Intake, digestibility, microbial protein production, and nitrogen balance of lambs fed with sorghum silage partially replaced with dehydrated fruit by–products

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Abstract: The objective of this study was to evaluate intake, digestibility, microbial protein production, and nitrogen balance of lambs fed with different dehydrated fruit residues replacing sorghum silage. The experiment was conducted using twenty-five mixed-breed male lambs (20.64 ± 4.20 kg) with an average age of 8 months. Treatments consisted of sorghum silage and 75% (DM basis) replacement of sorghum silage for dehydrated pineapple, banana, mango, or passion fruit by-products. The experiment was conducted in a completely randomized design with five treatments and five repetitions. Results were subjected to one-way analysis of variance and means were compared using the Tukey test at 5% of probability. Daily nutrient intake did not differ (P>0.05) between the different treatments evaluated regardless of how it was expressed (kg/day or % body weight [BW]), except for NDFap (% BW) that was higher (P<0.05) in the diet with passion fruit residue than in diets with banana and mango residues. The digestibility of ethereal extract was higher (P<0.05) for diets with sorghum silage, pineapple, and passion fruit compared to the diet with banana residue. The digestibility of neutral detergent fiber corrected for ashes and protein was higher (P<0.05) on animals receiving sorghum silage than diets with mango and passion fruit residues. No difference (P>0.05) was observed for purine derivative excretion, microbial efficiency, nitrogen intake, nitrogen loss (urine and faeces), and nitrogen balance between diets. In conclusion, dehydrated fruit by-products (pineapple, banana, mango, and passion fruit) are good options for partial replacement of sorghum silage (75%) and potentially reduce feeding costs.

Keywords: Alternative feedstuff, Fruit residues, Lamb, Microbial nitrogen efficiency, Nutritional value.

1. Introduction

Seasonal productivity of tropical forage is an important constraint to lamb production in regions of tropical climate. Most production of forage occurs during the rainy season due to greater availability of water and high temperatures, which in turn are essential for tropical climate forages to express their potential growth (Silva et al. 2008). The opposite is observed during the harmattern season, which is characterized by relatively low temperatures and water precipitation, resulting in forage shortage. Thus, there is an irregular production of forage throughout the years, and the use of by-products of fruit processing as feed for sheep could be an alternative during the dry season.

Fruit production and processing has been growing, and so is the amount of by-products produced. The use of agricultural technologies such as irrigation (Lousada Junior et al. 2005) has improved the production of fruits and promoted the expansion of fruit processing agribusiness. A side consequence of this expansion has been the increasing amount of residues produced over the years from different fruits (Matias et al. 2005), since most part of the fruit is not used in industrial process. According to Waughon (2006), about 77.5% of pineapple fruit production consists of bark, leaves, stems, crown, and discarded fruits. About 40 to 60% of mango weight become residue after processed for juice (Porras 1989). Only 23.2% of passion fruit weight is used for juice production (Ferrari et al. 2004).

Use of residues from fruit processing as sheep feed would reduce the environmental impacts of fruit processing as well as reduce costs of animal feeding (Lousada Junior et al. 2005). Ruminants have the unique ability to use fibrous materials as energy source due to the physiological adaptation of their rumen. This means that the use of these feedstuffs thereby could replace conventional feedstuff, reducing the competition between humans and animals over these conventional feed ingredients.

Much of the residue produced is lost or misused due to the lack of knowledge about its potential use. Precise estimates of dry matter (DM) intake is needed to promote efficient nutrient intake in ruminants (NRC 2001). Physical-chemical characteristics of dietary feedstuff and their interactions may have a great effect on dry matter intake (Allen 2000). In addition, digestibility evaluation is essential to determine the nutritional value of feedstuffs (Valadares Filho et al. 2000). According to Pereira (2003), knowledge about nutrient digestibility of alternative feedings is essential to establish the energy they supply.

Therefore, our study is aimed at evaluating intake, digestibility, microbial protein production, and nitrogen balance of lambs fed with different dehydrated fruit residues replacing sorghum silage.

2. Materials and Methods

All animal procedures were carried out in accordance with the guidelines described in the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS 2010). In addition, Ethics Committee on the Use of Animals from the Federal University of the Jequitinhonha and Mucuri Valleys (UFVJM) approved the experimental procedures used in this study (Protocol nº 018/2011 – UFVJM).

The experiment was conducted in the Ruminants Laboratory on the Experimental Farm of Moura of the UFVJM, located in Curvelo – MG, Brazil at 18º 49’ South latitude and 44º 23’ West longitude. According to Köppen classification, the weather of the region is

Aw - Tropical Savanna with dry winter (Reboita et al. 2015). Bromatological analyses were carried out in the Food Analysis Laboratory of the UFVJM – JK Campus, Diamantina – MG, Brazil.

2.1. Animals, diets, and handling

Twenty-five non-castrated mixed breed Santa Inês and Texel male lambs with mean age and body weights of 8 months and 20.64 ± 4.20kg respectively were used for the study. They were placed in individual metabolic crates of 1.5 x 1.0 m equipped with individual feeding bunk and drinking fountain. The crates were cleaned on a daily basis. At the beginning of the experiment, the animals were orally dewormed against endoparasites using medicine with active ingredient of albendazole – 2 ml per 10 kg of live weight.

The experiment was carried out for 48 days between September and October of 2011, consisting of 10-day acclimatization period, and 38 days for data collection. Lambs received a total mixed ration formulated to have equal amount of protein and energy as recommended by the NRC (2007) (Table 1).

We evaluated the inclusion of different fruit by-product as a substitute for sorghum silage (dry matter basis). The animals were randomly assigned to one of the following five treatments: (1) control, sorghum silage as forage source and no inclusion of fruit residue; (2) pineapple, 75% replacement of sorghum silage for pineapple (*Ananas comosus* L.) residue; (3) banana, 75% replacement of sorghum silage for banana (*Musa* spp.) residue; (4) mango, 75% replacement of sorghum silage for mango (*Mangifera indica*) residue; and (5) passion fruit, 75% replacement of sorghum silage for passion fruit (*Passiflora* ssp.) residue. The forage to concentrate ratio of the diets were 40:60 (DM basis) (Table 1) and were mixed together right before the animals were fed. The lambs within each treatment were fed ad libitum diets twice a day (07:00 and 15:00). The amount supplied to each animal was adjusted every day based on the leftovers of the previous 24 hours allowing for approximately 10% of leftovers. Animals were provided with water and mineral mixture ad libitum.

Throughout the study period, quantity of feed provided and quantity leftover as unconsumed were daily recorded in order to measure individual consumption and to adjust the amount supplied to ensure free-choice access. Diets and leftovers were daily sampled as well, placed in plastic bags, and kept at - 10º C until analyses.

Different residues were composed of different parts of the fruit. Pineapple residue was composed of the fruit skin and pressed pulp. Banana residue was composed of the fruit peels. Mango residue was composed of the fruit peels, seeds, and pressed pulp. The passion fruit residue was composed of the fruit peels and seeds. Upon arrival to the experimental farm, residues were spread on top of a black plastic forming a 5 cm thick layer. They were exposed to the sun for drying, being revolved three times a day, until they show a dry and crumbly aspect. Then, they were ground on sieve No. 1 and used to feed the animals. Nutrient composition of the residues and sorghum silage are shown in Table 2.

Apparent digestibility of the nutrients was estimated on digestibility trials carried out from days 30 to 34 of the experiment (five consecutive days). The total amount of feces produced was collected using nappa leather (83% polyester and 17% cotton) bags adapted into the animal's body. Before morning feeding, the feces produced by each animal were weighed, sampled (about 10% of the total), and kept frozen at -20° C for later analyses.

Spot urine samples were used to quantify microbial protein production and nitrogen balance. Urine samples were collected from day 35 to 37 at 08:00, 12:00, and 16:00h. We attached a plastic bag to a galvanized wire loop and tied them to the back of the animals using an elastic band. When spontaneous urination occurred, the bag was removed and the urine sample was immediately processed. A sample of 10 ml of urine was measured and diluted in 40 ml of 0.036 N sulfuric acid to prevent bacterial destruction of urinary purine derivatives and precipitation of uric acid (Chen and Gomes 1992). Another 50 ml sample was collected to quantify total nitrogen. Samples were labelled and stored at -15° C for future analyses.

Blood was sampled in the jugular vein on the 38th day, approximately four hours after the morning feeding using 8 ml tubes (Vacutainer Gel & Clot Blood Tube). Blood samples were then centrifuged at 3,500 rpm for 15 minutes. Plasma was extracted, placed in plastic tubes (Eppendorf® Safe-Lock Microcentrifuge Tube), and kept at -15° C for future analyses.

2.2. Chemical analyses and measurements

Feedstuff (sorghum silage, fruit residues, and concentrate), leftovers, and faecal samples, after drying, were grounded in a Wiley mill (Thomas Model 4 Wiley® Mill; Thomas Scientific, Swedeboro, NJ, USA) to pass through a 1-mm stainless steel curved round-hole sieve. Samples were analyzed for DM, organic matter (OM), crude protein (CP), ethereal extract (EE), and ashes (AOAC 1997). Neutral detergent fiber (NDF) contents were obtained using thermostable amylase (Termamyl120L,Novozymes) according toMertens (2002). We used the Ankom® system for NDF evaluations, using bags (5.0 x 5.0 cm, porosity of 100 micrometers) which was made using non-woven fabric (TNT 100

g/m^2). Acid detergent fiber (ADF), acid detergent insoluble nitrogen (ADIN), neutral detergent insoluble nitrogen (NDIN), and lignin (LIG) (72% sulfuric acid) were obtained by the sequential method of Robertson and Van Soest (1981) and presented as suggested by Licitra et al. (1996).

Dry matter intake (DMI) was calculated based on the relationship between the DM provided and the DM of the leftovers as follows: $DMI = (DM_{diet} \times \text{Quantity consumed}) - (DM_{leftover} \times \text{Quantity of leftovers})$. Nutrient intake (NI) was calculated based on the relationship between a nutrient and DM, and its content on diet and leftover as follows: $NI = (\%\ Nutrient_{diet} \times DM_{ingested}) – (\%\ Nutrient_{leftover} \times DM_{leftover})$. Apparent digestibility (AD) of the nutritional components from the diet was obtained using the equation proposed by Silva and Leão (1979):

$$AD = \frac{(DM_{intake} \times \%nutrient) - (DM_{excreted} \times \%nutrient)}{DM_{intake} \times \%nutrient} \times 100$$

Non-fiber carbohydrates (NFC) were estimated according to Hall and Akinyode (2000): $NFC = 100 – ([CP_{total} - CP_{urea} + \%urea] + NDF + EE + MM]$.

Total digestible nutrients (TDN) of the diet were calculated using the equation proposed by the NRC (2001): TDN = CPd + 2.25 × EEd + NDFapD + NFC; where TDN = total digestible nutrients; CPd = digestible crude protein; EEd = digestible ethereal extract; and NDFapD = neutral detergent fiber corrected for ashes and digestible protein; and NFC= non-fibrous carbohydrates.

Creatinine and uric acid concentrations in urine as well as urea concentration in urine and plasma were measured using a commercial kit (In Vitro®). Total volume of urine (TVU) was estimated using the following equation (Chizzotti et al. 2006, Kozloski et al. 2005):

$$\mathrm{TVU} = \frac{\mathrm{BW} \times \mathrm{Cre}_{\mathrm{ref}}}{\mathrm{Cre}},$$

where TVU is the total volume of urine produced (L); BW is the animal live body weight (kg); Cre_{ref} is the referential daily excretion of creatinine (23 mg kg^{-1} of BW); and Cre is the concentration of creatinine on urine spot samples (mg l^{-1}). Urea nitrogen was obtained by multiplying urea values by 0.4667. Purine derivatives (allantoin, xanthine, and hypoxanthine) were determined in the diluted urine samples by the colorimetric method proposed by Fujihara et al. (1987) and described by Chen and Gomes (1992). The total excretion of purine derivatives (PD) was calculated by summing the results of allantoin, uric acid, xanthine, and hypoxanthine excreted in the urine.

Absorbed microbial purines (Pabs) were calculated based on the excretion of purine derivatives (EPD) in the urine using the equation proposed by Chen and Gomes (1992) for sheep: $EPD = 0.84Pabs + (0.150\ BW^{0.75}\ exp^{-0.25Pabs})$, where $BW^{0.75}$ is the metabolic BW of the animal. Pabs was estimated by solving the equation using the Newton-Raphson iteration process (Chen and Gomes 1992).

The intestinal flow of microbial nitrogen (MN) was estimated based on Pabs using equation proposed by Chen and Gomes (1992):

$$\mathrm{MN} = \frac{\mathrm{Pabs} \times 70}{0.116 \times 0.83 \times 1000}$$

Nitrogen balance (NB) was calculated as the difference between nitrogen intake and nitrogen lost in urine and feces.

2.3. Statistical analyses

The experiment was conducted in a completely randomized design with five treatments and five repetitions. Each animal was considered the experimental unit (n=5 per treatment). The data were analysed using one-way analysis of variance and means were compared using the Tukey test at 5% of probability. The analysis was done using SAS version 9.0. The statistical model used was:

$$Y_i = \mu + T_i + \varepsilon_i$$

where Y_i is the dependent variable (intake; feed digestibility; nitrogen balance etc.), μ is the overall mean, T_i is the ith treatment (pineapple, banana, mango or passion fruit residue; sorghum silage) effect, and ε_i is the residual error of the ith observation.

3. Results

The inclusion of dehydrated fruit by-products did not reduce the acceptability of the diets. Treatments evaluated did not affect (P>0.05) the daily intake of DM, OM, CB, EE, NDF, NDFap, NFC, NFCap, and TDN express in kg/day (Table 3). Treatments did not affect (P>0.05) nutrients and TDN intake expressed as percentage of BW as well, except for NDFap that was higher (P<0.05) among animals on passion fruit diet than animals on banana and mango diets (Table 3).

The inclusion of pineapple, banana, mango, and passion fruit by-products as a partial substitute to sorghum silage did not affect (P>0.05) the apparent digestibility coefficients of DM, OM, CP, NFCap, and TDN (Table 4). The digestibility of EE was lower (P<0.05) for banana diet compared to pineapple, passion fruit, and control diets. Animals on passion fruit and mango diets showed lower (P<0.05) digestibility of NDFap compared to the control diet.

The inclusion of fruit by-products as a partial substitute for sorghum silage did not affected (P<0.05) urinary excretion of allantoin, xanthine-hypoxanthine, and uric acid with average of 14.29, 2.34, and 1.02 mmol/day, respectively. The same was observed for total PD and Pabs with an average of 17.62 and 20.318 mmol/day, respectively (Table 5). The proportion of allantoin, xanthine-hypoxanthine, and uric acid as a percentage of the total was 80.65, 13.48, and 5.86%, respectively.

Sorghum silage replacement for dehydrated fruit residues did not affect (P>0.05) microbial efficiency as well as urea nitrogen concentration in the urine (P>0.05). However, animals on control diet had the highest (P<0.05) serum urea nitrogen, which in turn was not different (P>0.05) from animals on banana residue diet (Table 5). Animals on pineapple, mango, and passion fruit diets had about 33.09% lower serum nitrogen concentration (average of 17.35 mg/dL) than animals on control diet (25.93 mg/dL).

The treatments evaluated did not affect (P>0.05) the intake and loss (feces and urine) of nitrogen as well as nitrogen balance regardless of how it was expressed (g/day or g/kg BW^{075}) (Table 6).

4. Discussion

We have carried out a study to evaluate the effect of partially replacing sorghum silage with fruit by-products. The average dry matter intake DMI (1.13 kg/day; 3.46% BW) was lower than expected, but was in agreement with the results found by other authors (Lousada Junior et al. 2005, Vieira et al. 1999). NRC (2007) suggests that animals weighing on average 20 kg would eat 1.2 kg of DM per day (6.0% BW). Lousada Junior et al. (2005) evaluated the nutritive value of different fruit processing by-products for sheep. They observed average DMI of 0.92 kg/animal and 1.20 kg/animal for diets with pineapple and passion fruit by-products, respectively. The intake range in their study was 1.4 (Barbados cherry by-product) to 4.4% BW (guava by-product). These results are similar to those found in our study.

We did not find differences in NDF intake in diets using dehydrated fruit by-products as a substitute for sorghum silage. Sena et al. (2015), working with different levels of substitution of Tifton 85 hay for passion fruit residue in diets for sheep, did not find a significant difference for NDF intake between the treatments as well. They reported an average NDF intake of 0.61 kg/day, which was higher than what we found (0.27 kg/day). Diets with high NDF content are not desirable, because high NDF may result in low DMI due to the physical filling effect of the rumen (Mertens 1994).

A possible explanation for the highest consumption (% BW) of neutral detergent fiber corrected for ashes and protein (NDFap) on control, passion fruit, and pineapple diets would be the concentration of NDFap on these feedstuffs as well as the characteristic of their fiber. In general, fruit residues show high variation on their NDFap content; Therefore, using only their NDF content to explain animals' feed intake as proposed by NRC (2007) would not be appropriate for animals fed fruit by-products. The variation of NDFap composition is the result of differences in cell wall composition. The proportion of each cell wall component influences the intake of NDFap, mainly because they influence its digestibility that in turn affect nutrient intake.

The lower digestibility of NDFap on passion fruit diet compared to the control diet could be explained by the high lignin content of this by-product. The presence of lignin tends to increase the indigestible fraction of the fiber, reducing the potentially digestible fraction (Wilson 1994).

The average TDN digestibility (67.01%) from our study was higher than reported by Lousada Junior et al. (2005) for diets with pineapple (45.6%) and passion fruit (52.9%) residues. We believe it was due to differences in the by-product composition, especially the pineapple residue because the crown was not included as part of the by-product in our study. In addition, the intake of TDN (0.85 kg/ day; 2.62 % BW) was not affected by the inclusion of any fruit by-products evaluated in our study. Altogether, these results indicated that the use of fruit residues as a partial replacement for sorghum silage would not impair the intake and digestibility of TDN.

The results of PD found in our study were similar to other studies. Allantoin was the most abundant PD similar to Ma et al. (2013). They reported urinary allantoin values of 14.36, 10.24, and 6.33 mmol/day for *ad libitum*, 70%, 50% feed intake treatments, respectively. They also reported values of xanthine-hypoxanthine ranging from 1.54 to 0.98 mmol/day and uric acid ranging from 2.52 to 1.73 mmol/day, respectively, for *ad libitum*, 70%, and 50% feed intake treatments. In our study, we found an average of 14.29, 2.34, and 0.98 mmol/day, respectively, for allantoin, xanthine-hypoxanthine, and uric acid.

The flow of microbial nitrogen (average of 12.50 g/day) found in our study was lower than reported by Fonseca et al. (2006), who observed values ranging from 15.7 to 20.6 g/day for dairy goats, but it was within the range of 14.2 to 8.0 g/day as reported by Santos et al. (2016) for lambs.

Microbial efficiency observed in our study was lower than established recommendations. Valadares Filho et al. (2006) proposed the value of 120 g microbial N/kg TDN for cattle raised under tropical weather condition while the NRC (2001) establishes the value of 130 g microbial N/kg TDN. In our study, however, we found an average of

93.92 g microbial N/kg TDN which was lower than recommended as well as lower than the average of 115.82 g microbial N/kg TDN reported by Silva et al. (2016).

Serum urea nitrogen of animals receiving control diet was higher than animals receiving experimental diets with pineapple, mango, and passion fruit residues. Ruminal microorganisms degrade about 50 to 70% of the CP that reaches the rumen and release ammonia as the result. When ruminal ammonia concentration exceeds the microorganisms' capability of metabolization, it is absorbed and reaches the liver where is transformed in urea. Hence, plasma urea concentration it is the result of urea synthesized in to the liver as well as the urea from amino acid metabolism. Part of this urea is recycled and returned to the rumen through the saliva or absorbed through the rumen wall, while the remaining is excreted in the urine (Kozloski 2002). Our results suggest that animals fed with residues made better use of the nitrogen from the diet as opposed by those that received sorghum silage.

Nitrogen balance was not different between experimental diets evaluated, which indicates the animals retained protein from the diets, achieving the main objective of the nutritional planning. When protein degradation rate exceeds carbohydrate fermentation, large amount of nitrogen compounds can be eliminated through the urine and low performance is observed due to unbalanced energy and protein intake as well as hepatic production of urea (Van Soest 1994). Therefore, our results indicated that the experimental diets provided a balanced supply of protein and energy, which in turn may have improved the use of dietary protein.

In a conclusion, dehydrated fruit processing by-product (pineapple, banana, mango, and passion fruit) could be used as a partial replacement of sorghum silage (75% DM basis) to feed mixed-breed lambs since it did not affect nutrient intake (kg/day), microbial protein synthesis, purine derivative excretion, and nitrogen balance. In addition, they are a good alternative during forage shortage and their use could potentially reduce feeding costs.

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Statement of Animal Rights

All procedures performed in studies involving animals were in accordance with the ethical standards of the institution or practice at which the studies were conducted.

Conflict of interest Statement

The authors have no conflict of interest to declare.

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Table 1. Ingredients and chemical composition of the experimental diets[1].

Item[2]	Treatment				
	Pineapple	Banana	Mango	Passion fruit	Sorghum silage
	30	30	30	30	40
Ingredients (g kg^{-1})					
Sorghum silage	10	10	10	10	-
Ground corn	30	40	25	37	43
Soybean meal	15	18.5	18.5	13	15
Wheat bran	13.5	-	15	8.5	-
Urea/Ammonium sulfate (9:1)	-	-	-	-	0.5
Mineral premix[3]	1.5	1.5	1.5	1.5	1.5
Composition					
DM (*g kg^{-1}*)	86.4	86.4	86.9	87.1	71.2
g kg^{-1} (DM basis)					
OM	92.5	90.7	92.9	88.1	91.5
CP	16.8	17.4	18.1	16.9	17.3
NDIN	12.6	28.8	13.4	14.9	16.7
ADIN	6.8	14.6	6.4	10.2	9.8
EE	2.6	4.2	3.7	3.5	2.8
Ashes	7.4	9.3	7.1	11.9	8.4
TC	73.0	69.7	71.4	67.9	71.4
NDF	27.7	27.3	26.0	30.8	30.2
NDFap	21.9	19.1	17.9	26.0	24.3
NFC	45.0	41.9	45.0	35.8	41.2
NFCap	50.9	50.0	53.2	41.6	47.1
ADF	13.1	11.6	11.8	16.8	13.4
HEM	14.5	15.6	14.2	14.0	16.8
CEL	10.9	7.9	9.1	11.3	10.9
LIG	2.0	3.5	2.5	4.9	2.4

[1]Experimental diets consisted of sorghum silage (control diet) and 75% replacement of sorghum silage for dehydrated fruit processing by-products.

[2]DM = Dry matter; OM = organic matter; CP = crude protein; NDIN = neutral detergent insoluble nitrogen ($g\ kg^{-1}$ of total nitrogen); ADIN = acid detergent insoluble nitrogen ($g\ kg^{-1}$ of total nitrogen); EE = ethereal extract; TC = total carbohydrates; NDF = neutral detergent fiber; NDFap = neutral detergent fiber corrected for ashes and protein; NFC = non-fibrous carbohydrate; NFCap = non-fibrous carbohydrate corrected for ashes and protein; ADF = acid detergent fiber; HEM = hemicelulose; CEL = cellulose; LIG = lignin.

[3]The premix contained (per kg): 147 g Na, 120 g Ca, 87 g P, 18 g S, 3800 mg Zn, 1800 mg Fe, 1300 g Mn, 870 mg F, 590 mg Cu, 300 mg Mo, 80 mg I, 40 mg Co, 20 mg Cr, and 15 mg Se.

Table 2. Nutrient composition of sorghum silage and dehydrated fruit processing by-products.

Item[1]	Pineapple	Banana	Mango	Passion fruit	Sorghum silage
DM	91.8	90.7	92.2	93.6	41.1
g kg^{-1} (DM basis)					
CP	11.0	12.0	9.5	12.0	6.2
NDIN	25.7	81.6	26.9	28.6	36.7
ADIN	6.8	14.1	6.4	10.2	9.8
EE	2.2	7.5	4.7	3.8	2.6
Ashes	6.5	16.4	3.1	13.2	5.3
TC	80.5	66.3	83.7	72.0	86.0
NDF	50.6	44.3	33.7	53.4	57.5
NDFap	46.1	35.1	25.5	52.0	52.8
NFC	28.7	20.2	49.0	13.8	28.5
NFCap	33.3	29.4	57.1	18.9	33.2
ADF	27.1	23.6	20.8	38.8	28.1
HEM	23.5	20.7	12.9	14.7	29.4
CEL	23.3	14.9	15.5	24.5	23.5
LIG	3.3	8.2	4.7	12.5	4.3
TDN	71.8	72.1	74.9	63.9	70.6

[1] DM = Dry matter; CP = crude protein; NDIN = neutral detergent insoluble nitrogen (*g kg^{-1}* of total nitrogen); ADIN = acid detergent insoluble nitrogen (*g kg^{-1}* of total nitrogen); EE = ethereal extract; TC = total carbohydrates; NDF = neutral detergent fiber; NDFap = neutral detergent fiber corrected for ashes and protein; NFC = non-fibrous carbohydrate; NFCap = non-fibrous carbohydrate corrected for ashes and protein; ADF = acid detergent fiber; HEM = hemicelulose; CEL = cellulose; LIG = lignin; TDN = total digestible nutrients.

Table 3. Nutrients intake of mixed-breed male lambs fed experimental diets[1].

Item[2]	Treatment[3] Sorghum silage	Pineapple	Banana	Mango	Passion fruit	CV[4] (%)
Kg day^{-1}						
DM	1.0	1.2	1.1	1.1	1.2	19.8
OM	0.8	1.1	1.1	1.0	1.1	19.8
CP	0.2	0.2	0.2	0.2	0.2	19.3
EE	0.03	0.03	0.04	0.04	0.04	33.8
NDF	0.3	0.2	0.2	0.3	0.4	35.4
NDFap	0.2	0.2	0.2	0.2	0.3	22.1
NFC	0.4	0.6	0.5	0.5	0.4	25.0
NFCap	0.4	0.5	0.5	0.5	0.4	17.8
TDN	0.7	1.0	0.9	0.9	0.8	19.0
% BW						
DM	3.1	3.7	3.4	3.4	3.7	15.8
OM	2.5	3.4	3.2	3.1	3.2	14.7
NDF	0.9	0.7	0.7	0.9	1.1	32.0
NDFap	0.7[ab]	0.7[ab]	0.6[b]	0.6[b]	0.9[a]	18.6
TDN	2.2	2.9	2.7	2.6	2.6	17.0

[1]Experimental diets consisted of sorghum silage (control diet) and 75% replacement of sorghum silage for dehydrated fruit processing by-products.

[2]DM = Dry matter; OM = organic matter; CP = crude protein; EE = ethereal extract; NDF = neutral detergent fiber; NDFap = neutral detergent fiber corrected for ashes and protein; NFC = non-fibrous carbohydrate; NFCap = non-fibrous carbohydrate corrected for ashes and protein; TDN = total digestible nutrients.

[3]Means followed by different superscript letters in line are statistically different by Tukey test at 5% level of probability.

[4]CV = coefficient of variation.

Table 4. Apparent digestibility of DM, OM, CP, NDFap, NFCap, and TDN of mixed-breed male lambs fed experimental diets[1].

Item[2] (*g kg⁻¹*)	Treatment[3]					CV[4] (%)
	Sorghum silage	Pineapple	Banana	Mango	Passion fruit	
DM	71.0	69.2	66.4	69.5	65.3	5.4
OM	72.9	70.8	68.5	70.1	65.7	5.3
CP	68.3	65.9	60.0	66.1	67.0	8.2
EE	73.8[a]	75.4[a]	47.9[b]	65.8[ab]	76.0[a]	18.0
NDFap	53.5[a]	39.5[ab]	38.3[ab]	36.3[b]	28.9[b]	21.4
NFCap	85.3	85.6	83.3	87.1	86.3	2.8
TDN	69.9	68.2	66.8	66.7	63.4	19.0

[1]Experimental diets consisted of sorghum silage (control diet) and 75% replacement of sorghum silage for dehydrated fruit processing by-products.

[2]DM = dry matter; OM = organic matter; CP = crude protein; EE = ethereal extract; NDFap = neutral detergent fiber corrected for ashes and protein; NFCap = non-fibrous carbohydrate corrected for ashes and protein; TDN = total digestible nutrients.

[3]Means followed by different superscript letters in line are statistically different by Tukey test at 5% level of probability.

[4]CV = coefficient of variation.

Table 5. Urinary excretion of purine derivatives and microbial efficiency of mixed-breed male lambs fed experimental diets[1].

Item	Treatment[2]					CV[3] (%)
	Sorghum silage	Pineapple	Banana	Mango	Passion fruit	
Allantoin (mmol day^{-1})	10.9	14.6	17.7	14.9	13.3	34.2
Xanthine-hypoxanthine (mmol day^{-1})	1.3	1.9	2.4	2.7	3.4	65.8
Uric acid (mmol day^{-1})	1.0	0.9	1.2	0.7	1.0	38.1
Allantoin ($g\ kg^{-1}$)	81.9	83.3	82.7	80.9	74.5	10.8
Xanthine-hypoxanthine ($g\ kg^{-1}$)	10.3	11.3	11.3	14.9	19.6	64.8
Uric acid ($g\ kg^{-1}$)	7.8	5.4	5.9	4.2	5.9	36.5
Total PD (mmol day^{-1})	13.2	17.4	21.3	18.4	17.7	30.1
Absorbed PD (mmol day^{-1})	15.0	19.9	24.7	21.4	20.5	31.11
Microbial nitrogen (g day^{-1})	9.2	12.3	15.2	13.2	12.6	31.1
Microbial efficiency (g microbial N/kg TDN)	83.6	80.6	110.8	101.2	93.3	37.6
Serum urea N (mg dL^{-1})	25.9^{a}	17.3^{b}	18.7^{ab}	16.6^{b}	18.2^{b}	19.5

[1]Experimental diets consisted of sorghum silage (control diet) and 75% replacement of sorghum silage for dehydrated fruit processing by-products.

[2]Means followed by different superscript letters in line are statistically different by Tukey test at 5% level of probability.

[3]CV = coefficient of variation.

Table 6. Nitrogen balance of mixed-breed male lambs fed experimental diets[1].

Item	Treatment[3]					CV[4] (%)
	Sorghum silage	Pineapple	Banana	Mango	Passion fruit	
Nitrogen intake						
g/day	27.4	34.7	32.6	34.3	32.6	19.3
g/BW$^{0.75}$	2.3	2.8	2.8	2.9	2.7	13.6
Fecal nitrogen[2]						
g/day	8.6	12.8	15.1	12.5	11.9	31.8
g/BW$^{0.75}$	0.7	1.0	1.3	1.0	1.0	22.4
Urine nitrogen[2]						
g/day	4.2	3.6	3.2	3.3	2.6	28.2
g/BW$^{0.75}$	0.4	0.3	0.3	0.3	0.2	30.6
Nitrogen balance						
g/day	14.7	18.3	14.2	18.6	18.2	23.3
g/BW$^{0.75}$	1.3	1.5	1.2	1.6	1.5	22.5

[1]Experimental diets consisted of sorghum silage (control diet) and 75% replacement of sorghum silage for dehydrated fruit processing by-products.

[2]Nitrogen excreted from feces and urine respectively.

[3]Means followed by different superscript letters in line are statistically different by Tukey test at 5% level of probability.

[4]CV = coefficient of variation.