Evaluation of Nutritive Value and *in-vitro* Degradation of Sorghum Silage, *Moringa oleifera* (Moringa) and *Sesbania sesban* (Sesbania) Leaf Meals

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Abstract

The study was carried out to evaluate the feeding value of Sorghum silage, Moringa oleifera (Moringa) and Sesbania sesban (Sesbania) leaf meals. Certified Sorghum (Ikinyaruka) seeds and Sesbania were cultivated while Moringa leaves were collected from farmers in Kiorimba location in Tharaka Nithi County. Proximate analysis was carried out for Moringa, Sesbania and Sorghum silage. The organic matter ranged from 907.2 g Kg^{-1} dry matter (DM) to 928.0g Kg^{-1} DM. Crude protein (CP) content ranged from 93.76 g Kg^{-1} DM to 288.2g Kg^{-1} DM in Moringa meal. Crude Fibre (CF) ranged from 100.17g Kg^{-1} DM to 270.8 g Kg^{-1} DM. Nitrogen Free Extract ranged from 283.2 g Kg^{-1} DM to 475.0 g Kg^{-1} DM. Ether extract (EE) ranged from content was 49.6 g Kg^{-1} DM to 325.67 g Kg^{-1} DM. Neutral Detergent fiber (NDF) was 148.07 g Kg^{-1} DM to 570.3 g Kg^{-1}DM. Acid detergent Fibre (ADF) ranged from 99.2 g Kg^{-1} DM to 212.3 g Kg^{-1} DM for Moringa meal, SLM, and Sorghum silage respectively. Acid detergent lignin ranged from 57.07 g Kg^{-1} DM to245.6g Kg^{-1} DM. Fiber content was the highest for all cases in Sorghum silage. The nutritive values of the meals and silage fell within the animal portions as they had a CP of more than 70 g Kg^{-1}DM, the minimum required for rumen function according to National Research Council (NRC). Amino acids (lysine and methionine) were higher in Sesbania than Moringa. Polyphenols contents were higher in Sesbania while Sorghum silage had the highest rate of degradation at 48hrs. It is concluded that the forage legumes can be utilized to improve animal nutrition.

Keywords: Animal nutrition, Feeding value, Forage legumes

Introduction

Globally, agriculture plays a key role in improving livelihoods, especially in rural communities. In the arid and semi-arid lands (ASALs), the contribution of livestock to most households in Kenya is about 90% (Kenya Ministry of Agriculture, 2008). During the dry season there is reduced availability of feed when natural pastures are mature and highly fibrous (Oni *et al.,* 2010) and are of low nutritive value (Moyo *et al.,* 2012). Intake and digestibility of these poor-quality roughages could be improved through supplementation with concentrates (Nurfeta, 2010). Utilization of fodder trees like Moringa and Sesbaniaas supplements for ruminant nutrition in the tropics provides cheaper high quality protein sources and micronutrients (Moyo *et al.,* 2012). The use of fodder trees, shrubs and browses as supplements for ruminant nutrition in the tropics has been shown to improve intake of poor-quality roughages, increase growth rates and improve reproduction efficiency in ruminants (Amata, 2014). Farmers hardly ever store extra feed to balance out feed supplies during times of scarcity. Lack of conservation is mostly related to farmers' low feed conservation awareness, which leaves them unprepared to feed their animals during dry spells. Additionally, it has been observed that an obstacle to feed conservation is low fodder output, which is principally related to scarce land resources (Phelan *et al.,* 2014).

Sorghum can be used during the dry season as it is adapted to hot and dry environments and high salt tolerance (Yan *et al.,* 2012). Silage is one of the viable solutions, especially during the dry season, according to research by Lyimo *et al.* (2016). Sorghum plants are frequently used as silage because of their high nutrient content, notably in soluble carbohydrates (Yucel and Erkan, 2020). The objective of this study was to evaluate the nutritive value and in-vitro degradation of Sorghum silage, Moringa and Sesbania leaf meals.

Materials and methods

The National Commission of Science and Technology under the permit No: License No: NACOSTI/P/23/28404 had approved the materials and procedures of this study. The study was conducted at KALRO Dairy Research Institute Naivasha in Nakuru County. The station is located at latitude 0°N 18°S and longitude 36°W 09°E, 1920m Above Sea Level (ASL).

Preparation of Experimental Diets

One and a half acres of certified sorghum (Ikinyaruka) seeds was cultivated at the station using research bred seeds from KALRO Beef Research Institute, Lanet. The experimental field was ploughed and harrowed prior to the onset of the rains. Sesbania was also planted at the institute while Moringa leaves were harvested from farmers in already established fields in Tharaka Nithi County. The leaves of the legumes were air dried under a shade and heaped separately in bags ready for use.

Silage making

Sorghum was harvested at the dough stage and cut into approximately 2.5cm long pieces using a chaff cutter and ensiled in trench silos and 2 % of molasses (2 litres of molasses in 10 kg of sorghum) spread over the material to be ensiled. Compaction of the material was done to create anaerobic conditions necessary for the production of good quality silage. Assessment of the silage was done for acceptability, colour and fermentation by looking at the physical characteristics and sensory evaluation. The silage was sampled from different points (top, bottom and middle) and the pH determined using a pH meter.

Chemical analysis

Dry matter (DM), organic matter (OM) and crude protein (CP) contents were measured according to standard methods (AOAC, 2006). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to the methods of Van Soest *et al.* (1991). The extraction of phenolics was done using 70% aqueous acetone. The concentration of total extractable phenolics (TEPH) was determined using Folin Ciocalteu and tannic acid standard as outlined by Makkar (2003). The total extractable tannins (TET) were estimated indirectly after being absorbed to insoluble polyvinyl polypyrrolidone (PVP). The concentration of TET was calculated by subtracting the TEPH remaining after PVP treatment from the TEPH.

Rumen Fluid Sampling and In-Vitro Digestibility

Eight growing lambs weighing about 15±2.2 Kg live weight after feeding with the experimental diets for 14 days were used to obtain rumen fluid. Rumen fluid was collected before morning feeding from the eight lambs by vacuum pump through a stomach tube. One litre of rumen fluid from the lambs was kept in thermos flask after being filtered through two layers of cheese-cloth to obtain strained rumen fluid which was then continually flushed with carbon dioxide (CO_2) to maintain anaerobic conditions until used. Rumen fluid was used in combination with buffers to simulate the action of saliva and the role of rumen microorganisms in digestibility of diets.

Two hundred (200 mg) of sample (milled through a 1.0 mm sieve) were incubated *in vitro* with rumen fluid was placed into 100 ml glass syringes in triplicates. The syringes were lubricated with petroleum jelly to ease the sliding of the piston and also prevent gas escape, and then the silicon rubber was closed with a plastic clip. The fermentative activity of the mixed microbial population was determined using gas production technique (Menke, 1988). The rumen fluid and buffer medium were mixed in the ratio of 1:2 (v/v). 30 ml of buffer-rumen fluid mixture was put into syringes holding the feed samples, swirled gently and any air bubbles released. The syringes containing the sample plus the mixture were incubated in a thermostatically controlled water bath at 39°C from 0-96 hours. Both the samples and blank (rumen fluid +buffer) were run in triplicates. The volume of gas produced was determined at 0, 3, 9, 12, 24, 48, 72, and 96 hours by reading the calibration of the syringe. The gas produced was the total increase in volume minus the mean blank value from the accurately recorded gas production of all samples to give the net gas production. After 96 hours of incubation, the residues were used for the determination of in-vitro DM, NDF, and ADF digestibility. Calculation for in-vitro DM and NDF digestibility was as follows: *In-vitro* DM digestibility (%) = [A-(B-C)/A] *100, Where A = dry weight of sample; B = dry weight of residue after digestion; C = dry weight of reagent blank

NDF digestibility = $[(NDF_{feed} - NDF_{residue})/NDF_{feed}]$ *100

The calculated values of gas production were fitted into the model developed by Ørskov and McDonald, (1979) to determine the degradability of the feed:

$Y= a + b\ (1-e^{-ct})$,

where: Y = the volume of gas produced (ml) with time (t)

a = initial gas production (ml)

b = gas produced during incubation (ml) at time t

c = gas production rate constant (fraction /hour)

Then (a+b) represents the potential extent of the gas production. Calculated values for short chain fatty acids (SCFA mmol/200mg DM), percentage Organic matter digestibility (OMD %) and Metabolizable energy (ME MJ/kg DM), were derived from equations given by Menke and Steingass (1989).

Statistical analysis

Data collected on proximate, fibre, tannins and Gas production results were subjected to the analysis of variance (ANOVA) in a completely randomized design (CRD) using the General linear model procedure of Statistical Analysis System (SAS, 2002) version 9.0. The model will be as follows:

$Y_{ij} = \mu + T_i + \mathcal{E}_{ij}$

Where:

Y_{ij}	=	dependent variable
μ	=	overall mean
T_i	=	effect of the treatment
$\mathcal{E}_{ij}$	=	random error term

Results

The results of Chemical composition of diets are shown Table 1 and Figure 1. Dry matter (DM) content ranged between 928 g Kg^{-1}DMin silage to 907.2 g Kg^{-1}DM in Moringa. Ash content ranged between 908.5 g Kg^{-1}DM in Sesbania to107.95 g Kg^{-1}DM in Moringa. Ether extract (EE) ranged between 325.67 g Kg^{-1}DM in Moringa to 49.6 g Kg^{-1}DM in Sesbania. Moringa leaf meal had the high mean in crude protein (CP) of 288.2 g Kg^{-1}DM in Moringa to 93.76 in silage. Mean crude fiber (CF) ranged between 270.8 g Kg^{-1}DM in silage to 100.17g Kg^{-1}DM in Sesbania. NDF content ranged between 570.3 g Kg^{-1} DM in silage to 148.07g Kg^{-1} DM Sesbania. ADF ranged from 99.2g Kg^{-1} DM in Moringa meal, 101.97 g Kg^{-1} DM in Sesbania meal and 212.3 g Kg-1 DM in Sorghum silage. ADL ranged from 57.07 g Kg^{-1} DM in Moringa, 68.53 g Kg^{-1} DM in Sesbania meal and 245.6 g Kg^{-1} DM in Sorghum silage and was highly significant as indicated ($P<.0001$). Total Extractable Phenolic (TEPH) ranged 245.6g Kg^{-1} DM , 68.53g Kg^{-1} DM , and 57.07g Kg^{-1} DM in Sorghum silage , Sesbania meal and Moringa meal respectively, Total Extractable Tannins (TET) was 3.546, g Kg^{-1} DM , 2.714g Kg^{-1} DM and 1.158g Kg^{-1} DM in Sesbania leaf meal, Moringa leaf meal and Sorghum silage respectively, while Condensed Tannins (CT) was 0.448g Kg^{-1} DM in Sesbania meal , 2.714 g Kg^{-1} DM for Moringa meal and 1.158 g Kg^{-1} DM in Sorghum silage($P<.0001$). Methionine (Meth) levels in Sesbania meal was 24.07 g Kg^{-1} DM and 10.89g Kg^{-1} DM in Moringa meal, Lysine (Lys) recorded 21.735 g Kg^{-1} DMin Sesbania meal and 10.677g Kg^{-1} DMin Moringa meal. Gas production and fermentation parameters are presented in Table 2 and Figure 2.

There was a difference in gas production among Moringa, Sesbania leafs meal and sorghum silage (Table 2). The Initial gas

Table 1: Chemical composition (gKg-1DM) of Moringa, Sesbania leaf meal and Sorghum silage

Sample	DM	ASH	CP	EE	CF	NFE	NDF	ADF	ADL	TEPH	TET	CT	Meth	Lys
Moringa meal	907.2^{a}	107.95^{b}	288.2^{a}	325.67^{a}	102.7^{b}	420.7^{ab}	190.7^{b}	99.2^{b}	57.07^{b}	3.628^{b}	2.714^{b}	0.239^{b}	10.89^{b}	10.677^{b}
Sesbania meal	910.0^{b}	908.5^{c}	281.57^{a}	49.6^{b}	100.17^{b}	475.0^{a}	148.07^{b}	101.97^{b}	68.53^{b}	4.241^{a}	3.546^{a}	0.448^{a}	24.07^{a}	21.735^{a}
Sorghum Silage	928.0^{a}	577.7^{a}	93.76^{b}	59.6^{b}	270.8^{a}	283.2^{b}	570.3^{a}	212.3^{a}	245.6^{a}	1.656^{c}	1.158^{c}	0.166^{c}	N/A	N/A
SEM	0.244	1.098	1.403	1.098	0.961	1.048	3.069	3.069	0.994	0.020	0.020	0.0023	0.211	0.174
P value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0.0011	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

DM; Dry matter; CP; Crude Protein; EE; Ether Extracts; CF; Crude Fiber; NFE; Nitrogen Free Extract; NDF; Neutral Detergent Fiber; ADF; Acid Detergent Fiber; ADL; Acid Detergent Lignin; TEPH; Total Extractable Phenolic; TET; Total Extractable Tannins, CT; Condensed Tannins. Meth; Methionine; Lys; Lysine; SEM; Standard Error of Mean; ^{abc} means values in a column without common superscript differ at $P<0.05$; * 0.05 Significance levels; $^{a, b, c, d,}$ Column means with the different superscript are significantly different ($p<0.05$).

Table 2: In-vitro gas production (ml/200mg DM) at 24 and 48hrs and fermentation characteristics of Moringa, Sesbania leaf and sorghum silage

			Fermentation Characteristics							
Sample	24	48	a	b	c	a+b	RSD	SCFA	OMD%	ME
Moringa	9.904 ^{a}	3.901^{b}	3.022 ^{a}	3.955 ^{a}	8.833 ^{b}	5.939 ^{a}	4.260 ^{ab}	1.589 ^{a}	18.778 ^{a}	15.695^{a}
Sesbania leaf meal	8.772 ^{a}	1.097 ^{c}	1.744 ^{a}	3.686 ^{a}	12.235 ^{a}	5.430 ^{a}	4.603 ^{b}	0.190 ^{a}	21.064 ^{a}	7.679 ^{b}
Sorghum Silage	8.598 ^{a}	6.984 ^{a}	2.715 ^{a}	3.225^{a}	0.070 ^{c}	5.549^{a}	3.186 ^{b}	0.186 ^{a}	25.489 ^{a}	4.944^{b}
SEM	0.655	0.455	0.901	0.877	0.877	0.386	0.336	0.793	2.528	1.048
P value	<.0001	<.0001	0.0085	<.0001	<.0001	<.0001	<.0001	0.3923	<.0001	<.0001

a, b, c are constants in the equation (Ørskov and McDonld, 1979); $^{a, b, c,}$ Means with the same letter superscript in a column are not significantly different ($p<0.05$).OMD: Organic Matter Digestibility;RSD: Residual Standard Deviation; SCFA: Short Chain Fatty Acids; A is initial gas produced; B is actual gas produced during DM degradation; A+B is the total gas produced during fermentation

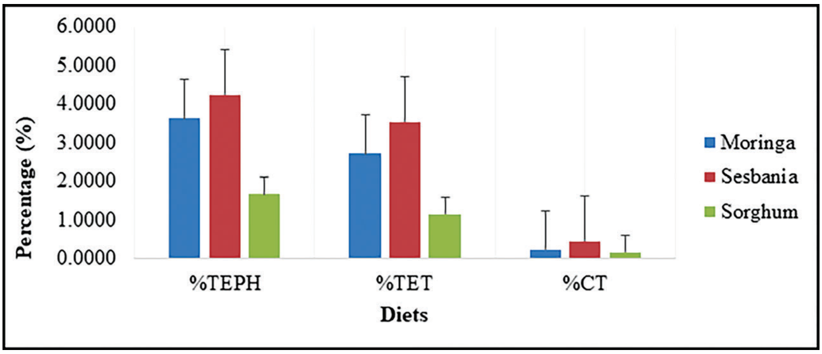

Figure 1: Total extractable phenolic (TEPH), Total Extractable tannins (TET) and condensed tannins (CT) contents of Moringa, Sesbania leaf meal and Sorghum silage(With standard error bars)

production (A) and rates of gas production (C) differed ($p<0.05$) among Moringa, Sesbania leaf meal and sorghum silage. The results from In-vitro gas production measured from 0 to 96 hours for Moringa, Sesbania leaf meal and sorghum silage is shown in Table 2. At 24 hours fermentation, the rate of gas production was highest in Moringa at 9.904% followed by Sesbania leaf meal at 8.77 and lastly sorghum silage at 8.59% gas production. At 48hour fermentation, silage was highest at 6.984% gas production followed by Moringa and lastly Sesbania leaf meal at 1.097% gas production and was highly significant($p<.0001$).

Rate constant gas production (C) shows variation in the diet degradability and variation with Sorghum silage at 3.19, Moringa 4.26 and the highest was Sesbania leaf meal at 4.603.OMD% is calculated (Menke and Steingass, 1988). It was high for Sorghum silage (25.49%) followed by Sesbania (21.06%) and the least was Moringa at 18.778%. All the diets had less than 50% OMD this can be attributed to presence of anti-nutritional factors such as tannins, phenols and suppressant of digestion.

Figure 2 shows the trends in In-vitro gas production fermentation of Moringa, Sesbania leaves meal and Sorghum silage. Sesbania and Sorghum silage show highest degradation after twelve and forty hours respectively. Sesbania leaf meal and the Sorghum silage show a lower amount of gas at later hours of fermentation.

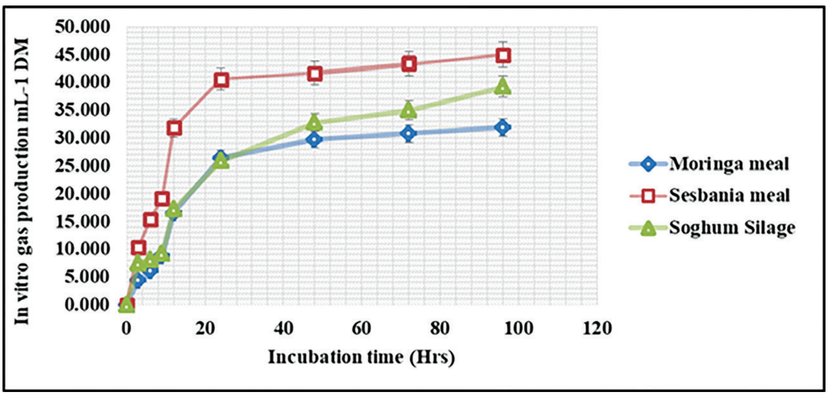

Figure 2: Patterns of in-vitro cumulative gas production on Sorghum silage, Moringa and Sesbania Leaf meal

digestibility potential, with Sesbania showing the highest (12.24%) and Moringa and Sorghum silage at 8.83% and 0.07% respectively. The Residual Standard Deviation (RSD) showed

Discussion

Chemical composition

The crude protein (CP) content of Moringa was slightly higher than values of 268.0 g Kg-

$^{-1}$reported by Muremera *et al.* (2022) but in agreement by studies carried out by Mohamood *et al.* (2022) and Lesten (2018) who both got CP value of 280 g Kg^{-1} and Simbaya *et al.* (2020) who got a value of 286.0g Kg^{-1}.The crude protein of Sesbania showed a higher value compared to the value of 236.5 g Kg^{-1} got by Kumar *et al.* (2017). *Sesbania sesban* tree has a high level of foliage nitrogen and is an excellent supplement to protein-poor roughage (Sabra *et al.,* 2010). The leaves are easily digestible when consumed by ruminants (Gomase *et al.,* 2012).

According to the study, NDF values for Moringa and Sesbania were 190.7 g Kg^{-1}and148.07 g Kg^{-1}, respectively. The current study's results for Moringa are close to those from Muremera *et al.* (2022) with a value of 55.83, but slightly higher than the results from Mohamed *et al.* (2014) and Kumar *et al.* (2017) who got values of 46.24 and 45.27, respectively. Ether extract (EE) in Moringa leaf meal of 325.67 g Kg^{-1}DM is in line with the results from Sasu *et al.,* 2023 who got a value of 343Kg^{-1}DM. In this study, sorghum silage had a CP content of 93.76 g Kg^{-1} was in agreement with studies by Kaplan (2013) but higher than results got by Mwangi *et al.* (2013). The nutritive values of the meals and silage fell within the animal portions as they had a CP of more than 70 g Kg^{-1}DM, which is the minimum required for rumen function according to National Research Council (NRC).

Ash is the total mineral content of forage

Internal ash is the naturally occurring minerals found in plants, some of which have nutritional value to livestock such as calcium, potassium and phosphorus. Different factors influencing the mineral concentration of plants include minerals in the soil and availability to the plant, soil type, and soil pH and stage of growth (Lukhele & Ryssen, 2003). The highest amount of ash content was recorded in Sesbania leaf meal, followed by Sorghum silage while the least was recorded Moringa leaf meal with 107.95 g Kg^{-1} DM.

There was high concentration of Total Extractable Phenolic, Total Extractable Tannins, and Condensed Tannins in Moringa meal and Sesbania meal than in Sorghum silage (Table 1). In prior studies, Ondiek *et al.* (2010) and Kemboi *et al.* (2017) have shown that consumption of plant species with high CT contents significantly reduces voluntary feed intake, while medium or low consumption does not. Sorghum silage had higher levels of NDF, ADF, and ADL than did Moringa and Sesbania meal.

***In-vitro* dry matter degradability**

Moringa, Sesbania and Sorghum silage were highly degraded at 24 hours compared to the 48hours. The gas is usually produced by the fermentation and degradation of organic matter by microbes in the feed (Blümmel & Fernandez-Rivera, 2002).

The feed with highest gas production at 24 and 48 hour was Moringa (9.90%) and Sorghum silage at 6.98% ml per 200mg DM respectively. Ebeid *et al.* (2020) found that Moringa leaves had a higher nutritional value than seeds. They discovered that Moringa leaves showed an effective degradability and high DM disappearance. The actual gas production during fermentation (B) was highest in Moringa with 3.955% gas production followed by Sesbania, and lastly Sorghum silage at 3.23%. The total gas production (A+B) did not follow the same pattern. Moringa registered 5.94% followed by Sorghum silage and Sesbania leaf meal with a mean of 5.55% and 5.43% gas production respectively which compares with the results of Abdulrazak *et al.* (2000) and Kemboi *et al.* (2017). Moringa ranked the lowest in gas production potential; this could be due to the high level of tannins and other anti-nutritive factors which affect nutrient utilization by the microbes. Because of the tannins and other phenolic chemicals found in Moringa leaves, the meal is less palatable, digestion takes longer, and conditioned versions might form (Foley *et al.,* 1999; Kholif & Olafadehan, 2021).Moringa had a high fat content. High dietary fat content can stop rumen bacteria that break down fibre from working. This is due to the fact that specific lipids and fatty acids may be toxic to protozoa and rumen bacteria, decreasing their capacity to break down complex carbohydrates such as cellulose and hemicellulose. Thus, an excessive fat content may result in a decrease in the digestion of fibre (Hervás *et al.,* 2021).

Sesbania and Sorghum Silage showed the highest degradation after twenty-four (24) and forty-eight (48) hours respectively. Sorghum silage had a high degradation probably due to low tannin levels despite the high NDF levels. Moringa leaf meal and the Sorghum Silage show a lower amount of gas at later hours of fermentation.

Conclusions

After observing strong relationship between Sesbania leaf meal, Sorghum silage at 0 to 24 hours incubation time, the highest values obtained in in-vitro gas production parameters in Sesbania Leaf meal, Sorghum silage, followed by Moringa meal, show superior feed degradability by rumen microorganisms.

Recommendation

Sesbania sesban and Moringa oleifera should be used in livestock feed because they have the nutritional potential to supplement low-quality basal forages like sorghum silage in the semiarid regions of Kenya, according to the results of chemical composition and in vitro degradability tests.

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