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The feeding value of deseeded pods from *Moringa stenopetala* and *Moringa oleifera* as evaluated by chemical analyses and *in vitro* gas production

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ABSTRACT

This study evaluates the nutrient composition and *in vitro* fermentation characteristics of deseeded green pods of *Moringa stenopetala* and *Moringa oleifera* cultivated at low and moderate altitudes. Crude protein (CP) content (g/kg DM) varied from 103 in *Moringa oleifera* to 135 in *Moringa stenopetala*. The CP contents for *Moringa stenopetala* cultivated at low and moderate altitudes were 135 and 127 g/kg DM, respectively. The CP values for *Moringa oleifera* were 103 and 105 g/kg DM at low and moderate altitudes, respectively. Low values of neutral detergent fibre, acid detergent fibre, and cellulose were found in *Moringa stenopetala*. High concentrations of Ca, P, K, Mg, Mn, and Cu were observed in *Moringa oleifera*. Significantly high values of metabolizable energy (ME), organic matter digestibility, and short-chain fatty acids were found in *Moringa stenopetala*. These values were also significantly high at moderate altitude. The ME values were 7.35 and 5.80 MJ/kg DM for *Moringa stenopetala* and *Moringa oleifera*, respectively. In conclusion, deseeded pods of the Moringa tree could be used as an alternative, cheap source of home-grown energy supplements for low quality crop residues of tropical livestock while using the seeds for human consumption.

KEY WORDS: *in vitro* gas production, nutrient compositions, *Moringa oleifera*, *Moringa stenopetala*, deseeded Moringa pods

INTRODUCTION

The livestock sector plays a significant economic role in most developing countries, and is essential for the food security of rural populations. The

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productivity of farm animals in most tropical countries is generally low, mainly due to poor quality and inadequacy of available feeds. Moreover, conventional feed resources (grains, cereals, legumes, etc.) for animal production are scarce and highly expensive in many parts of the world. Thus searching for alternative unconventional feed sources that may have valuable components of animal diets is indispensable. For instance, feeding by-products from agricultural and food processing industries to livestock can be one of the solutions (Negesse et al., 2009; Szumacher-Strabel et al., 2011; Zhou et al., 2012). The use of tree parts as alternative feed resources for ruminant livestock is becoming increasingly important in many parts of the tropics and sub-tropics (Silanikove, 2000; Melesse et al., 2009). Moringa trees are multi-purpose trees of economic importance with several industrial and feeding values. The genus *Moringaceae* is represented by 14 species to which *Moringa stenopetala* and *Moringa oleifera* belong. *M. stenopetala* has a wide range of adaptation from arid to humid climates and can be grown in a various land use patterns. It is cultivated both for human food and animal feed in Southern Ethiopia and has been recently distributed to other regions of Ethiopia beyond its original sites. *M. oleifera* is native to the sub-Himalayan tracts of north-west India, Pakistan, Bangladesh and Afghanistan (Makkar and Becker, 1997). It is a pan-tropical multipurpose tree and is characterized by high biomass yield and can tolerate unfavourable environmental conditions (Foidl et al., 2001).

Although studies have reported the chemical composition of leaves, seeds and seedpods of both Moringa species (Makkar and Becker, 1996; Melesse et al., 2009), no information has been available on the chemical and mineral compositions as well as ruminal fermentation characteristics of deseeded green pods as an alternative animal feed sources in the tropics. The objectives of this study were thus: 1. to assess the altitudinal variations in chemical and mineral compositions of deseeded pods from *M. stenopetala* and *M. oleifera* cultivated at low and moderate altitudes; 2. to evaluate the potential of this Moringa tree part as a ruminant feed using an *in vitro* gas production method.

MATERIAL AND METHODS

Sampling sites

Samples of whole green pods from *M. stenopetala* and *M. oleifera* were collected from nursery sites of the Southern Agricultural Research Institute located in districts of Hawassa (altitude 1700 m a.s.l.) and Arbaminch (altitude 1100 m a.s.l.) representing moderate and low altitudes, respectively. The Arbaminch site (low altitude) lies between 06^{o} 03’ latitude north and 37^{o} 33’ longitude east and

has a warm agro-ecology with an average rainfall of less than 900 mm (with a range of 640-1130 mm), that peaks during the months of July and August (National Metrological Agency). Similarly, the Hawassa site (moderate altitude) lies between 07° 03' latitude north and 38° 28' longitude east and has a sub-moist warm agro-ecology with an average rainfall of less than 1000 mm (with a range of 700-1200 mm), the peak being during the month of August. The mean monthly maximum and minimum temperatures of the Hawassa site are 27.5 and 13.3°C, respectively. The corresponding temperature values for the Arbaminch site are 29.9 and 16.8°C (National Metrological Agency).

Sample collection and preparation

Samples were collected from nursery sites during the dry season (December) in 2009 from 6-year-old Moringa trees cultivated at low and moderate altitudes. From each Moringa species, three trees were randomly sampled per altitude from which whole green pod samples were collected. Deseeded pods were then prepared by manual removal of seeds from each whole green pod, chopping the pods with a knife, and partially sun-drying them to reduce the moisture content. Samples collected from three trees were handled separately and dried at 65°C for 48 h and ground to pass a 1 mm sieve. Ground feed samples were kept in sealed plastic containers and transported to Hohenheim University (Germany) for analysis.

Chemical analysis

Analyses of proximate nutrients and fibre fractions were performed as outlined by Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten (VDLUFA, 2006). The samples were analysed for DM, ash, crude protein (N multiplied by 6.25), petroleum ether extract, and crude fibre. Neutral detergent fibre (NDF) assayed with a heat stable amylase and acid detergent fibre (ADF) and acid detergent lignin (ADL) were analysed according to VDLUFA (2006) and were expressed inclusive residual ash. Cellulose and hemicellulose were computed as ADF minus ADL and NDF minus ADF, respectively. The non-fibre carbohydrate (NFC) content was calculated as 100-(NDF + CP + crude fat + ash) according to NRC (2001).

For mineral analysis, samples were incinerated at 550°C and the remaining ash was treated with 6 mol per l HCl. Minerals were determined from filtered ash solutions using an Inductively Coupled Plasma spectrometer (ICP-OES) (Rodehutscord and Dieckmann, 2005).

All chemical analyses were conducted in duplicate on each individual sample.

In vitro measurement protocols

Gas production was determined according to the procedure of the VDLUFA official method (VDLUFA, 2006) and Menke and Steingass (1988). About 200 mg of feed sample were weighed in two replicates and transferred into 100 ml calibrated glass syringes, fitted with pistons. To prepare the inoculum, rumen fluid was collected before the morning feeding from two rumen-fistulated, non-pregnant and non-lactating Holstein-Friesian cows. The cows were fed twice a day at 8 a.m. and 4 p.m. and received a daily quantity of 8 kg meadow hay and 2 kg of a commercial dairy concentrate (18% CP, 7.6 MJ Net Energy for Lactation). Water and a mineral lick were available *ad libitum*. Rumen fluid was manually pumped directly into pre-warmed thermo flasks and taken immediately to the laboratory.

The rumen fluid was then filtered through two layers of cheesecloth and diluted with buffered mineral solution, which was maintained in a water bath at 39°C under continuous flushing with CO_2. In each run, three incubation units each with Hohenheim gas test standard hay and standard concentrate were included, serving as control units for successful incubation. Moreover, six parallel glass syringes that contained rumen fluid-media mixtures without substrate were used as blanks. A total of 30 ml incubation medium (consisting of 10 ml rumen fluid, 5 ml of bicarbonate buffer, 5 ml of macro-mineral solution and 10 ml of distilled water) was dispensed into pre-warmed glass syringes containing the respective experimental feeds (200 mg), reference standards and blank syringes. After gently shaking the syringe and removing air bubbles, the clip on the silicon tube attached to the tip of the syringe was closed, initial reading recorded, and the syringe was placed in a temperature-controlled incubation rotor set at 39°C. Incubation was completed in duplicate within each run; runs were replicated two times yielding four observations per sample. The gas volume was recorded at 2, 4, 6, 8, 10, 12, 14, 18, 24, 30, 36 and 48 h of incubation according to the time described by Blümmel and Becker (1997). The volume of gas in a glass syringe was readjusted to 30 ml whenever it exceeded 60 ml.

The gas produced by test substrates was corrected by that produced in the blank syringes (containing no substrate) and 24 h gas production was corrected by the standards for the estimation of organic matter digestibility (OMD), metabolizable energy (ME) and short-chain fatty acids (SCFA). Accordingly, the values of ME (MJ /kg DM) and OMD (%) were estimated according to Menke et al. (1979) and Menke and Steingass (1988) and SCFA (mmol) were calculated using the equation of Blümmel et al. (1999) as described below:

$$ME\ (MJ/kg\ DM) = 2.20 + (0.136 \times Gv) + (0.0057 \times CP) + (0.00029 \times EE)$$

$$OMD\ (\%) = 14.88 + (0.889 \times Gv) + (0.45 \times CP) + (0.651 \times XA)$$

$$SCFA\ (mmol/l) = 0.0239 \times Gv - 0.0601$$

where: Gv, CP, EE and XA - gas volume (ml 200 mg/DM), crude protein, crude fat and ash (g kg/DM) of the incubated samples, respectively.

Statistical analysis

The experimental procedure was a completely randomized design having two factors, in which factor 1 was *Moringa* species with two categories (*M. oleifera* and *M. stenopetala*) and factor 2 was altitude with two categories (low and moderate altitudes). From each *Moringa* species, three trees were randomly sampled per each altitude consisting of a 2 x 2 factorial ANOVA design with a total sample size of 12. Data were subjected to ANOVA with Moringa species and altitudes as main effects and all two-way interactions using General Linear Models (GLM) Procedure of Statistical Analysis System (SAS, 2002). Differences of means were separated by Duncan Multiple Range Test. All statements of statistical differences were based on $P<0.05$ unless noted otherwise. Time series measurements of gas volumes from 2-48 hrs of *in vitro* incubation were used for the curve fitting to mathematically express gas production over incubation time. Model fitting for gas production kinetics and parameter estimation were done according to Beuvink and Kogut (1993) described in detail by Boguhn et al. (2008) by using the software GraphPad Prism 4.02 for Windows (GraphPad Software, Inc. La Jolla, CA, USA).

RESULTS

Chemical compositions

The chemical compositions of deseeded pods of both *Moringa* species at moderate and low altitudes, including two-way interactions, are presented in Table 1. Except for hemicellulose, the effect of *Moringa* species was significant for all investigated nutrients. Similarly, altitude had a significant effect on all nutrients except CP, ADL, and hemicellulose. Significant interactions of *Moringa* species x altitude were also observed in all compounds except for ADL and hemicellulose contents.

The ash content was generally higher for *M. oleifera* cultivated at both altitudes than for *M. stenopetala* with significant altitude × *Moringa* species interactions. The highest and lowest CP values were noted for *M. stenopetala* and *M. oleifera* cultivated at low altitude, respectively, with significant altitude × Moringa species interactions. The fat content was generally highest for *M. stenopetala* cultivated at low altitude, but lowest for *M. oleifera* at moderate altitude, as indicated by the highly significant altitude-by-species interactions. The NFE and NFC contents of *M. stenopetala* were generally higher than those of *M. oleifera*. The contents CF,

NDF, ADF and cellulose were generally lower, however, in *M. stenopetala* than in *M. oleifera* at both altitudes.

Table 1. Least square means of chemical compositions (g/kg DM) in deseeded pods of *M. stenopetala* and *M. oleifera*

Species (Sp)	*M. stenopetala*		*M. oleifera*		SEM	ANOVA		
Altitudes (A)	mid	low	mid	low		sp	A	Sp × A
Ash	91.6	105	127	128	1.27	***	**	**
Crude protein	127	135	105	103	1.47	***	NS	*
Crude fat	10.3	16.0	6.67	9.33	0.87	***	***	***
Crude fibre	320	388	459	469	3.79	***	***	***
NFE	452	344	303	290	3.79	***	***	***
NDF	482	554	659	653	3.41	***	***	***
ADF	420	493	591	610	5.78	***	***	**
ADL	106	116	101	99.7	2.39	**	NS	NS
Cellulose	314	377	489	510	3.77	***	***	***
Hemicellulose	62.0	61.0	68.3	43.7	7.66	NS	NS	NS
NFC	290	180	103	106	4.65	***	***	***

* P<0.05; ** P<0.01; ***P<0.001; NS - not significant; NFE - N-free extractives; NDF - neutral detergent fibre; ADF - acid detergent fibre; ADL - acid detergent lignin; NFC - non-fibre carbohydrate; SEM - standard error of the mean

Generally, nutritive value parameters in *M. oleifera* were little affected by altitude, whereas large changes in ash, fat, CF, NDF, ADF, cellulose and NFC due to altitude were observed in *M. stenopetala*. As a result, the contents of ash, fat, CP, CF, NDF, ADF, ADL and cellulose in *M. stenopetala* were generally higher at low altitude than those at moderate elevation. In *M. oleifera*, however, the contents of ash, CP, CF, NFE, NDF, ADF, ADL and NFC were similar between altitudes.

Mineral concentrations

The mineral composition of both *M. stenopetala* and *M. oleifera* as affected by altitude and their two-way interactions is presented in Table 2. The effect of Moringa species was significant for all investigated minerals except for Zn. The effect of altitude was significant for P, Na, Fe, Zn and Cu. The interactions between species and altitude were significant for all investigated minerals except for P and Mn.

The Ca, P, K, Mg, Mn, and Cu concentrations for *M. oleifera* were generally higher than those of *M. stenopetala* cultivated at both altitudes. The Ca concentration (g/kg DM) ranged from 2.47 in *M. stenopetala* to 3.82 in *M. oleifera* grown at moderate altitude. The highest Zn concentration for *M. stenopetala* was noted at moderate altitude and the lowest at low altitude. The Ca, K, Mg, Fe and Cu concentrations for *M. stenopetala* were generally higher at low altitude; whereas those of P, Na, Mn and Zn concentrations were higher at moderate altitude. In contrast, Ca, P, K, Mg, Fe, Mn, and Zn concentrations for *M. oleifera* were generally higher at moderate altitude than at low altitude.

Table 2. Concentrations of macro and trace minerals in deseeded pods of *M. stenopetala* and *M. oleifera*

Species (Sp)	*M. stenopetala*		*M. oleifera*		SEM	ANOVA		
Altitudes (A)	moderate	low	moderate	low		sp	A	Sp × A
Macro minerals, g/kg DM								
calcium	2.47	2.98	3.82	3.34	0.12	***	NS	**
phosphorous	3.97	3.20	5.56	5.02	0.05	***	**	NS
potassium	37.7	41.4	53.8	51.3	1.29	***	NS	*
magnesium	2.00	2.29	2.61	2.54	0.06	***	NS	*
sadium	0.65	0.50	0.47	0.48	0.02	***	**	**
Ca:P	0.62	0.93	0.69	0.67	0.01	-	-	-
Trace minerals (mg/kg DM)								
iron	302	584	622	580	28.5	**	*	**
manganese	18.1	17.2	23.6	20.1	1.09	**	NS	NS
zinc	24.2	14.8	22.8	20.9	1.15	NS	**	*
copper	2.72	4.80	9.32	9.65	0.26	***	**	*

* P<0.05; **P<0.01; ***P<0.001; NS - not significant

Ca:P - calcium to phosphorous ratio; SEM - standard error of the mean

In vitro gas production characteristics and estimated parameters

Among the investigated Moringa types, *M. stenopetala* produced a significantly higher *in vitro* gas volume than *M. oleifera* (Figure 1). The increase in gas volume was highest during the initial phase of incubation and consistently increased thereafter.

As presented in Figure 2, although not significant, the *in vitro* gas production of deseeded pods cultivated at moderate altitude was higher than that of at low altitude. In general, although the *in vitro* gas volume increased with advancing time of incubation, the greatest proportion of gas production occurred in the first 24 h of incubation (Figures 1 and 2).

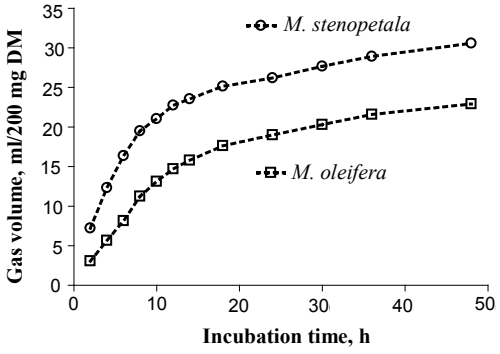

Figure 1. Pattern of *in vitro* gas production in deseeded pods of *M. stenopetala* and *M. oleifera* measured over 48 h of incubation

The corrected 24 h gas volume, *in vitro* estimated values of ME, OMD, and SCFA as affected by altitude and Moringa species are presented in Table 3. The values of these parameters corrected 24 h gas volume and values of ME, OMD and SCFA were significantly higher at moderate altitude than at low altitude. Moreover, there were significant differences among Moringa species in the corrected 24 h gas volume, and estimated parameters of ME, OMD, and SCFA values. Accordingly, *M. stenopetala* had significantly higher corrected 24 h gas volume and values of ME, OMD and SCFA than those of *M. oleifera* (Table 3).

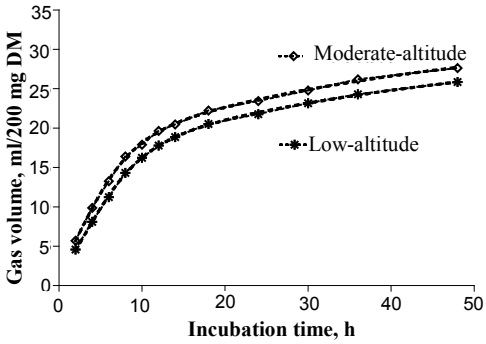

Figure 2. Development of *in vitro* gas production in deseeded pods cultivated at low and moderate altitudes measured over 48 h of incubation

Table 3. Corrected 24 h gas production, i*n vitro* estimates of ME, OMD and SCFA in deseeded pods as affected by Moringa species and altitude (n=12 each, means and pooled standard error)

Factors	Gas volume ml/200 mg DM	ME MJ/kg DM	OMD %	SCFA mmol/l
Moringa species				
M. stenopetala	32.3[a]	7.35[a]	55.9[a]	71.2[a]
M. oleifera	22.1[b]	5.80[b]	47.5[b]	46.7[b]
SEM	1.29	0.17	0.96	3.08
Altitudes				
moderate	29.4[a]	6.86[a]	53.4[a]	64.3[a]
low	24.9[b]	6.27[b]	50.0[b]	53.5[b]
SEM	2.43	0.36	1.97	5.79

[a,b] means between column within each factor with different superscripts are significantly ($P<0.05$) different; ME - metabolizable energy; OMD - organic matter digestibility; SCFA - short-chain fatty acids; SEM - standard error of the mean

As presented in Table 4, at low altitude, the average plateau value of gas production (parameter b) for *M. stenopetala* and *M. oleifera* was 28.0 and 27.03 ml, respectively, whereas the corresponding values at moderate altitude were 37.54 and 21.90 ml. At both altitudes, the average rapid gas production rate during early stages of fermentation (parameter mr) was generally higher

for *M. stenopetala* than *M. oleifera*. Nonetheless, the average values of slower gas production rate during the later stages of fermentation (parameter ms) from *M. oleifera* were comparatively higher than obtained from *M. stenopetala* cultivated at both altitudes (Table 4).

The average maximum gas production rate was also generally higher for *M. stenopetala* at both altitudes. The average maximum gas production rate ranged from 1.484 ml/h for *M. oleifera* to 4.35 ml/h for *M. stenopetala* cultivated at moderate altitude. At both altitudes, *M. oleifera* had a longer lag time and point of inflection time than *M. stenopetal*a (Table 4).

Table 4. Estimated parameters (means±SE) of incubated deseeded pods of *M. stenopetala* and *M. oleifera* by fitting a sigmoid model of Beuvink and Kogut (1993)

Parameters[1]	Low altitude		Moderate altitude	
	M. stenopetala	*M. oleifera*	*M. stenopetala*	*M. oleifera*
b	28.00 ± 2.010	27.03 ± 5.75	37.54 ± 4.364	21.90 ± 2.96
mr	1.079 ± 0.333	0.557 ± 0.334	1.439 ± 0.534	0.884 ± 0.570
dr	0.415 ± 0.083	0.210 ± 0.081	0.525 ± 0.107	0.319 ± 0.167
ms	0.041 ± 0.026	0.348 ± 0.030	0.030 ± 0.018	0.058 ± 0.016
ds	0.058 ± 0.025	0.135 ± 0.032	0.049 ± 0.025	0.065 ± 0.070
R^2	0.985	0.980	0.98	0.962
Maximum gas production rate (ml/h)	2.520	1.694	4.350	1.484
Time point of inflection, h	2.762	4.050	2.122	4.240
Lag time, h	0.123	0.463	0.117	0.617

[a-c] means within a column with no common superscripts differ significantly ($P<0.05$)

[1] b - the plateau value of gas production (ml); μr - the rapid gas production rate (ml/h) during early stages of fermentation; dr - the fractional decay constant for mr; ms - the slower gas production rate (ml/h) during later stages of fermentation; ds - the fractional decay constant for ms

DISCUSSION

Chemical compositions. To the author's knowledge, no work has been published on the chemical composition of deseeded green pods of *M. stenopetala* and *M. oleifera*. Some studies on the edible portion of *M. oleifera* pods have been reported, but comparisons with our results (expressed on a DM basis) are difficult. The CP content of seedpods of *M. stenopetala* reported by Melesse et al. (2009) was much lower than that found in the current study. The NDF and ADL values for *M. stenopetala* are similar to those reported for lucerne hay (Bueno et al., 2010), but the NDF, ADF, and ADL contents for *M. stenopetala* were generally lower than those reported for four varieties of cassava leaves by Oni et al. (2010).

Considerable differences in the morpho-physiological traits of plants were observed when they were grown at different altitudes (Todaria and Purohit, 1979). In the present study, a significant interaction between altitude and *Moringa*

species was noted for most chemical and mineral compositions. Singh et al. (2010) observed significantly higher ash and CP contents in foliages of *Celtis australis* L. grown at high altitude than those from low altitude. The present study suggests that altitude significantly influenced the chemical composition but less the mineral components of both *Moringa* species.

Diets containing high K levels are known to reduce Mg absorption (Jittakhot et al., 2004) and cause an increase in the percentage of Mg excreted in the faeces. Thus, the high K in *M. oleifera* might affect Mg absorption. High levels of Fe have been observed and may interfere with the absorption of Zn, Cu and Mn, as reported by Gengelbach et al. (1994). The P, K and Ca concentrations showed a strong positive correlation with elevation range of foliage. On average, high altitude foliage exhibited comparatively higher values for P, Ca and K (Singh et al., 2010). Similarly, the concentrations of Ca, P, K, Mg, Fe, Mn, and Zn were higher in *M. oleifera* cultivated at moderate altitude.

In vitro fermentation characteristics and estimated parameters. Gas volume produced at 24 h from *M. stenopetala* was comparable with that of Abas et al. (2005) for wheat straw and Oni et al. (2010) for four varieties of cassava leaves. The incubated feed samples from *M. stenopetala* produced significantly more gas than those from *M. oleifera*. The explanation could be that *M. stenopetala* contained more ME and NFC than *M. oleifera*, and these components are positively associated with the gas production potential of feedstuffs (Tylutki et al., 2008). The low gas volume observed in *M. oleifera* might be caused by the presence of highly fibrous substances, as shown in Table 1. High fermentation rates indicate high nutrient availability for ruminal microorganisms, while lower rates may be the result of greater NDF and ADF contents (Table 1); the chemical components of NDF and ADF may slow down the speed of substrate fermentation (Fievez et al., 2005). Thus, the extent of *in vitro* fermentation in *M. stenopetala* suggests that it is of higher nutritional value than that of *M. oleifera*.

The calculated high maximum gas production rate of 4.4 ml/h for *M. stenopetala* cultivated at moderate altitude was comparable to that of lucerne leaves (4.1 ml/h) reported by Bulang (2005), but the lag time (time for microbial attachment and start of degradation) in the present study was more than tenfold smaller than obtained from lucerne leaves (2.6 h). Hence it is most likely that the degradability and consequent nutrient availability, especially nitrogen in ruminants, will be increased at a faster rate. The observed shorter lag time for *M. stenopetala* from both altitudes might be related to the high content of fermentable carbohydrates (relatively high NFC content, Table 1). The lag time reported by Makkar and Becker (1996) for *M. oleifera* leaves (0.23 h) was twofold lower than found in the present study of the same *Moringa* species. The overall lag times observed in the present study are generally lower than those reported by Oni et al. (2010) for four varieties of cassava leaves.

M. oleifera cultivated at both altitudes had the longest lag times. This would indicate slower nutrient availability from deseeded pods of *M. oleifera*. Nonetheless, the influence of high structural carbohydrates (NDF, ADF and cellulose) and low concentrations of soluble carbohydrates (notably low NFC value) in *M. oleifera* on the gas production profile should be taken into account when explaining the long lag time.

The livestock feed resources in tropical and subtropical regions are usually poor quality for the majority of any feed year and are deficient in critical nutrients for efficient microbial growth in the rumen. Low quality feed resources with high fibrous contents are considered the primary reasons for high methane gas emissions by ruminants. The green pods might contain phytochemicals, like tannins and flavonoids, that may have antimethanogenic properties that could act as chemical inhibitors of ruminal methane formation, as suggested by Szumacher-Strabel et al. (2010, 2011). Phenolic compounds (e.g., tannins), may reduce rumen methanogenesis in sheep and cattle (Boadi et al., 2004), while flavonoids have been demonstrated to modify microbial metabolism in the rumen (Broudiscou and Lassalas, 2000). It would be thus helpful to further study the presence of anti-nutritional factors (tannins, phenols, etc.) in deseeded pods of both Moringa species and its effect on the performance of farm animals.

In vitro rumen gas production has been extensively used to accurately predict the ME content of a wide variety of feeds (Melesse et al., 2009). These authors reported 5.1 MJ/kg DM of ME for *M. stenopetala* seedpods, which is comparable to that of *M. oleifera* in the current study. In agreement with the present findings for *M. oleifera*, Magalhaes et al. (2010) reported a ME value of 5.66 MJ/kg DM for elephant grass.

A high correlation has been reported between *in vivo* OMD and *in vitro* gas volume at 24 h (Menke et al., 1979). The OMD value obtained from *M. oleifera* in the present study was comparable with that of lucerne hay (44.7%) and wheat straw (45.2%) reported by Sallam et al. (2008) and Abas et al. (2005), respectively. Similarly, the calculated OMD values for grass and vetch hays reported by Abas et al. (2005) were in good agreement with the current findings for *M. stenopetala*. These findings suggest that deseeded pods from both Moringa species, particularly from *M. stenopetala,* could be used as an alternative energy supplement to tropical ruminants when the availability of improved forages and grasses becomes scarce during the dry season.

Since the SCFA content is an indicator of the energy value of diets, its prediction from *in vitro* gas measurements is useful under circumstances where laboratories lack gas chromatography equipment, especially in developing countries. The high production of gas and predominance of SCFA in *M. stenopetala* vs *M. oleifera* could probably describe an increased proportion of acetate and butyrate but a decrease in propionate production. Moreover, *M. stenopetala* contains more

fermentable carbohydrate (notably NFC and NFE) which is a vital substrate for growth of ruminal microorganisms (Van Soest, 1994). In general, the ME, OMD, and SCFA values obtained from the present study were higher than those reported by Negesse et al. (2009) for agro-industrial and kitchen waste products.

CONCLUSIONS

M. stenopetala had a better chemical composition and *in vitro* degradability of nutrients, while *M. oleifera* had comparatively high mineral concentrations. The moderate altitude appears to have favored nutrient compositions and *in vitro* degradability characteristics, suggesting its suitability for Moringa cultivation for better utilization. The present findings further suggest that deseeded green pods may be used as alternative and sustainable sources of home-grown energy supplements for low quality crop residues in livestock feeding under smallholder farmer conditions, while using the seeds for human consumption. The effects of feeding deseeded green pods to ruminants on their performance require further studies, however.

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