 9%. Neither sequence nor sequence X interval of feeding interactions had significant ($P>0.05$) effect on total DMI but the interval of feeding had significant ($P<0.05$) effect on total DMI and the effect was more marked on total DMI per metabolic liveweight where intake by CB2 rams were significantly ($P<0.001$) higher than those by CB1 rams by 13%.

Live weight changes

In this study, all the rams had positive weight changes (Table 3). The greatest and least mean total weight gains were observed in GB2 and CB1, respectively. The total weight gain was significantly ($P < 0.01$) affected by the feeding interval. Collectively, CB2 and GB2 rams gained more (64.37 %) weight than CB1 and GB1 rams, the gain being more marked ($P<0.001$) between CB1 and CB2 rams. Also, sequence X time interval of feeding interaction significantly affected total weight gain whereby rams which received grass hay 1 h before supplement (GB1) had outstanding improvement ($P<0.01$) in weight gain than rams receiving supplement 1 h before grass hay (CB1). Increasing interval of offering the feeds from 1 h to 2 h significantly ($P<0.05$) affected the ADG of the rams. Collectively, CB2 and GB2 rams gained more (75.80 %) weight than CB1 and GB1 rams, the gain being only significant ($P<0.05$) between CB1 and CB2 rams. Feeding sequence X time interval interaction had no effect ($P>0.05$) on ADG.

Table 3: Feed intake, live-weight change and feed efficiency of Yankasa weaner rams as influenced by sequence and feeding interval of roughage and concentrate supplement

	Feeding sequence							
	Concentrate before grass		Grass before concentrate			Level of significance		
Parameters	CB1	CB2	GB1	GB2	SEM	FS	FI	Interaction
Feed intake(g/d)								
Hay	311.78	325.63	320.72	291.74	28.33	NS	**	NS
Concentrate	209.23	244.18	239.15	232.83	25.46	NS	***	NS
Total DMI	521.01	569.82	559.86	524.57	52.52	NS	*	NS
DMI as %BW	3.38	3.86	3.62	3.64	0.13	NS	**	NS
DMI /kg$W^{0.75}$	66.83	75.33	71.08	70.86	3.24	NS	***	NS
Live weight(kg)								
Initial	15.23	14.81	15.44	14.35	1.64	NS	NS	NS
Final	16.38	17.64	17.79	17.48	1.65	NS	NS	NS
Weight change	1.14	2.83	2.35	2.90	0.32	NS	**	NS
ADG(g/d)	10.26	28.28	23.55	31.13	7.93	NS	*	NS
FE (g gain/kg of feed)	18.29	55.56	35.54	57.39	13.17	NS	P= 0.06	NS

ADG=average daily weight gain, BW=body weight, FE=feed efficiency, NS=not significant ($P>0.05$), SEM=standard error of the means, *= significant at ($P<0.05$) **= significant at ($P<0.01$); ***= significant at ($P<0.001$);
FS = feeding sequence, FI = feeding interval

Feed efficiency

The interval of feeding CS and GH influenced the feed efficiency significantly ($P < 0.05$). Collectively, rams fed the supplement 2 h before the grass hay (CB2 group) and those that received the grass hay 2 h before the supplement (GB2 group) had significant ($P<0.05$) improvement of 110% in feed efficiency than their counterparts fed the supplement before grass hay (CB1 group) and grass hay before the supplement (GB1 group) at 1 h interval.

Rumen metabolites

Table 4 shows the influence of sequence and interval of feeding CS and GH on the mean concentrations of ruminal total volatile fatty acids (VFAs), rumen ammonia-nitrogen (NH_3-N) and rumen pH (pre-feeding and 3 h after offering the second feed). The highest mean total VFAs values, pre-feeding and 3 h post-second feeding were recorded in GB2 rams. CB2 rams had the least pre-feeding total VFAs value, while GB1 rams had the least mean total VFAs value 3 h after second feeding. The total VFA values, 3 h post-second feeding, were affected ($P < 0.05$) by the interval of feeding CS and GH. Collectively, CB2 and GB2 rams had greater values of VFAs (23.12% increase) compared to the CB1 and GB1 rams with the increase more pronounced or marked ($P<0.05$) between GB1 and GB2 rams. Neither the treatments nor their interactions affected ($P > 0.05$) the mean rumen NH_3-N concentrations of the rams before feeding and 3 h post- second feeding.

The interval of feeding CS and GH had significant ($P < 0.05$) effect on pH values at 3 h post-second feeding. CB2 and GB2 rams together had greater (1.64 %; $P < 0.05$) mean rumen pH value than CB1 and GB1 rams with the increase more marked ($P<0.05$) between CB1 and CB2. Furthermore, the effect of sequence X interval of feeding interactions tended towards significance ($P = 0.06$) on mean rumen pH values of rams 3 h post- second feeding when CB2 was compared to GB2.

Blood metabolites

The mean values of blood metabolites are reported in Table 5. Blood glucose concentrations pre-feeding were affected by the time interval of feeding the supplement and the grass hay. It was only the rams which received grass hay 2 h before supplementation (GB2) that had significant ($P<0.01$) 8% decrease in concentrations in relation to the rams fed grass hay 1 h before supplementation (GB1). There was significant ($P<0.05$) effect of sequence X time interval of feeding interaction on pre-feeding glucose concentrations observed as the rams which received grass hay 1 h before supplement (GB1) had 10% increase ($P<0.05$) over those of rams fed supplement 1 h before grass hay (CB1). The concentrations 4 h post-feeding of second feed was also significantly ($P<0.05$) affected by time interval of feed with rams receiving supplement 2 h before grass hay (CB2) having 6% rise in concentrations over those of rams which received supplement 1 h before grass hay (CB1). The sequence X time interval of feeding interaction did not significantly ($P>0.05$) affect glucose concentrations 4 h post-feeding of the second feed.

The treatments did not affect the mean concentrations of BUN and protein of the rams pre-feeding and 4 hours post-second feeding. The pre-feeding blood creatinine concentrations were affected by the interval of feeding the supplement and the grass hay. The rams fed the grass hay 2 h before the supplement was fed had significant ($P<0.05$) 7% increase in concentrations over those of the rams fed grass hay 1 h before the supplement was offered. There tended ($P=0.07$) to be sequence X time interval of feeding interaction on the creatinine concentrations pre-feeding with the rams which received grass hay 2 h before supplementation (GB2) having 16% greater concentrations than those fed the supplement 2 h before offering the grass hay (CB2). The interval of feeding CS and GH affected ($P < 0.05$) serum creatinine concentrations at 4 h post-second feeding. The creatinine concentrations of CB2 and GB2 rams collectively were 6.26% higher ($P<0.05$) than CB1 and GB1 rams with the increase more marked (11%; $P<0.01$) between GB1 and GB2 rams. The effect of sequence X time interval of feeding interactions on serum creatinine concentrations 4 h post-second feeding was significant as the concentrations of GB2 rams were 14% higher ($P<0.05$) than those of CB2 rams.

Discussion

Dry matter intake

The highest value of the total DMI (Table 3) recorded in CB2 suggests that feeding CS 2 h prior to feeding GH impacted most on intake. Consumption of concentrate before grass had sufficiently stimulated the gut and provided the required nutrients to enhance microbial growth for degradation of the feeds. The comparable values of DMI between the sequence of feeding (i.e. whether supplement was fed before or after feeding grass) agrees with the findings of Nocek (1992), Robinson (1994) and Chassaing *et al.* (1996) on dairy cow performance fed hay before or after concentrate supplement. It disagrees with those of Morita and Nishino (1991) and Carro *et al.* (1994) who recorded significantly higher DMI and OMI, respectively, when concentrate supplement was fed 1 h subsequent to hay.

The improved DMI observed in CB2 compared to depressed DMI in GB2 was due to sufficient time for degradation of concentrate which resulted in increased rumen microbial population which in turn gave rise to a more rapid degradation of the GH, higher digesta passage rate, and less residence time of dry matter in the rumen? An increase in total DMI is associated with improved N and energy supply to cellulolytic bacteria, leading to increased degradation of roughage, and to a higher digesta passage rate (Goodchild and McMeniman, 1994; Chakeredza *et al.*, 2002).

The range of 497.88 to 589.81 g/d DMI is

Table 4: Influence of feeding sequence and feeding interval of roughage and concentrate supplement on rumen metabolites and pH of Yankasa weaner rams

	Feeding sequence							
	Concentrate before grass		Grass before concentrate			Level of significance		
Parameters	CB1	CB2	GB1	GB2	SEM	FS	FI	Interaction
Total VFAs (mmol/L)								
Pre-feeding	22.29	20.57	21.71	23.41	2.21	NS	NS	NS
3 h post-second feeding	25.14	29.71	23.43	30.10	2.0	NS	*	NS
NH_3-nitrogen (mg/dl)								
Pre-feeding	6.58	7.29	7.73	8.00	0.89	NS	NS	NS
3 h post-second feeding	6.93	8.18	8.27	7.86	0.63	NS	NS	NS
Rumen Ph								
Pre-feeding	7.15	7.15	7.11	7.01	0.09	NS	NS	NS
3 h post-second feeding	6.67	6.86	6.70	6.73	0.04	NS	*	NS

VFAs=volatile fatty acids, NH_3=ammonia, SEM=standard error of means, NS=not significant ($P>0.05$);*= significant at ($P<0.05$)

FS = feeding sequence, FI = feeding interval

Table 5: Blood metabolites of Yankasa weaner rams as affected by feeding sequence and feeding interval of roughage and concentrate supplement

	Feeding sequence							
	Concentrate before grass		Grass before concentrate			Level of significance		
Parameters	CB1	CB2	GB1	GB2	SEM	FS	FI	Interaction
Blood glucose(Mmol/L)								
Pre-feeding	3.65	3.83	4.02	3.69	0.11	NS	**	*
4 h post- second feeding	4.02	4.27	4.19	4.11	0.10	NS	*	NS
BUN (mmol/L)								
Pre- feeding	2.47	2.41	3.12	3.12	0.30	NS	NS	NS
4 h post- second feeding	2.36	2.08	2.69	2.44	0.30	NS	NS	NS
Protein (g/L)								
Pre- feeding	68.60	69.31	69.12	68.13	1.73	NS	NS	NS
4 h post- second feeding	67.08	67.58	67.99	67.46	1.47	NS	NS	NS
Creatinine (μmol/L)								
Pre- feeding	87.29	86.38	93.17	100.00	4.41	NS	*	NS
4 h post- second feeding	88.59	89.67	92.01	102.23	3.49	NS	**	*

BUN=blood urea nitrogen, SEM=standard error of the means, NS=not significant ($P > 0.05$); *= significant at ($P < 0.05$); ** = significant at ($P<0.01$); FS = feeding sequence, FI = feeding interval comparable to the range of 556 to 582 g/d DMI reported by Olateru and Adegbola (2001) for Yankasa sheep of an average live-weight of 18 kg fed sorghum stover as basal diet.

Live-weight change

The observed apparent ADG value for GB2 rams which is nonetheless comparable to that of CB2 rams could be due to more efficient utilization of absorbed nutrients by the GB2 rams. French and Kennelly (1990) reported improved daily gains and food conversion efficiencies when concentrate was given 1 h after hay. Robinson (1994) reported numerical differences in weight changes which favoured feeding concentrate subsequent to forage-based mixed ration. It also agrees with the conclusion (Nocek, 1992; Chassaing *et al*., 1996) that milk production and milk fat concentration of dairy cow were not modified by changing the sequence of feeding concentrate and roughage. A possible explanation for higher final weight recorded for GB2 rams compared to CB2 rams might be a better synchronized nutrients availability, which enhanced optimal ruminal fermentation, increased microbial protein synthesis and nutrient uptake, and improved growth rate. Synchronized rate of carbohydrate and protein availability in the rumen is beneficial in increasing microbial protein synthesis and growth rate in lambs (Sinclair *et al*., 1993; Witt *et al*., 1997; Chumpawadee *et al*., 2006).

Feed efficiency

The greatest feed efficiency recorded in GB2 rams was because of longer residence time of the grass hay in the rumen occasioned by the 2 h interval which allowed it to be digested more as intake reduced. Illius and Gordon (1991) reported that feed that stays longer in the rumen is more efficiently digested. Also, the feeding of CS 2 h after GH ensured a synchrony of coupling of released dietary nutrients from a rapidly degraded CS and slowly degraded GH fed 2 hours earlier to benefit net microbial protein synthesis. Highly synchronous dietary nutrients enhance optimal ruminal fermentation, net microbial protein synthesis and nutrient uptake (Chumpawadee *et al*., 2006). There is an established link between higher ruminal microbial synthesis and growth rate (Sinclair *et al*., 1995; Witt *et al*., 1997).

Rumen metabolites

Rumen VFAs concentration

The volatile fatty acids production in the rumen is the primary source of metabolizable energy for the ruminant animals (Sastradipradja, 1998). The higher concentration of total VFA in the rumen 3 h post-second feeding in both CB2 and GB2 indicates that sufficient time is needed for degradation of the feed through enhanced production of rumen microbes as probably the case in CB2 rams where feeding concentrate mixture first would have increased microbial population in readiness for degradation of grass hay fed 2 h later. Also, longer time for degradation of grass hay in GB2 rams, before concentrate was offered 2 hours later, might have resulted in increase in molar proportion of acetic acid before the additive effect of degradation of a relatively degradable feed, the concentrate.

Rumen ammonia nitrogen

A close look at Table 4 showed that the pattern of rumen NH_3-N production was dependent on the pattern of intakes of hay, concentrate and total DMI; increased intake of protein from concentrate component of the diet was associated with higher concentration of NH_3-N in the rumen. Dietary protein level or intake has effect on rumen NH_3-N level (Mutsvangwa*et al*., 2016). Ammonia is the nitrogen source of main microbes in the rumen (Bandla and Gupta, 1997) and NH_3-N concentration is an indicator of degradation and utilization of nitrogen source by rumen microbes

(Wang *et al*., 2008). In this study, NH_3-N concentration ranged from 6.58 to 8.27 mg/dL. This is above the 5 mg/dL reported to be possible minimal concentration for optimum microbial protein synthesis (Satter and Slyter, 1974). This implies that NH_3-N is unlikely to be a limiting factor for microbial synthesis.

Rumen pH

The pH values, 3 h post-second feeding, were comparable to the range of 6.2 – 6.8 reported to be favourable for optimal cellulolytic activities by rumen microbes (Ishler *et al*., 1996; Enemark *et al*., 2002). The pH values were apparently a reflection of the pattern of production of total VFAs in the rumen (Table 4). CB2 and GB2 rams had the highest values for total VFAs and rumen pH. It is not clear whether a probable higher molar proportion of acetic acid elicited by these treatments might have influenced the rumen pH. It is however, known that the more the molar proportion of acetic acid in the rumen the more the rumen pH tends towards alkalinity. The significant rise, 3 h post-second feeding, in rumen pH value of CB2 rams compared to the little rise in pH value of the GB2 rams is attributed to higher rumen NH_3-N concentration. Increased nitrogen degradation results in higher rumen NH_3-N which in turn affects rumen pH value (Wang *et al*., 2008).

Blood metabolites

Blood glucose

The comparable values of serum glucose levels 4 h post-second feeding showed that irrespective of the sequence or time interval of feeding investigated in this study, the production of the required substrate in the rumen for glucose production through gluconeogenesis in the liver was not impaired or limiting. The blood glucose value of 3.65-4.27 mmol/L (65.7-76.86 mg/dl) observed in this study was within the normal blood glucose range (50-80 mg/dl) of sheep reported by Kaneko (1989), Meyer and Harwey (2004) and Dhanotiya (2004). The pre-feeding reduced blood glucose level of GB2 rams as opposed to the increased blood glucose level of CB2 rams was because of higher intake of concentrate by the CB2 rams compared to GB2 rams. Pre-feeding glucose concentrations had been observed to increase with increasing grain intake in young calves (Quigley III and Bernard, 1992).

Blood urea nitrogen

The higher pre-feeding and lower post-feeding BUN levels was due to catabolism of body protein before feeding. Fasting and low nitrogen diets increase BUN levels as body protein is catabolised (Leibholz, 1970). The BUN value of 2.36-3.12 mmol/l (14.16-18.72 mg/dL) obtained was within the normal range of 8-20 mg/dL reported for sheep (Kaneko, 1989; Mojabi, 2000; Banerjee, 2007). This implies adequate dietary protein intake, efficient utilization of dietary protein and absence of renal and liver diseases. The higher weight gain recorded in GB2 was because of greater feed efficiency in GB2 rams. Decreased blood urea-N concentrations are associated with increased nitrogen retention and efficient conversion of feed to live-weight gain (Galbraith and Watson, 1978; Gabr *et al*., 2009).

Blood serum total protein

The total protein value of 67.08-69.31 g/l (6.7-6.9 g/dL) recorded was also within the normal range of 5.97-8.23 g/dL reported for sheep (Kaneko, 1989; Mojabi, 2000; Meyer and Harwey, 2004). Increase in body weight is associated with increase in serum total proteins (Gabr *et al*., 2009). In this study, however, the degree of weight gain (ADG) did not reflect the serum protein levels as the GB2 rams which had the highest ADG had least serum protein levels numerically. It is difficult to explain why it was so.

Blood creatinine

The value of 86.38-102.23 µmol/L (0.98-

1.16 mg/dl) obtained in this study was within the normal range of blood creatinine (0.89-1.32 mg/dl) reported by Mojabi (2000), but a little lower than 1.2-1.9 mg/dL reported by Kaneko (1989) and Meyer and Harwey (2004). This result is indicative of good metabolism of dietary protein and amino acids in building body mass by the rams used in this study. The greater mean blood creatinine level observed in GB2 (Table 5) may be due to higher weight gain recorded for GB2 rams (Table 3). Elevated concentrations of creatinine in the serum are attributed to the influence of large muscular mass (Zvonko *et al*., 2008). According to Hatfield *et al*., (1998), creatinine is a product of nitrogen metabolism related to muscle contraction and its synthesis rate may be considered an index of endogenous protein catabolism.

Conclusion

From the results of this study, it is concluded that feed intake and performance of Yankasa weaner rams were not markedly influenced by the feeding sequence, but by the interval of feeding concentrate supplement and grass hay. However, based on the indices of feed efficiency and average daily gain, it is recommended that, under intensive or semi-intensive management systems and feedlot operations, concentrate supplement be fed 2 h subsequent to grass hay for the attainment of best growth rate and feed efficiency in Yankasa weaner rams.

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