DOI: 10.2478/ats-2021-0018 AGRICULTURA TROPICA ET SUBTROPICA, 54 OV, 174–183, 2021

Original Research Article

Nutritional potential of kenaf grain meal as a replacement for palm kernel cake in cassava peel-based concentrate for sheep

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Abstract

The study evaluated the nutrient intake, apparent nutrient digestibility, performance and nitrogen balance of West African Dwarf (WAD) sheep fed cassava peel-based diets containing kenaf grain meal (KGM) in replacement of palm kernel cake (PKC). Sixteen female WAD sheep with an average initial live weight of 9.71 ± 0.05 kg were selected for four dietary treatments, having four animals per diet. The diets comprised wilted guinea grass (*Panicum maximum*) as basal diet and cassava peel based diets with levels of replacement of PKC by KGM at 0%, 15%, 20% and 25%, respectively, as: 1) (25% PKC + 0% KGM), 2) (10% PKC + 15% KGM), 3) (5% PKC + 20% KGM), and 4) (0% PKC + 25% KGM). Increasing levels of KGM in the dietary treatments significantly ($p < 0.05$) influenced the total feed and nutrient intake (g/kg $W^{0.75}$), digestibility and weight gain. Total feed intake (108.48 g/kg $W^{0.75}$ or 662.82 g/day), nutrient intake, feed conversion ratio (21.47) and daily weight gain (30.95 g/day) were outstanding ($p < 0.05$) when PKC was completely replaced by KGM. Similarly, nutrient digestibility coefficients and nitrogen utilization values differed with increasing level of KGM inclusion, with the peak effects recorded in sheep at 5% PKC and 20% KGM inclusions than the other dietary groups. Thus, kenaf grain meal can successfully be used to replace palm kernel cake as an unconventional protein and energy source in cassava peel based diet for WAD sheep without causing any negative impact on nutrient intake and digestibility, nitrogen balance and growth performance.

Keywords: Cassava peel; digestibility; kenaf grain; nutrient intake; performance; sheep

INTRODUCTION

The perennial challenges of feed scarcity and limiting nitrogen (N) content of tropical grasses, especially in the dry season, contribute majorly to research on the exploration of crop residues, crop and agro-industrial by-products in ruminants feeding systems. The nutritional potential and efficient utilisation of some of these potential feed resources by ruminants had been evaluated via *in vitro* or *in vivo* methods (Fievez et al., 2005; Ngwe et al., 2012; Ajayi et al., 2016). Cassava peel and palm kernel cake amongst others are typical fibre-rich low protein feed resources often used to supplement herbages fed small ruminants kept intensively or semi-intensively. Meanwhile, cassava peel, a readily fermentable energy supplement to poor quality feed (Adegbola et al., 2010), is low in protein content and requires supplementation with a dietary protein source, preferably of plant origin, to make a nutritionally balanced feed suitable for ruminants. Similarly, palm kernel cake (PKC), a less efficient ingredient in poultry due to its reduced palatability and digestibility, is a widely utilised agro-industrial by-product with crop residue-based compounded rations for ruminants. PKC is a medium quality energy and crude protein source but high in fibre contents moderately enough to meet the requirements of most ruminants (Carvalho et al., 2005). While 30–50% PKC of the dietary dry matter is recommended for sheep, long-term feeding of PKC could lead to copper toxicity (Alimon et al., 2011). Often, a combination of any of these feedstuffs to form complete ration for ruminant is aimed at increasing the voluntary intake, digestibility and weight gain. However, PKC inclusion levels above 35% and 25–75% in the diets of goats and lactating cows, respectively, decreased the digestibility of dry matter, non-fibrous carbohydrates, protein and dry matter intake (Chanjula et al., 2010; Silva et al., 2013).

Forage (tree fodder or herbaceous) legumes has been the cheapest sources of protein in ruminant feeding systems to compensate for the limiting nitrogen content in tropical grass species and crop residue-based diets. Meanwhile, a promising and non-conventional protein, energy and fibre source for ruminants that has not received adequate attention is kenaf seed. Kenaf (*Hibiscus cannabinus* L.) is a well-known industrial and commercial fibre crop cultivated around the world (Webber et al., 2002), under different climatic conditions with a wide range of different seed yield. As an annual herbaceous fibre crop, it is increasingly gaining wider acceptance by the small- and large-scale crop farmers for propagation as raw materials for jute and fibre industries. Unfortunately, tons of kenaf seed, which is a valuable component of the plant that is meant for subsequent propagation, rapidly loses viability and get wasted because of poor storage conditions and high cost of storage facilities that are beyond the reach of resource-poor farmers in developing tropical countries. Hence, the seeds are discarded by setting it on a flame.

To prevent the wastage of the non-viable kenaf seeds and intensify efforts at promoting kenaf grain production for wider use in the livestock industry, this study investigated how to explore the potential of kenaf grain in small ruminant feeding strategy as supplemental feedstuffs when the grasses or natural forages and low-quality crop by-products are limiting in protein. Although kenaf seed is a suitable supplementary source of protein in livestock feed (Mariod et al., 2010), no clear understanding on the utilisation of non-viable kenaf seed as feed for ruminants. The high dietary fibre and edible oil or fat contents (Cheng et al., 2016) in kenaf seed also suggest its usefulness as a source of energy for livestock. Kenaf seed meal improved dry matter intake, nitrogen digestibility and nitrogen retained in sheep fed low-quality hay (Sgwane et al., 2008), ditto as a supplement in a rice ration for sheep (Phillips et al., 2002). In contrast, Palm kernel cake may not be a suitable protein source for ruminants due to high degradability of the protein in the rumen (Rahman et al., 2013a). Considering the dietary nutritional (protein and energy) potentials of palm kernel cake and kenaf seeds, it was hypothesised that Kenaf grain meal could replace palm kernel cake and also supplement cassava peel-based diet to promote nutrient intake, digestibility and nitrogen utilisation and growth of WAD sheep.

MATERIALS AND METHODS

Experimental location, animal management, and experimental design

The experiment was carried out in the research station of the Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria (7°15'–7°30'N, 3°45'–4°0'E). The area has a tropical humid climate with a mean annual rainfall of 1,415 mm and an average daily temperature between 28 and 35 °C. Sixteen WAD female sheep with an average live weight of 9.71 ± 0.05 kg were used for the study. The animals were randomly assigned to individual pens and each to one of four treatment diets in a completely randomised design with four animals per treatment. Before the commencement of the experiment, the animals were administered long-acting injectable antibiotics (Oxytetracycline) and dewormed with Albendazole^R 2.5% body weight oral suspension (Anthelmintics) at 1 mL/10 kg body weight. The sheep were also treated against ectoparasites with Diazintol at a dose of 2 mL to 6 litres of water. Animals were adjusted to their treatments diets over a 2-week preliminary period, followed by the 84-day feeding trial.

Experimental diets, feeding and growth trials

Feed ingredients were sourced from animal feedstuff vendors, whereas dried kenaf grain was collected from the Kenaf and Jute Fibre Programme of the Institute of Agriculture Research and Training (IAR & T), Ibadan. Guinea grass (*Panicum maximum*) was harvested from an established pasture in IAR & T and allowed to wilt under room temperature before feeding. Kenaf grain and dried cassava peel were separately crushed with attrition and hammer mills, respectively, into small particle size (1.5–2.5 mm), to allow for proper mixing with other ingredients and to prevent selective eating. Thereafter, all the ingredients were separately weighed and mixed according to the proportion of each dietary treatment to form four experimental diets: Diet 1 = 25%

palm kernel cake and 0% kenaf grain meal; Diet 2 = 10% palm kernel cake and 15% kenaf grain meal; Diet 3 = 5% palm kernel cake and 20% kenaf grain meal; and Diet 4 = 0% palm kernel cake and 25% kenaf grain meal.

Feeding and growth trials

The animals were maintained in adherence to the accepted code of practice for the care and humane treatment of animals for experimental purposes approved by the Ethics Committee on animal welfare of Obafemi Awolowo University. Experimental diets were offered separately to individual animals at 3% of the body weight at 08:00 h and wilted Guinea grass was offered as a basal diet to all the sheep at 2% of the body weight at 16:00 h. Provision was made for a daily feed allowance of 10% above the previous week's consumption. Clean water was provided *ad libitum*. The initial live weights of animals were taken and recorded at the commencement, then weekly before feeding in the morning throughout the experimental period (105 days) excluding two weeks of the adaptation period. Daily feed intake was determined by subtracting feed refused from feed offered over a 24-h period.

Intake and performance evaluations

Intake and performance evaluations of animals such as total feed intake (g/day and g/kg $W^{0.75}$), intakes (g/kg $W^{0.75}$) of nutritional components (DM, CP, EE, Ash, NDF, ADF, and ADL) and weight gain (g/day) were determined. For an explanation of the abbreviations, see the Laboratory analysis section. The feed conversion ratio was determined as the average daily weight gain (ADWG) divided by the total feed intake (g/day), where ADWG is the difference between final body weight and initial body weight divided by the number of days in the experimental period. The apparent digestibility coefficients of all nutritional components (DM, CP, EE, Ash, NDF, ADF and ADL) were calculated by dividing the amount of nutrient consumed and its respective nutrient in faeces and the result was multiplied by 100. Nitrogen balance (g/kg $W^{0.75}$) was calculated as follows:

$$\text{Nitrogen balance} = \text{Nitrogen intake (g/kg } W^{0.75}) - [\text{Faecal nitrogen (g/kg } W^{0.75}) + \text{Urinary nitrogen (g/kg } W^{0.75})].$$

Digestibility and nitrogen balance

All the sheep were transferred into individual metabolic cages specially made for separate collection of faeces and urine at the end of the growth trial. The study was carried out for seven days for each treatment for measurements of feed intake, faeces, and urine from each sheep. Feed offered, feed refused, faeces and urine samples were sampled daily for dry matter determination and chemical analysis. Loss of nitrogen by volatilisation was prevented by adding 10 ml of 10% concentrated sulphuric acid (H_2SO_4) into plastic containers for the collection of urine (Chen and Gomes, 1995). Daily collections of faeces and urine were bulked, with 10% sub-sampled from each for analysis. Ten per cent of urine samples were taken and frozen at −20 °C pending subsequent nitrogen determination. Faecal samples were oven-dried to a constant weight in a forced air oven at 60 °C, ground and analysed for chemical components.

Laboratory analysis

Samples of the ingredients, feed offered (experimental diets and guinea grass), orts and faeces were oven-dried to a constant weight, ground to pass through a 1-mm screen, using a Wiley mill (Arthur H. Thomas, Philadelphia, PA, USA). The ground samples were analysed for dry matter (DM; Method 967.08), crude protein (CP; Method 988.05), ether extract (EE; Method 2003.06), and ash (Method 942.05) contents according to the methods of Association of Official Analytical Chemists (AOAC, 2005). The fibre fractions Neutral detergent fibre (NDF), Acid detergent fibre (ADF) and Acid detergent lignin (ADL) were determined according to the procedure of Van Soest et al. (1991). The urine samples were also analysed using the Micro-Kjeldahl distillation following Method 988.05 of the AOAC (2005).

The organic matter digestibility (OMD) was determined using the equation developed by Jarrige (1989) as follows:

$$\text{OMD} = 91.9 - (0.355 \times \text{NDF\%}) + (0.387 \times \text{ADF\%}) - (2.17 \times \text{ADL\%}) - (0.39 \times \text{EE\%})$$

where:
NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin and EE = ether extract. Metabolisable energy (ME) was determined using two separate equations and the average taken. The first was according to De Boever et al. (1997) equation as follows:

$$\text{ME (MJ/kg DM)} = 12.86 + 0.0265\ \text{EE} - 0.0056\ \text{ADF} - 0.0153\ \text{Ash} - 0.0253\ \text{ADL}$$

where:
EE = ether extract, ADF = acid detergent fibre and ADL = acid detergent lignin. The second was according to Moran (2005) equation as follows:

$$\text{ME (MJ/kg DM)} = 0.185\ \text{TDN} - 1.89$$

Where:
TDN = Total digestible nutrient, ME = metabolisable energy. The total digestible nutrients (TDN) in forage (guinea grass) and experimental diets, kenaf grain meal and palm kernel cake were determined according to the prediction equations of Jayanegara et al. (2019). Given that the prediction equation of TDN for forage and concentrate is:

$$TDN = pNDF + qNFC + rEE + xCP$$

where:
NDF = Neutral detergent fibre; NFC = Non-fibre carbohydrate; EE = ether extract, CP = crude protein and pqrx are coefficients.

Statistical analysis

Data were subjected to analysis of variance using a general linear model (PROC GLM) of SAS (2000), in a completely randomised design, with the following statistical model:

$$Yij = \mu + Di + eij$$

Where:
Yij = observed variation from animal and diet, μ = population mean, Di = fixed effect of diets (1–4) and eij = residual error. Duncan's Multiple Range Tests was used to identify differences among means and significant differences were declared at $p < 0.05$, where dietary treatments affect.

RESULTS AND DISCUSSION

Chemical composition of ingredients and experimental diets

Table 1 shows the chemical composition of the experimental diets, guinea grass, kenaf grain meal (KGM) and palm kernel cake (PKC). For the ingredients (KGM and PKC) and guinea grass, the crude protein (CP) contents were 21.44 %, 18.44 %, and 8.60 %, respectively. The NDF, ADF and ADL contents of KGM were lower than the PKC (Table 1). The value of dry matter (88.80–88.95 %) for the experimental diets was relatively similar. The CP level ranged from 14.73 % in Diet 1 (25 % PKC + 0 % KGM inclusion) to 16.22 % for Diet 3 (5 %

Table 1. Ingredient proportions (kg) and chemical composition (g/100 g DM) of experimental diets

Ingredients (kg)	Diet 1	Diet 2	Diet 3	Diet 4	KGM	PKC	Guinea grass
Dried cassava peel	55.00	55.00	55.00	55.00	–	–	–
Corn bran	15.00	15.00	15.00	15.00	–	–	–
Palm kernel cake	25.00	10.00	5.00	0.00	–	–	–
Kenaf grain meal	0.00	15.00	20.00	25.00	–	–	–
Soya bean meal	2.50	2.50	2.50	2.50	–	–	–
Di–calcium phosphate	1.00	1.00	1.00	1.00	–	–	–
Limestone	0.75	0.75	0.75	0.75	–	–	–
Premix	0.25	0.25	0.25	0.25	–	–	–
Salt	0.50	0.50	0.50	0.50	–	–	–
Nutrients							
Dry matter	88.81	88.80	88.87	88.95	93.23	93.80	88.76
Crude protein	14.73	14.93	16.22	15.73	21.44	18.44	8.60
Ether extract	2.84	2.95	3.08	3.14	3.48	6.82	2.85
Ash	7.48	7.33	7.15	7.27	5.40	5.21	9.04
NDF	65.21	64.07	62.15	61.63	49.87	64.41	66.23
ADF	49.80	50.12	49.10	48.64	28.91	48.48	46.03
ADL	18.37	18.14	16.16	15.87	10.64	17.94	16.86
Determined nutrients							
TDN	47.90	48.77	50.13	50.37	58.94	52.44	51.76
OMD (%)	47.06	48.05	52.58	53.18	60.95	45.15	48.56
ME (MJ/kg DM)							
ME 1	12.08	12.09	12.15	12.16	12.44	12.24	12.11
ME 2	6.97	7.13	7.38	7.43	9.01	7.81	7.69
Mean ME	9.52	9.61	9.77	9.79	10.73	10.02	9.90

KGM = Kenaf grain meal; PKC = Palm kernel cake; NDF = Neutral detergent fibre; ADF = Acid detergent fibre; ADL = Acid detergent lignin; ME = Metabolisable energy; OMD = Organic matter digestibility; TDN = Total digestible nutrients.

PKC + 20% KGM inclusions). The ash content ranged from 7.15% to 7.48%, being highest (7.48%) in Diet 1 and least in Diet 3 (7.15%). Ether extract was highest (3.14%) in Diet 4 (0% PKC + 25% KGM). Except for the ADF in Diet 2 (10%PKC + 15% KGM), the NDF, ADF and ADL contents in the diets decreased as the percentage of KGM inclusion increases, with values ranging from 61.63% to 65.21%, 48.64% to 49.80% and 15.87% to 18.37%, respectively. In contrast, the determined values of Total Digestible Nutrients (TDN), Organic matter digestibility (OMD%) and mean Metabolisable energy (ME) by the equations of De Boever et al. (1997) and Moran (2005) progressively increased as the percentage of KGM in the diets increases, with highest values observed in Diet 4 (12.24%, 50.37%, 53.18% and 9.79 MJ/kg DM) and lowest in Diet 1(9.75%, 47.90%, 47.06% and 9.52 MJ/kg DM).

The range of CP level (14.73% to 16.22%) for all experimental diets is above the values (13.6% to 13.7% CP) reported by Rahman et al. (2013b) for goats fed concentrate mixture of 32% PKC. The relatively high CP levels in Diet 4 (15.73%) compared to Diet 1 (14.73%) revealed that Kenaf grain meal can replace palm kernel cake to meet the protein requirement of WAD sheep. Similarly, the highest CP value (16.22%) observed in Diet 3 (5% PKC + 20% KGM inclusions) compared to the levels (15.48% to 15.89% CP) for goat diets with varying inclusions of palm kernel cake (Chanjula et al., 2010) further elucidates the positive associative effects of dietary protein in kenaf grain meal with the moderate CP content of palm kernel cake. Additionally, the range (2.84–3.14%) of ether extract for all experimental diets were not above the range of dietary fat (5–6%) considered as maximum (Kucuk et al., 2003) for ruminants that could inhibit microbial activity and reduce nutrient digestibility.

The high fibre fractions of all the diets were not far-fetched as the notable ingredients mixtures (cassava peel, kenaf grain and palm kernel cake) are naturally fibrous (Mok, 2013; Dierenfeld and Fagbenro, 2014; Ayadi et al., 2016). Comparatively, contamination of palm kernel cake with nutshells during oil extraction could have contributed to high fibre fractions of diets containing a varying proportion of PKC and KGM relative to diet replaced with KGM. Similarly, the hard fibrous seed coat of kenaf grain might also be a reason for the high NDF values observed for diet replaced with kenaf grain. Remarkably, the determined metabolisable energy (ME) values show that all the diets irrespective of the proportion of replacement were sufficient to supply the energy required for growth and maintenance of small ruminants as documented (Salah et al., 2014). The nutritional contents of all the experimental diets revealed that kenaf grain meal could successfully

Table 2. Feed and nutrient intake and weight gain of WAD sheep fed experimental diets according to varying inclusions of palm kernel cake and kenaf grain meal

Parameters	T1	T2	T3	T4	SEM	*P*-value
Feed intake (g/day)						
Cassava peel-based concentrate	280.71[d]	295.15[c]	313.63[b]	344.27[a]	6.15	<.0001
Guinea grass	258.25[b]	315.06[a]	320.37[a]	318.55[a]	6.81	<.0001
Total feed intake (g/day)	538.96[d]	610.21[c]	634.00[b]	662.82[a]	11.85	<.0001
Total feed intake (g/kgW$^{0.75}$)	93.41[c]	106.12[b]	106.74[b]	108.48[a]	1.56	<.0001
Nutrient intake (g/kgW$^{0.75}$)						
Dry matter	82.93[d]	94.26[c]	94.80[b]	96.39[a]	1.38	<.0001
Crude protein	11.01[d]	12.38[c]	13.20[b]	13.35[a]	0.24	<.0001
Ash	7.69[d]	8.72[b]	8.65[c]	8.81[a]	0.12	<.0001
Ether extract	2.66[d]	3.08[c]	3.16[b]	3.26[a]	0.06	<.0001
Neutral detergent fibre	61.37[d]	69.21[b]	68.54[c]	69.26[a]	0.86	<.0001
Acid detergent fibre	44.82[d]	50.97[b]	50.75[c]	51.41[a]	0.70	<.0001
Acid detergent lignin	16.48[d]	18.56[a]	17.63[c]	17.73[b]	0.19	<.0001
Weight gain (g/day)						
Initial body weight (kg)	9.48	9.62	9.86	9.88		
Final body weight (kg)	11.20[c]	10.97[d]	11.66[b]	12.48[a]	0.15	<.0001
Average daily weight gain (g/day)	20.48[b]	16.07[c]	21.43[b]	30.95[a]	1.42	<.0001
Feed conversion ratio	26.37[c]	37.97[a]	29.59[b]	21.47[d]	1.57	<.0001

[abcd] = Means with the same superscripts in the same row are significantly different ($p < 0.05$) SEM = standard error of the mean; P-value = Probability value
TI = 25% PKC + 0% KGM; T2 = 10% PKC+15% KGM; T3 = 5% PKC + 20% KGM; T4 = 0% PKC + 25% KGM.

replace palm kernel cake to meet the nitrogen and energy requirements of small ruminants.

Feed and nutrient intake and weight gain

The feed intake, intake of nutrients (g/kg $W^{0.75}$) and weight gain (g/day) by WAD sheep were influenced ($p < 0.05$) by the replacement levels of palm kernel cake with kenaf grain meal across the treatments (Table 2). Total feed intake (g/day and g/kg $W^{0.75}$) values ranged from 538.96 to 662.82 and 93.41 to 108.48, respectively, with highest values (662.82 g/day and 108.48 g/kg $W^{0.75}$) observed for sheep fed Diet 4 (25% KGM inclusion) and lowest (538.96 g/day and 93.41 g/kg $W^{0.75}$) in sheep fed Diet 1(25% PKC inclusion). However, total feed intake (g/kg $W^{0.75}$) was similar ($p > 0.05$) for sheep fed Diets 2 (10% PKC + 15% KGM) and 3 (5% PKC + 20% KGM), respectively. The intake of nutrients (g/kg $W^{0.75}$) differed ($p < 0.05$) significantly. Except for the lignin fraction, sheep fed cassava peel-based concentrates diet in which KGM totally replaced PKC (0% PKC + 25% KGM inclusion), had a higher ($p < 0.05$) intake of DM (96.39 g/kg $W^{0.75}$), CP (13.35 g/kg $W^{0.75}$), Ash (8.81 g/kg $W^{0.75}$), EE (3.26 g/kg $W^{0.75}$), NDF (69.26 g/kg $W^{0.75}$) and ADF (51.41 g/kg $W^{0.75}$) compared to other treatments.

As the intake of DM (94.80 g/kg $W^{0.75}$), CP (13.20 g/kg $W^{0.75}$) and EE (3.16 g/kg $W^{0.75}$) by sheep fed Diet 3 (5% PKC + 20% KGM) closely followed sheep fed Diet 4 (0% PKC + 25% KGM inclusion), values of intake of nutrients by sheep fed Diet 1 (without replacement for PKC) was relatively lower than other sheep fed diets of PKC inclusion, either partially (10% PKC + 15% KGM or 5% PKC + 25% KGM) or replaced with KGM. While similar ($p > 0.05$) weight gain was observed for sheep fed Diets 1 and 2, respectively, weight gain (30.95 g/day) and efficiency of feed conversion (21.47) were significantly ($p < 0.05$) highest for sheep fed diet containing a higher percentage of KGM without PKC inclusion compared to other treatment groups.

The total feed intake (610.21–662.82 g/day) observed in this study is below the range (668.27–829.82 g/day) reported (Fentie and Melaku, 2008) for Farta sheep. However, the dry matter intake (82.93–96.39 g/kg $W^{0.75}$) is above the range (58.6–82.2 g/DM kg $W^{0.75}$) for the same breed of sheep. Briefly, the higher total feed intake (610.21–662.82 g/day and 106.12–108.48 g/kg $W^{0.75}$) observed for WAD sheep fed diets containing KGM is an indication that experimental diets were readily accepted from the comparable dry matter intake (82.93–96.39 g/kg $W^{0.75}$) observed among the dietary groups. High lipid intake above the maximum by animals reduces dry matter intake often orchestrated by physiological satiety mechanism (Leonhardt and Langhans, 2004). However, the comparable ($p < 0.05$) dry matter intake among the dietary groups in this study could be attributed to the ether extract (2.84–3.14%) content in the diets, which was lower than 50–70 g/kg DM ether extract considered as maximum to negatively affect the dry matter intake. The trend of increase in dry matter intake observed in the present study also corroborates the findings of Sgwane et al. (2008) when sheep fed low-quality hay was supplemented with kenaf seed. This also suggests that the nitrogen content of kenaf seed and fibre fractions was sufficient in nutrients to improve ruminal microbial activities for feed degradability and consequently translates to a higher dry matter intake.

Similarly, the crude protein (14.93–16.22%) and ether extract contents of all the diets with KGM inclusions was sufficient to elevate the intake of CP and EE, ditto the ash intake. Therefore, highest total feed intake (662.82 g/day and 108.48 g/kg $W^{0.75}$), weight gain (30.95 g/day) and efficiency of feed conversion (21.47) recorded for sheep fed Diet 4 (25% KGM inclusion), implies a superior performance from the total replacement of PKC with KGM compared to other treatment groups. Furthermore, body weight gains ($p < 0.05$) by sheep fed Diet 3 (21.43g/day) and 4 (30.95g/day), respectively, compared with sheep fed Diet 2 (10% + PKC 15% KGM) affirmed that between 20–25% of KGM could successfully replace PKC in cassava peel-based ration for sheep. However, the intake of NDF in this study is contrary to the range of 55–60% NDF in feed reported to limit intake (Meissner and Paulsmeier, 1995). Acceptable intake by the sheep of the generally high NDF fraction for all experimental diets, though considered as medium quality fibre for ruminants may have been enhanced, probably by increasing chewing and rumination activities as documented (Yang and Beauchemin, 2009). Thus, higher intake in this study, especially with increasing replacement of palm kernel cake by kenaf grain meal affirmed that non-viable kenaf seed is rich in rumen-degradable nutrients, particularly nitrogen, sulphur and essential minerals required for optimal rumen microbial growth.

Apparent nutrient digestibility

Apparent nutrient digestibility coefficient differed ($p < 0.05$) significantly. The DM, CP and EE digestibility values across the treatments ranged from 63.37% to 73.35%, 86.06% to 79.49% and 81.79% to 87.26%, respectively while the NDF, ADF and ADL digestibility values also ranged from 74.36% to 81.32%, 74.70% to 81.66% and 80.58% to 85.52%, respectively. Sheep fed Diet 3 (5% PKC + 20% KGM inclusions in cassava

Table 3. Apparent nutrient digestibility (%) by WAD sheep fed experimental diets according to varying inclusions of palm kernel cake and kenaf grain meal

Nutrient (%)	TI	T2	T3	T4	SEM	*P*-value
Dry matter	63.59^{c}	68.65^{b}	73.35^{a}	63.37^{d}	1.06	<.0001
Crude protein	79.49^{d}	84.41^{b}	86.06^{a}	80.36^{c}	0.70	<.0001
Ether extract	81.79^{d}	83.40^{b}	87.26^{a}	82.60^{c}	0.54	<.0001
Ash	68.43^{c}	72.62^{b}	76.35^{a}	67.48^{d}	0.91	<.0001
Neutral detergent fibre	75.08^{c}	78.76^{b}	81.32^{a}	74.36^{d}	0.73	<.0001
Acid detergent fibre	75.70^{c}	78.87^{b}	81.66^{a}	74.70^{d}	0.71	<.0001
Acid detergent lignin	81.21^{c}	83.30^{b}	85.52^{a}	80.58^{d}	0.50	<.0001

^{abcd} = Means with the same superscripts along the same row are significantly different ($p < 0.05$). SEM = standard error of the mean; *P*-value = Probability value
TI = 25% PKC + 0% KGM; T2 = 10% PKC + 15% KGM; T3 = 5% PKC+20% KGM; T4 = 0% PKC + 25% KGM

peel-based concentrate) had higher ($p < 0.05$) DM, CP, EE, Ash and fibre (NDF, ADF, ADL) digestibility values compared to other treatment groups. However, nutrient (DM, NDF, ADF and ADL) digestibility coefficients of sheep fed Diet 1 (25% PKC + 0% KGM) was higher ($p < 0.05$) than those on Diet 4 (0% PKC + 25% KGM), totally replaced with KGM.

Nutrient digestibility is dependent on the cell wall constituents; especially neutral detergent fibre and lignin. Despite the high cell wall concentration of experimental diets in this study, replacement of PKC with KGM improved dry matter and nutrient intake by WAD sheep. As evidently shown, the crude protein (14.93%–16.22%) and relatively lower ether extract (2.95%–3.14%) contents of all the diets with KGM inclusions could have provided sufficient substrates for optimal rumen activities for enhanced fibre degradability and intake of NDF and ADF compared to sheep fed diet without KGM inclusion. Considering the high rumen degradability and solubility of the protein in kenaf seed and palm kernel cake (Kucuk et al., 2003; Carvalho et al., 2005), protection of nitrogen from total degradation in the rumen for subsequent absorption in the abomasum and small intestine (Rotger et al., 2006) could have been provided by cassava peel, a highly fermentable carbohydrate in a ruminant ration.

Nitrogen utilisation

Nitrogen (N) utilisation by the sheep was affected ($p < 0.05$) by the inclusion levels of palm kernel cake and kenaf grain meal in the diets (Table 4). N-intake values increased across the treatment as the percentage of replacement with KGM in the feed increases. N-intake values were highest (2.14 g/kg $W^{0.75}$) in sheep fed Diet 4 and lowest (1.76 g/kg $W^{0.75}$) in sheep fed diet without KGM inclusion. Similar trend of wider numerical ($p < 0.05$) differences for nitrogen absorbed and retained and apparent nitrogen digestibility were also observed between sheep fed Diet 1 (1.36 g/kg $W^{0.75}$, 1.40 g/kg $W^{0.75}$ and 79.46%) and Diets 2 to 4 (1.63 to 1.78 g/kg $W^{0.75}$, 1.67 to 1.82 g/kg $W^{0.75}$ and 80.40% to 86.04%), respectively.

Urinary N by the sheep was not influenced ($p > 0.05$) by the varying inclusion levels of either PKC or KGM in the feed. However, faecal N between sheep fed Diet 2 and 3, respectively, was similar ($p > 0.05$), but higher (0.42g/kg $W^{0.75}$) for sheep on Diet 4. Highest

Table 4. Nitrogen utilisation (g/kg $W^{0.75}$) by WAD sheep fed experimental diets according to varying inclusions of palm kernel cake and kenaf grain meal

Parameters	T1	T2	T3	T4	SEM	*P*-value
Nitrogen intake	1.76^{d}	1.98^{c}	2.11^{b}	2.14^{a}	0.04	<.0001
Faecal Nitrogen	0.36^{b}	0.31^{c}	0.30^{c}	0.42^{a}	0.01	<.0001
Urinary Nitrogen	0.04	0.04	0.04	0.04	0.00	1.000
N-retained	1.36^{d}	1.63^{c}	1.78^{a}	1.68^{b}	0.04	<.0001
N-absorbed	1.40^{d}	1.67^{c}	1.82^{a}	1.72^{b}	0.04	<.0001
% Nitrogen retained	77.27^{d}	82.15^{b}	84.26^{a}	78.55^{c}	0.72	<.0001
% Nitrogen absorbed	97.25^{d}	97.48^{c}	97.93^{a}	97.70^{b}	0.07	<.0001
Apparent nitrogen digestibility (%)	79.46^{d}	84.27^{b}	86.04^{a}	80.40^{c}	0.70	<.0001

^{abcd} = Means with the same superscripts along the same row are significantly different ($p < 0.05$). SEM = standard error of the mean; *P*-value = Probability value.
TI = 25% PKC + 0% KGM; T2 = 10% PKC + 15% KGM; T3 = 5% PKC + 20% KGM; T4 = 0% PKC + 25% KGM

N-utilization values [N-absorbed and retained (1.82 and 1.78 g/kg $W^{0.75}$), per cent N-retained and absorbed (97.93 and 8.26%)] were observed in sheep fed Diet 3, containing 5% PKC + 20% KGM inclusion levels. Apparent N-digestibility values were quite high, ranging from 79.46% in Diet 1 (25% PKC + 0% KGM) to 86.04% in Diet 4 (0% PKC + 25% KGM).

The nitrogen (N) balance across the dietary treatments unveiled the positive associative effects of palm kernel cake replacement with kenaf grain meal in the cassava-based concentrate on nitrogen utilisation. Highest N-retention by sheep on Diet 3 compared to the group on diet without KGM inclusion (Diet 1) could be attributed to the relatively higher protein content in the diet and lower N-excretion. Lower N-retention observed for sheep on Diet 1 could be linked to the high protein degradability of PKC in the rumen. However, the higher N-intake by sheep on Diet 4 suggests that the nitrogen was the most available and sufficient for maintenance and tissue deposition, which accounted for the highest and significant body weight gain. Similarly, greater N-digestibility observed especially for sheep fed diets with varying inclusion levels of PKC and KGM corroborates other findings (Phillips et al., 2002; Carvalho et al., 2005; Sgwane et al., 2008), which could have arisen from the positive associative effects of the high ruminal digestible protein. In summary, the significant N-utilisation observed for the experimental sheep may be from the readily fermentable energy substrates provided by cassava peel, corn bran and the by-pass protein from kenaf seeds which resulted in positive N retention as opined by Sgwane et al. (2008) and Sarwar et al. (2003).

CONCLUSION

The replacement of PKC with KGM increased the nutrient intake and digestibility, nitrogen utilisation and body weight gain of WAD sheep compared to sole PKC inclusion in cassava peel based concentrate. Meanwhile, sustenance of higher feed and nutrient intake, least feed conversion ratio and improved body weight gain with Diet 4(0% PKC + 25% KGM inclusion levels), without negative impact elucidate the possibility of total replacement of PKC with KGM in cassava peel ration for WAD sheep. Therefore, kenaf grain meal would be a supplementary protein and energy sources to cassava peel for small ruminant feeding.

CONFLICT OF INTEREST

The authors declared no conflicts of interest with respect to research, authorship and publication of this article.

REFERENCES

Adegbola A. A., Smith O. B., Okeudo N. J. (2010): Response of West African dwarf sheep fed cassava peel and poultry manure based diets. FAO corporate document repository, produced by ILRI. 1–8 pp. www.fao.org/airdocs/ILRI/x5536eop.htm.

Ajayi F. T., Babayemi O. J., Taiwo A. A. (2016): Performance and digestibility of N'Dama cattle fed concentrate diets containing varying levels of corncob. Nigerian Journal of Animal Production 43: 223–230.

Alimon A. R., Ivan M., Jalaludin, S. (2011): Effects of different levels of dietary sulfur and molybdenum on concentrations of copper and other elements in plasma and liver of lambs fed palm kernel cake diets. British Journal of Nutrition 106: 1224–1230.

AOAC (2005): Official methods of analysis. (18th edn.). Association of Official Analytical Chemists, Washington, DCA.

Ayadi R., Hanana M., Mzid R., Hamrouni L., Khouja M. L., Hanachi A. S. (2017): *Hibiscus cannabinus* L. "Kenaf": A review paper. Journal of Natural Fibres 14: 466–484, DOI: 10.1080/15440478.2016.1240639.

Carvalho L. P. F., Melo D. S. P., Pereira C. R. M., Rodrigues M. A. M., Cabrita A. R. J., Fonseca, A. J. M. (2005): Chemical composition, in vitro digestibility, N degradability and enzymatic intestinal digestibility of five protein supplements. Animal Feed Science and Technology 119: 171–178.

Chanjula P., Mesang A., Pongprayoon S. (2010): Effects of dietary inclusion of palm kernel cake on nutrient utilization, rumen fermentation characteristics and microbial populations of goats fed *Paspalum plicatulum* hay-based diets. Songklanakarin Journal of Science and Technology 32: 527–536.

Chen X. B., Gomes M. J. (1995): Estimation of microbial protein supply to sheep and cattle based on urinary excretion of purine derivatives – an overview of the technical details. International Feed Resources Unit, Rowett Research Institute, Bucksburn Aberdeen, UK, pp. 2–20.

Cheng W. Y., Akanda J. M. H., Nyam K. L. (2016): Kenaf seed oil: A potential new source of edible oil. Trends in Food Science Technology 52: 57–65. https://doi.org/10.1016/j.tifs.2016.03.014.

De Boever J. L., Cottyn B. G., De Brabandar D. L., Vanacker J. M., Boucque C. V. (1997): Prediction of the feeding value of maize silage by chemical parameters, *in vitro* digestibility and near infra-red spectroscopy (NIRS). Animal Feed Science Technology 66: 211–222.

Dierenfeld E. S., Fagbenro O. A. (2014): Use of cassava in livestock and aquaculture feeding programs. ILRI Discussion Paper 25. Nairobi, Kenya: International Livestock Research Institute.

Fentie B., Melaku S. (2008): Effects of supplementation of Farta sheep fed hay with sole or mixtures of noug seed meal and wheat bran on feed intake, digestibility and body weight change. Tropical Animal Health Production 40: 597–606.

Fievez V., Babayemi O. J., Demeyer D. (2005): Estimation of direct and indirect gas production in syringes: A tool to estimate short-chain fatty acid production that requires minimal laboratory facilities. Animal Feed Science Technology 12: 197–210.

Jarrige R. (1989): Ruminant Nutrition: Recommended Allowances and Feed Tables. INRA. John Libbey. London, 390 p.

Jayanegara A., Nahrowi R. M., Laconi E. B. (2019): Estimation and validation of total digestible nutrient values of forage and concentrate feedstuffs. 9th Annual Basic Science International Conference. IOP Conf. Series: Materials Science and Engineering, 546 p.

Kucuk O., Hess B. W., Ludden P. S., Rule D. C. (2003): Effects of increasing dietary forage in limited-fed ewes fed a 6% fat diet. Sheep and Goats Research Journal 18: 25–33.

Leonhardt M., Langhans W. (2004): Fatty acid oxidation and control of food intake. Physiology & Behavior 83: 645–651.

Mariod A. A., Fathy S. F., Ismail M. (2010): Preparation and characterization of protein concentrates from defatted kenaf seed. Food Chemistry 123: 747–752.

Meissner H. H., Paulsmeier D. V. (1995): Plant compositional constituents affecting plant and animal species prediction of forage intake. Journal of Animal Science 73: 2447–2457.

Mok C. H., Lee J. H., Kim B. G. (2013): Effects of exogenous phytase and beta mannanase on ileal and total tract digestibility of energy and nutrient in palm kernel expeller-containing diets fed to growing pigs. Animal Feed Science Technology 186: 209–213.

Moran J. (2005): Nutrient requirements of dairy cows. In Technical dairy farming: Feeding management for small dairy farmers in the humid tropics. Landlinks Press, pp. 51–59.

Ngwe T., Nukui Y., Oyaizu S., Takamoto G., Koike S., Ueda K., Nakatsuji H., Kondo S., Kobayashi Y. (2012): Bean husks as a supplemental fibre for ruminants: potential use for activation of fibrolytic rumen bacteria to improve main forage digestion. Animal Science Journal 83: 43–49.

Phillips W. A., Reuter R. R., Brown M. A., Fitch J. Q., Rao S. R., Mayeux H. (2002): Growth and performance of lambs fed a finishing diet containing either Alfalfa or Kenaf as the roughage source. Small Ruminant Research 46: 75–79.

Rahman M. M., Abdullah R. B., Wan Embong W. K., Nakagawa T., Akashi R. (2013a): Effect of palm kernel cake as protein source in a concentrate diet on intake, digestibility and live weight gain of goats fed Napier grass. Tropical Animal Health Production 45: 873–878.

Rahman M. M., Abdullah R. B., Wan Khadijah W. E., Nakagawa T., Akashi R. (2013b): Feed intake, digestibility and growth performance of goats offered Napier grass supplemented with molasses protected palm kernel cake and soya waste. Asian Journal of Animal and Veterinary Advances 8: 527–534.

Rotger A., Ferret A., Calsamiglia S., Manteca X. (2006): Effects of nonstructural carbohydrates and protein sources on intake, apparent total tract digestibility and ruminal metabolism *in vivo and in vitro* with high-concentrate beef cattle diets. Journal of Animal Science 84: 1188–1196.

Salah N., Sauvant D., Archimède H. (2014): Nutritional requirements of sheep, goats and cattle in warm climates: A meta-analysis. Animal 8: 1439–1447.

Sarwar M., Ajmal Khan M., Mahr-un-Nisa (2003): Nitrogen retention and chemical composition of urea treated wheat straw ensiled with organic acids or fermentable carbohydrate. Asian-Australasian Journal of Animal Sciences 16: 1583–1592.

Sgwane T. S., Teleni E., Gardiner C. P. (2008): Kenaf seeds (*Hibiscus cannabinus* L.) as a protein supplement to sheep. In: Proceedings of Australian Rangeland Society 15th Biennial Conference. 28th September–26th October 2008: Charters Towers, QLD, Australia, Australian Rangeland Society.

Silva R. L. N. V., Oliveira R. L., Ribeiro O. L., Leao A. G., Carvalho G. G. P., Ferreira A. C., Pinto L. F. B., Pereira E. S. (2013): Palm Kernel Cake for Lactating Cows in Pasture: Intake, Digestibility, and Blood Parameters. Italian Journal of Animal Science 12: 257–264.

SAS (2000): Statistical Analysis System User's Guide. Version 8.1, SAS Institute Inc., Cary, NC, USA.

Van Soest P. J., Robertson J. B., Lewis B. A. (1991): Methods for dietary fibre, neutral detergent fibre and non-starch polysaccharides in relation to animal performance. Journal of Dairy Science 74: 3583–3597.

Webber C. L. III, Bhardwaj H. L., Bledsoe V. K. (2002): Kenaf production: Fibre, feed and seed. Trends in New Crops and New Uses (Eds J. Janick and A. Whipkey), ASHS Press, Alexandria, VA, pp. 327–329.

Yang W. Z., Beauchemin K. A. (2009): Increasing physically effective fibre content of dairy cow diets through forage proportion versus forage chop length: Chewing and ruminal pH. Journal of Dairy Science 92: 1603–1615.

Received: October 9, 2020
Accepted after revisions: November 6, 2021