Effects of varying levels of dietary palm oil in concentrate rations on dry matter intake, nutrients digestibility and nitrogen retention in Red Sokoto goats

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Abstract

Twenty Red Sokoto bucks (average liveweight of 21.4 ± 3.2 kg) were used to evaluate the effects of varying levels of palm oil (PO) in concentrate rations on nutrients digestibility and nitrogen retention. Five iso-nitrogenous concentrate supplements (CP 160 g/kg concentrate) compounded with 0, 40, 80, 120 and 160 g palm oil/kg of concentrate, were used to supplement a basal diet of woolly finger grass (*Digitaria smutsii*, Stent) hay. The five supplements were designated as treatments 0-PO (control), 40-PO, 80-PO, 120-PO and 160-PO. The bucks were each fed 536 g/d of hay, and 343 g/d of concentrate to give a ratio of 60:40 hay to concentrate. Results showed that inclusion of PO in the concentrate rations did not affect ($P > 0.05$) total dry matter intake of the goats but intake values declined slightly with further increase in levels of PO beyond 40 g/kg concentrate. No adverse effects on total tract digestibility of nutrients were observed. Nitrogen retention of the goats was positive and not affected ($P > 0.05$) by dietary levels of PO. It was concluded that inclusion of palm oil in the concentrate supplement beyond 40 g/kg level for the Red Sokoto goats marginally depressed total dry matter intake, but had no adverse effects on the total tract digestibility of nutrients and nitrogen retention.

Keywords: Goats, Palm oil, Nutrient digestibility, Nitrogen retention

Introduction

Fat sources have played important roles in increasing energy density of diets and offer alternatives to feeding excessive amount of cereals, and thus prevent problems of ruminal acidosis, off-feed, lameness and low milk yield (Sudweeks *et al.*, 1981; Harmon *et al.*, 1985; Groehn *et al.*, 1992). Other benefits of inclusion of fats in diets of ruminants were reported by Schroeder *et al.* (2004). However, one of the limitations of including fat in the diets of ruminants is the impairment of microbial activities in the rumen (Palmquist and Jenkins, 1980; Onetti *et al.*, 2001; Franzolin, *et al.*, 2010) by adsorbing onto bacteria (Jenkins, 1993) or defaunating the rumen microbes (Franzolin *et al.*, 2010; Bhatt *et al.*, 2011),

especially, the cellulolytic protozoa - the Diplodiniinae (Franzolin *et al.*, 2010). It has been reported that such impairment resulted in reduced cellulolysis and low fibre digestion in the rumen (Jenkins, 1993; Bhatt *et al.*, 2011) which was associated with decreased concentration of ruminal acetic acid (Khorasani *et al.*, 1992; Onetti *et al.*, 2001). Polyunsaturated fats are more soluble and decrease fibre digestion than saturated fats (Palmquist and Jenkins, 1980; Sutton *et al.*, 1983; Schauff and Clark, 1989; Coppock and Wilks, 1991; Brown-Crowder *et al.*, 2001) but in terms of positive contribution to the environment, they are more effective in reducing methane emissions (Jouany, 1996; Machmüller *et al.*, 1998).

Effect of supplemental fats on rumen function and performance of animals depend on fat content of diet, fat sources, forage types and species of animals (Jenkins, 1993; Smith *et al.*, 1993; Ben Salem *et al.*, 1993; Onetti *et al.*, 2002; Doreau and Ferlay, 1995; Franzolin *et al.*, 2010). Smith *et al.* (1993) using tallow or cottonseed and Ben Salem *et al.* (1993) using rapeseed oil demonstrated that depression in digestibility of nutrients and performance by cows was reversed when corn silage-based diets were partially or wholly replaced with alfalfa hay-based diets. The type of forage and perhaps the amount of it fed are important in modulating the effect of supplemental fat in the rumen.

Palm oil produced from oil palm (*Elaeis guineensis*, Jacq) is abundantly available in Nigeria. It has equal levels of saturated and unsaturated fatty acids (Edem, 2002). *In vitro* study with some fats indicated that palm oil has minor effects on degradation of neutral detergent fibre (NDF) (Dohme *et al.*, 2000). Most *in vivo* studies with palm oil in respect of its effects on digestibility and utilization by ruminants involved the use of protected or rumen-inert palm oil (Bayourthe *et al.*, 1994; Martín *et al.*, 1999; Meyer *et al.*, 2001; Onetti and Grummer, 2004; Appeddu, *et al.*, 2004; Franzolin *et al.*, 2010). Similar reports on the use of unprocessed or ruminally active palm oil in diets of ruminant animals are few (Solomon *et al.*, 1992; Lough *et al.*, 1993 and 1994), and more so in Nigeria. The Red Sokoto goats has uniformly dark red coat colour, and is the most numerous and widely distributed breed of goats in Nigeria. Other details concerning the Red Sokoto breed of goats had been reported (Otaru *et al.*, 2011). There has been paucity of information on the effects of palm oil on digestibility of nutrients by indigenous goat breeds in

Nigeria. This study was carried out to evaluate the effects of varying dietary levels of palm oil in concentrate rations on dry matter intake, nutrients digestibility and nitrogen balance by Red Sokoto goats fed basal diet of *Digitaria smutsii* hay.

Materials and methods

Location of study

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

Metabolism trial

Twenty Red Sokoto bucks with average liveweight of 21.4 ± 3.2 kg were obtained from the flock of Red Sokoto goats of the Small Ruminant Research Programme, and used in a randomized complete block design for nutrient digestibility and nitrogen balance study. The animals were blocked according to weight and randomly allocated to five dietary treatment groups to give a total of four animals per treatment group.

The experimental diets consisted of Woolly finger grass (*Digitaria smutsii*, Stent) hay fed as basal diet. The supplements were concentrate mixtures compounded to contain palm oil (PO) at levels of 0, 40, 80, 120, or 160 g/kg of concentrate designated as: 0-PO (control), 40-PO, 80-PO, 120-PO or 160-PO, respectively. The concentrate mixtures were iso-nitrogenous (160 g crude protein (CP)/kg concentrate dry matter (DM)) as shown in Table 1. The source of palm oil and the procedure for mixing of the concentrate supplements were as described by Oturu *et al.* (2011).

The animals were de-wormed one week before the commencement of the study. They were also dipped in acaricide (Steladone® 300EC) solution to control ecto-parasites. On the first day of the study, they were weighed and placed in individual metabolism crates designed for separate collection of total faeces and urine, the latter flowing down a gradient to be collected into 5-litre capacity plastic jericans which protects the urine against draught. The bucks were individually fed 536 g/d of hay, and 343 g/d of concentrate to give a ratio of 60:40 hay to concentrate. The procedure and duration of feeding the diets each day were as described by Oturu *et al.* (2011) in an earlier feeding trial with lactating Red Sokoto goats. After 14-day adjustment period, measurements of feed offered and remnants, total faeces and urine voided, as well as amounts of water consumed were taken for a period of seven consecutive days. For each animal, total urine output was collected into plastic container containing 20 ml of 0.2N HCl to prevent loss of nitrogen (ILCA, 1993). Total faecal output from each animal was also collected and weighed fresh. Ten percent of each day's collection of urine and faeces was bulked at the end of the trial, and the urine kept in refrigerator until required for nitrogen analysis. The faecal samples were dried in the oven for 48 h at 70 °C, milled and stored in polythene bags kept inside tins until required for proximate analyses. Sub samples of feed offered and refused were also taken daily, bulked, milled and stored for proximate analysis. Final weights of the animals were taken at the end of the experiment but not shown in the Tables.

Chemical analysis

Samples of the diets and faeces were dried, ground through 1mm sieve and further

dried at 105 °C for one hour to determine the residual dry matter of samples (AOAC, 1980). The nitrogen (N) in the urine, diets and faeces were determined according to Kjeldahl procedure (AOAC, 1980). The crude protein (CP) content was obtained by multiplying N by a factor of 6.25. The Neutral detergent fibre (NDF) and Acid detergent fibre (ADF) contents of the diets, feed ingredients and faecal samples were determined according to the procedure of Goering and Van Soest (1970). The AOAC (1980) procedures were followed to determine the ether extract (EE) and ash contents of the diets and faecal samples. The gross energy content of the diets was determined using ballistic bomb calorimeter (Gallenkamp).

Calculations and Statistical analyses

Non-structural carbohydrate (NSC) concentrations of the diets was estimated by equation: OM - (CP% + NDF% + ether extract%) (Arieli *et al.*, 2005).

Data on daily intakes of nutrients, DM and water whose values were correlated because of repeated measures, were subjected to analysis of variance for repeated measure analysis using PROC MIXED procedure of SAS (SAS, 2000, version 8.1, SAS Institute Inc., Carry NC). The statistical model used is: $Y_{ijk} = \mu + t_i + b_j + p_k + tp_{ik} + e_{ijk}$, where, Y_{ijk} is the response of animal j in treatment i at time k , μ is the overall mean, t_i is a fixed effect of the i th treatment ($i = 1, 2, 3, 4, 5$), b_j is the random effect of the j th animal ($j = 1, 2, 3, 4$) nested within the i th treatment, p_k is the fixed effect of k th time ($p = 1, 2, \dots, 7$), tp_{ik} is the interaction between the i th treatment and the k th time, e_{ijk} is the random error. For each variable analyzed under this model, animal as a subject nested within treatment was subjected to four covariance structures: Compound symmetry (CS), unstructured

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Table 1: Composition of hay and concentrate mixtures containing different levels of palm oil (PO)

Ingredient composition, g/kg (as fed)	Levels of PO in concentrate (g/kg)				
	0- PO	40- PO	80- PO	120- PO	160- PO
Maize	378.7	338.7	298.7	258.7	218.7
Maize offal	189.4	189.4	189.4	189.4	189.4
Palm oil	0.0	40.0	80.0	120.0	160.0
Cotton seed cake	391.9	390.4	389.0	387.5	386.1
Urea	0.0	1.5	2.9	4.4	5.8
Bone meal	25.0	25.0	25.0	25.0	25.0
Common salt	15.0	15.0	15.0	15.0	15.0

Chemical composition, g/kg DM	D. smutsii hay					
OM	901.1	900.9	893.0	900.6	905.1	907.7
CP	60.00	161.9	166.9	166.5	174.2	175.0
EE	61.4	117.5	127.6	169.7	219.4	246.6
NDF	696.7	397.7	395.9	379.8	371.0	358.7
ADF	451.0	245.7	230.3	163.4	209.4	274.2
Ash	71.6	66.3	70.3	68.2	73.3	70.3
Non-structural carbohydrate (NSC)	83.0	224.1	202.6	184.6	140.5	127.4
Gross energy (GE, MJ/kg DM)	17.66	16.05	16.08	17.97	19.56	20.09

(UN), autoregressive order [AR(1)] and heterogeneous autoregressive [ARH (1)]. The covariance structure that yielded the smallest Akaike's Information Criterion (AIC) was used. UN was used for total DM intake, total OM intake, concentrate DM intake, and intakes of CP, NDF, ADF, NSC and water. Autoregressive order [AR(1)] was used for the intakes of EE and hay DM. When effect of treatment, time or treatment x time interaction 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 (2000) to establish the linear, quadratic and cubic relationships between the variables and dietary palm oil levels.

Digestibility coefficients of nutrients, urine and faecal outputs, nitrogen intake and retention were analyzed by ANOVA using the General Linear Model (GLM) procedures of the statistical Analysis Systems (SAS, 2000) in accordance with the following statistical model: $Y_{ij} = \mu + b_j + t_i + e_{ij}$, where Y_{ij} is the response of animal j in treatment i , μ is the overall mean, b_j is a fixed effect of the j th block ($j = 1, 2, 3, 4$) within the i th treatment, t_i is a fixed effect of the i th treatment ($i = 1, 2, 3, 4, 5$), e_{ij} is the random error. Least-Squares Means were separated using the PDIF option of SAS (SAS, 2000).

Differences between treatment means were declared significant at $P < 0.05$. Tendency to differences between treatments were declared at $P > 0.05$ and < 0.1 .

Results

Nutrient intake

Table 2 shows the intake and apparent digestibility coefficients of nutrients of the goats. The total dry matter intake (DMI) was not significantly different ($P > 0.05$)

between treatments, even though total DMI peaked at 40-PO level and declined thereafter. According to the observed intakes of hay and concentrates, final level of PO in the total diet was 0, 19, 40, 64 or 78 g/kg dry matter, for 0-PO, 40-PO, 80-PO, 120-PO or 160-PO treatments, respectively. The ratio of hay intake to that of concentrate was on the average 50:50 across diets. Similar to the total DMI, no significant ($P > 0.05$) differences were observed between the treatments for the intakes of OM, CP, NDF and ADF. The intake of EE was significantly ($P < 0.05$) affected by treatment. The highest intake of EE was recorded by goats fed 120-PO concentrate which consumed 67% ($P < 0.01$) and 47% ($P < 0.05$) more EE than goats which correspondingly received 0-PO or 40-PO concentrate. Furthermore, the intake of EE by goats receiving 160-PO concentrate was significantly ($P < 0.05$) higher than the intake of those fed 40-PO concentrate but comparable to that of the group offered 80-PO concentrate. The differences in the intake of NSC between goats receiving 0-PO or 40-PO concentrate and their counterparts fed 160-PO concentrate tended to be significant ($P = 0.07$). The EE intake showed a linear ($P < 0.01$) increase to levels of PO in the concentrate, whereas NSC intake exhibited a linear ($P < 0.05$) decrease.

Digestibility and nitrogen balance

The digestibility coefficient values for most of the nutrients were generally less than 600 g/kg except those for EE and NSC, which were between 610 and 740 g/kg. The treatment had no effect ($P > 0.05$) on the digestibility of all the nutrients, however, the differences between 0-PO or 40-PO and 160-PO for crude protein digestibility, and between 0-PO and 120-PO or 160-PO for ether extract digestibility tended to be

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Table 2: Intake and apparent digestibility coefficients of nutrients in Red Sokoto goats (bucks) fed concentrate diets containing varying levels of palm oil (PO)

Parameter	0-PO	40-PO	80-PO	120-PO	160-PO	SEM	PO level effect, P<		
							L	Q	C
Dry Matter intake (g/d)									
Hay	409.03	444.20	379.12	382.06	364.49	65.49	NS ¹	NS	NS
Concentrate	382.87	406.07	384.06	429.77	342.71	60.94	NS	NS	NS
Total	791.89	850.26	763.18	811.83	707.20	124.23	NS	NS	NS
Nutrient intake (g/d)									
OM	735.54	787.93	708.24	751.51	655.74	115.21	NS	NS	NS
CP	89.32	97.75	89.39	100.09	83.81	14.35	NS	NS	NS
EE	72.33 ^c	81.83 ^{bc}	91.20 ^{abc}	120.49 ^a	109.42 ^{ab}	11.62	0.01	NS	NS
NDF	450.40	485.05	422.11	436.61	386.76	70.15	NS	NS	NS
ADF	286.91	303.03	240.56	269.12	265.10	44.23	NS	NS	NS
NSC	123.61	123.31	105.53	94.32	75.75	17.10	0.02	NS	NS
Digestibility (g/kg)									
DM	506.5	523.1	558.1	554.0	554.0	47.0	NS ¹	NS	NS
OM	543.9	554.0	584.0	584.5	578.3	45.2	NS	NS	NS
CP	335.5	334.1	442.7	434.8	473.5	52.4	0.04	NS	NS
EE	611.7	641.1	703.5	738.0	733.3	45.7	0.04	NS	NS
NDF	542.2	516.4	561.7	542.2	543.2	58.7	NS	NS	NS
ADF	425.4	378.0	403.2	380.5	499.2	92.2	NS	NS	NS
NSC	620.0	671.3	664.0	709.4	620.3	50.7	NS	NS	NS

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

¹NS = P>0.05.

L, Q, and C = Linear, quadratic and cubic response to palm oil level.

Table 3: Nitrogen intake and retention in Red Sokoto bucks fed concentrate diets containing varying levels of palm oil (PO)

Parameter	0-PO	40-PO	80-PO	120-PO	160-PO	SEM	PO level effect, P<		
							L	Q	C
Total nitrogen intake (g)	13.21	14.47	13.59	15.00	12.44	2.22	NS	NS	NS
Water intake (l/d)	2.29	2.58	2.07	2.32	1.80	0.36	NS	NS	NS
Total urine output (ml)	471.57	594.93	327.00	462.89	243.82	146.85	NS ¹	NS	NS
Total faecal output (g)	412.50	424.10	319.29	368.93	330.54	85.41	NS	NS	NS
Faecal nitrogen output (g)	9.02	9.71	7.60	8.42	6.67	1.89	NS	NS	NS
Urine nitrogen output (g)	3.18	3.42	2.13	3.49	2.29	0.77	NS	NS	NS
Total nitrogen output (g)	12.21	13.13	9.73	11.91	8.96	2.50	NS	NS	NS
Nitrogen balance (g)	1.00	1.33	3.86	3.10	3.49	1.33	NS	NS	NS
Nitrogen retention (g/kg NI)	98.6	99.2	287.2	184.1	298.0	78.8	NS	NS	NS

¹NS = P>0.05.

L, Q, and C = Linear, quadratic and cubic response to palm oil level.

NI = Nitrogen intake

significant ($P = 0.08$). Digestibility of CP and EE both showed significant ($P < 0.05$) linear increase to increasing levels of palm oil in the concentrate.

The mean daily nitrogen intake and retention are presented in Table 3. The effect of levels of PO in the concentrate on water intake, nitrogen intake and retention, urine and faecal output was not significant ($P > 0.05$), but the mean values for per cent nitrogen retention were positive for all treatments, and tended to increase linearly ($P = 0.07$) to dietary level of palm oil.

Discussion

Nutrient intake

Increasing the levels of dietary palm oil did not markedly affect the DMI of goats. This agrees with similar findings on cows (Schauuff and Clark, 1989) and goats (Sanz Sampelayo *et al.*, 2002; Mele *et al.*, 2008) fed diets containing supplemental fats. From our results, it would appear that while there were no significant differences between treatments, DMI peaked at 40-PO and declined by as much as 17% with further increase in the level of dietary PO. The lack of significant effect of palm oil on DMI as observed in this study contradicts previous reports where cows receiving supplemental fat had significantly lower DMI than those fed diets without fat supplement (Onetti *et al.*, 2001 and 2002). Findings from a recent study on lambs fed *Ailanthus excelsa* leaves supplemented with concentrate mixture containing 0, 25, 50 and 75 g coconut oil/kg (Bhatt *et al.*, 2011) showed that DMI was significantly affected by coconut oil supplementation compared with the control group either in the pre or post weaning period. Dry matter intake (DMI) increased linearly during the pre weaning phase and decrease linearly during the post weaning phase with further increases in levels of dietary coconut oil.

The difference between the observed DMI in this study and that of Onetti *et al.* (2001) and (2002) may be attributed to differences in the nature of forage and supplemental fat fed, and the form in which the diets were fed. The author used corn silage or mixture of corn silage and alfalfa silage, and tallow or choice white grease all of which were fed as total mixed ration. *Digitaria smutsii* hay was used in this study, and was offered *ad libitum*. According to Jenkins (1993) fats that normally inhibit fermentation and digestion often cause less inhibition when hay content of the basal diet is high. The sheep used by Bhatt *et al.* (2011) were young lamb and might not have gotten well developed rumen to cope with digestion of diets containing supplemental fat, thus underscoring differences between our study (where mature bucks were used) and theirs in terms of intake response.

The positive linear relationship between EE intake and the levels of PO in the concentrate shows that the goats offered higher amounts of dietary PO significantly ingested more EE than those fed lower levels of dietary PO. The observed marked treatment effect in this study is consistent with earlier reports which showed that inclusion of supplemental fat in the diets significantly increased fat intake in cows (Storry *et al.*, 1967) and ewes (Appeddu *et al.*, 2004). Although intakes of OM, CP, NSC and fibre components were unaffected significantly, successive increase in dietary level of PO elicited linear decrease in that of NSC. Intake of NSC decreased probably because PO replaced maize grain which was the main source of NSC in the diets.

Digestibility and nitrogen balance

The digestibility of nutrients in goats receiving palm oil containing diets were not different from those of goats fed the control diet, thus agreeing with the findings of

Schauff and Clark (1989) on cattle receiving fat supplement, while conflicting with those of similar works on sheep (Machmüller *et al.*, 2000; Appeddu *et al.*, 2004; Bhatt *et al.*, 2011) where supplemental fat markedly reduced digestibility of nutrients. One of the limitations of fat supplement is their effect on ruminal fiber digestion by exerting negative effects on cellulolytic and methanogenic microorganisms in the rumen through the direct action of fatty acids on cellular membrane of the microbes, or/and indirect effect of reduction in the ruminal availability of cations such as calcium and magnesium (Schroeder *et al.*, 2004). Fibre digestion was not significantly affected in the present study probably because of the nature of fat source used. Palm oil has equal level of saturated and unsaturated fatty acids (Edem, 2002). The higher the level of unsaturation in fats the more the reduction in fibre digestibility (Brown-Crowder *et al.*, 2001).

The linear increase in ether extract digestibility to dietary levels of palm oil supports consistent increase in EE digestibility when calcium salts of fatty acids (Bayourthe *et al.*, 1994) or coconut oil (Bhatt *et al.*, 2011) in the diets of sheep was successively increased.

Although treatment differences were not significant for all nitrogen balance parameters measured, the mean values for per cent nitrogen retention were positive and showed a tendency towards a linear increase with increase in dietary level of PO. This is consistent with earlier observation in sheep fed supplemental fat (Bayourthe *et al.*, 1994) but contradicts reports on sheep where supplemental fat (coconut oil) linearly decreased nitrogen retention (Bhatt *et al.*, 2011). The difference between the present result and those of

Bhatt *et al.* (2011) in terms of response of nitrogen retention to supplemental fat could be accounted for by the differences in the age of the animals used. We used fairly mature goats as opposed to young lambs used by Bhatt *et al.* (2011).

Based on the virtual linearity of per cent nitrogen retention to increase in dietary levels of PO, it is tempting to infer that intake of more energy enhanced more nitrogen retention (Lykos and Varga, 1997; Huhtanen *et al.*, 1995) because glucogenic amino acids or protein are spared and not used for gluconeogenesis (Lemosquet *et al.*, 2004) due to utilization of ruminal propionate subsequent to enhancement of its production by ingestion of fat (Johnson and Johnson, 1995). But this was not likely the case because a critical look at Table 3 indicates that the level of nitrogen retention was more associated with or influenced by the amount of urine and faecal output and their derivatives (that is, urine and faecal nitrogen output). Animals with large quantities of urine and/or faeces had the lowest nitrogen retention. Earlier, in a similar study, Bayourthe *et al.* (1993) attributed the nitrogen and energy retention they obtained in sheep to the decrease in fecal and/or urinary excretion(s). The quantities of urine and faeces voided might have had a link with the amount of water consumed which in turn was influenced by DMI.

Conclusion

It was concluded that inclusion of palm oil in the concentrate supplement up to 40 g/kg level for the Red Sokoto goat (bucks) elicited the highest DMI. Further increase in level of palm oil beyond 40 g/kg of concentrate caused marginal decline in DMI and had no adverse effects on the total tract digestibility of nutrients and nitrogen retention.

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