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Original Research

Chemical and mineral compositions of pods of *Moringa stenopetala* and *Moringa oleifera* cultivated in the lowland of Gamogofa Zone

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Abstract

This study was conducted to evaluate the chemical and mineral compositions of whole and seeds-removed fresh pods of *Moringa stenopetala* and *Moringa oleifera*. Feed samples were collected from five trees of each Moringa species and analyzed for chemical and mineral compositions using standard methods. The results indicated that whole fresh pods of both Moringa species contained significantly ($p<0.05$) higher crude protein (CP) and fat values than seeds-removed pods. The highest CP (182 g/kg DM) was obtained from whole fresh pods of *M. stenopetala* while the lowest from seeds-removed fresh pods of *M. oleifera* (104 g/kg DM). In both Moringa species, seeds-removed fresh pods contained significantly ($p<0.05$) higher crude fiber, neutral detergent fiber, cellulose and hemicellulose than that of whole fresh pods. In *M. stenopetala*, calcium content was 3.72 and 2.98 g/kg DM in whole fresh pods and seeds-removed fresh pods, respectively. In *M. oleifera*, whole and seeds-removed fresh pods contained 3.34 and 2.74 g/kg DM calcium, respectively which differed significantly. In both Moringa species, the concentrations of phosphorous, magnesium and zinc in whole fresh pods were significantly ($p<0.05$) higher than those found in seeds-removed fresh pods. High zinc and iron concentrations were found in whole and seeds-removed fresh pods of both Moringa species, respectively. Both whole and seeds-removed fresh pods of *M. oleifera* had high copper values (9.3-9.7 mg/kg DM) compared with those of *M. stenopetala* (4.8-5.8 mg/kg DM). In conclusion, the fresh pods of both Moringa species could be used as alternative protein supplement sources for feeding ruminant and monogastric animals during dry periods of the year.

INTRODUCTION

The significance of evaluating the nutritional value of indigenous shrubs, trees and browse plants is evident as their foliage can make important contributions to the protein and energy consumption of ruminant animals. This is particularly important in the tropical climates where availability and quality of forage often become severely limited during the dry season. Furthermore, grazing lands are steadily shrinking by conversion to arable lands, and natural pastures are also restricted to areas that are marginal and have little farming potential [1].

Leaves and pods from browse and fodder trees form major parts of livestock feed in the tropical countries [2] and play a major role in improving dietary protein [3]. Tree leaves and pods can be rich in crude protein, minerals and digestible nutrients when compared to grasses. Thus, their use as a supplement can improve voluntary feed intake, digestibility and the animal's performance at large [4].

Both *M. stenopetala* and *M. oleifera* are commonly known Moringa species that are grown in the tropics and sub-tropics. It is reported that the edible parts of Moringa tree are exceptionally nutritious [5]. All parts of the tree except the wood are edible, providing a highly nutritious food for both humans and animals. The seeds are sometimes removed from more mature pods and eaten like peas or roasted like nuts. The flowers are even edible when cooked, and are said to taste like mushrooms.

M. stenopetala, often referred to as the African Moringa tree, is a multipurpose tree native to Ethiopia, northern Kenya and eastern Somalia, which has a wide range of adaptation from the arid to humid climates [6]. *M. stenopetala* is a fast growing tree on the sites that are not severely acidic, not water lodged and below 2000 altitude [7]. Due to its water storage capacity in the bottle shaped stem, *M. stenopetala* is well adapted to semi-arid areas of 500 mm annual rainfall and continued to grow during the exceptionally long dry season. Leaves are used for human consumption and animal feed [8, 9, 10]. A recent study conducted by Melesse et al. [11] indicated that the leaves of *M. stenopetala* are rich in protein (28.2%) and contain reasonable amounts of essential amino acids of which some are comparable with those found in soybean meal. It is a multipurpose tree that is cultivated both for human food and animal feed in Southern Ethiopia.

M. oleifera, commonly referred to as the `drumstick tree' (describing the shape of its pods), is native to the sub-Himalayan tracts of north-west India, Pakistan, Bangladesh and Afghanistan [12, 13]. It is a pan tropical multipurpose tree and is characterized by high biomass yield and can tolerate unfavorable environmental conditions [13]. This multipurpose tree has been introduced to Ethiopia over the last few years and is grown at nursery sites parallel to *M. stenopetala* in southern parts of the country. Unlike *M. oleifera* which is propagated using both seeds and stem cuttings, *M. stenopetala* is propagated by seeds [6, 14, 15], and the use of cuttings is not common in its major area of cultivation in Ethiopia [6].

Edible parts (leaves and fresh pods) of Moringa tree are used for human food, animal fodder, shade, windbreak and medicine. A study conducted by Melesse et al. [16] on *M. stenopetala* leaf meal as a protein supplement to the poultry diet showed improved feed intake and found no negative effect on health of the birds. In another study conducted by Gebregiorgis et al. [17] supplementation of sheep with dried *M. stenopetala* leaves has improved the growth performance parameters. However, complete information on the chemical compositions and feeding values of various edible parts of both Moringa species as cultivated in the lowland areas of southern Ethiopia is still scarce. Accordingly, this study was designed to evaluate the chemical and mineral compositions of fresh green pods.

MATERIALS AND METHODS

Sample collection

Samples of fresh pods of *M. stenopetala* and *M. oleifera* were collected at Chano Mille nursery site of Southern Agricultural Research Institute located in Gamogofa administrative zone, Ethiopia. The altitude is 1100 m a.s.l with annual rainfall of between 750 and 900 mm. The samples were collected from both Moringa trees aged 7 years old during the end of the rainy season. Each sample was collected randomly from five different Moringa trees. Seeds-removed pods were first prepared by removing seeds from each whole fresh pod by hand. Both whole and seeds-removed fresh pods were chopped using a knife and partially sun-dried to reduce the moisture content. Then, all samples were dried at 65 ^{o}C for 48 h and ground to pass 1 mm sieve size. Ground feed samples were labeled and kept in air-tight plastic containers until analysis.

Chemical analysis

The determination of dry matter (DM), ash, crude fat (EE) and crude fiber (CF) was performed according to AOAC [18]. Total nitrogen content of the feed was determined using micro-Kjeldahl method. The crude protein (CP) was then calculated as nitrogen (N) × 6.25. The neutral detergent fibre (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) contents were analyzed using the method of Van Soest et al. [19] in an ANKOM® 200 Fiber Analyzer (ANKOM Technology Corp., Fairport, NY, USA). Cellulose and hemicellulose were computed as ADF minus ADL and NDF minus ADF, respectively. Non-fiber carbohydrate (NFC) content was calculated as 100-(NDF + CP + EE + ash) according to NRC [20]. Nitrogen free extract (NFE) was computed by difference of organic matter and the sum of CF, EE and CP.

Phosphorus (P) was determined with continuous flow auto-analyzer [21]. The contents of calcium (Ca), sodium (Na), potassium (K), magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) were determined by atomic absorption spectrophotometer (Perkin-Elmer, Model 2380). All samples were analyzed in duplicates at Ethiopian Health and Nutrition Research Institute, Addis Ababa.

Statistical analysis

From each Moringa species, five trees were randomly sampled with a total of ten samples (2 × 5). Data were then subjected to one way ANOVA with Moringa species (*M. oleifera* and *M. stenopetala*) as main effects using General Linear Models (GLM) Procedure of Statistical Analysis System [22]. Differences of means were separated by Duncan Multiple Range Test. All statements of statistical differences were based on $p<0.05$ unless noted otherwise.

RESULTS

Chemical compositions

As presented in Table 1, whole fresh pods of *M. stenopetala* contained significantly higher values of ash, crude protein (CP), fat (EE) and acid detergent lignin (ADL) than seeds-removed pods. On the other hand, seeds-removed pods of *M. stenopetala* had significantly higher values of crude fiber (CF), nitrogen free extract (NFE), neutral detergent fiber (NDF), cellulose, hemicelluloses and none fiber carbohydrate (NFC) than those of whole fresh pods. No significance differences were observed in acid detergent fiber (ADF) values between whole and seeds-removed fresh pods of *M. stenopetala*.

In *M. oleifera*, the CP, EE, NFE and NFC values in whole fresh pods were significantly ($p<0.01$) higher than those of seeds-removed pods (Table 1). Conversely, seeds-removed pods of *M. oleifera* had significantly higher values of ash, CF, NDF, ADF, cellulose and hemicellulose than those of whole fresh pods. The ADL values were similar among whole and seeds-removed fresh pods of *M. oleifera*.

In both Moringa species, the whole fresh pods contained high CP and EE. However, the contents of CF, NDF, cellulose and hemicellulose in both Moringa species were generally higher in seeds-removed fresh pods than those of whole fresh pods. The highest and lowest ADF values were found in seeds-removed and whole fresh pods of *M. oleifera*, respectively. Higher NFC values were found in whole fresh pods of *M. oleifera* and seeds-removed fresh pods of *M. stenopetala*.

Mineral compositions

In whole pods of *M. stenopetala*, the contents of phosphorous (P), magnesium (Mg) and trace minerals zinc (Zn) and copper (Cu) were significantly higher than those found in seed-removed pods (Table 2). However, concentrations of sodium (Na) and trace mineral iron (Fe) were significantly higher in seeds-removed pods. No significant differences in the contents of calcium (Ca), Ca:P ratio, potassium (K) and manganese (Mn) was observed between whole and seeds-removed pods. In *M. oleifera*, seeds-removed fresh pods had significantly higher values of Ca, Ca:P, K, Na and Cu than whole fresh pods. Nevertheless, whole fresh pods contained significantly higher values of P, Mg and trace mineral Z than those of seeds-removed pods. No significant differences were noted in trace minerals Fe and Mn between whole and seeds-removed pods.

As presented in Table 2, the contents of P and Mg in whole fresh pods of both Moringa species were significantly higher than those of seeds-removed fresh pods. However, seeds-removed fresh pods of both Moringa species contained high ratios of Ca to P and Na contents. In both Moringa species, the Na and Fe contents were high in seeds-removed fresh pods. However, the Zn content was significantly higher in whole fresh pods of both Moringa species than in seeds-removed fresh pods. Both whole and seeds-removed fresh pods of *M. oleifera* had higher Cu value than those of *M. stenopetala*.

Table 1. Least square means (g/kg DM, ± SE) of chemical compositions of whole and seeds-removed fresh pods of *M. stenopetala* and *M. oleifera*

Nutrients	*M. stenopetala*		*M. oleifera*	
	Whole FP	SRFP	Whole FP	SRFP
Ash	115±1.42^a	106±2.01^b	98.0±0.89^b	131±1.26^a
Crude protein	178±1.97^a	137±2.79^b	166±1.09^a	100±1.55^b
Ether extract	58.0 ±1.35^a	27.9±1.92^b	46.8±2.65^a	9.27±3.75^b
Crude fiber	367±1.75^b	391±2.48^a	362±2.90^b	466±4.10^a
Nitrogen free extract	277±2.50^b	344±3.53^a	337±3.80^a	293±5.37^b
Neutral detergent fiber	524±2.05^b	554±2.90^a	523±5.02^b	650±5.02^a
Acid detergent fiber	500±3.89^a	493±5.51^a	488±3.62^b	610±5.11^a
Acid detergent lignin	147±2.02^a	117±2.86^b	102±1.90^a	99.8±2.68^a
Cellulose	351±4.11^b	377±5.81^a	387±4.81^b	512±4.81^a
Hemicellulose	30.6±4.35^b	60.4±6.15^a	34.4±4.40^b	43.4±6.22^a
Non fiber carbohydrate	119±2.30^b	179±3.25^a	176±3.99^a	106±5.64^b

[a,b] Means between tree parts within Moringa species are significantly different ($p<0.05$)

FP = fresh pods; SRFP = seeds-removed fresh pods; SE = standard error of the mean

Table 2. The contents of major and trace minerals in whole and seeds-removed fresh pods of *M. stenopetala* and *M. oleifera* (Least square means ± SE)

Minerals	*M. stenopetala*		*M. oleifera*	
	Whole FP	SRFP	Whole FP	SRFP
Major minerals (g/kg DM)				
Calcium (Ca)	3.72±0.38[a]	2.98±0.54[a]	2.74±0.19[b]	3.34±0.27[a]
Phosphorous (P)	5.01±0.05[a]	3.20±0.07[b]	5.49±0.02[a]	5.02±0.03[b]
Ca:P	0.74±0.06[a]	0.93±0.08[a]	0.50±0.06[b]	0.67±0.08[a]
Potassium	41.9±0.29[a]	41.4±0.41[a]	36.4±0.34[b]	51.3±0.48[a]
Magnesium	3.65±0.09[a]	2.29±0.13[b]	2.69±0.02[a]	2.54±0.03[b]
Sodium	0.39±0.01[b]	0.50±0.02[a]	0.38±0.01[b]	0.48±0.01[a]
Trace minerals (mg/kg DM)				
Iron	402±30.4[b]	575±43.0[a]	550±18.0[a]	579±12.7[a]
Manganese	17.6±0.55[a]	17.2±0.78[a]	19.7±0.34[a]	20.1±0.48[a]
Zinc	21.9±0.50[a]	14.8±0.70[b]	31.1±0.89[a]	20.9±1.26[b]
Copper	5.77±0.09[a]	4.80±0.12[b]	9.26±0.15[b]	9.65±0.21[a]

[a,b] Means between tree parts within Moringa species are significantly different ($p<0.05$)

FP = fresh pods; SRFP = seeds-removed fresh pods; SE = standard error of the mean

DISCUSSION

Chemical compositions

To the authors' knowledge, limited works have been published on chemical composition of fresh pods of both Moringa species, in particular for *M. stenopetala*. 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 contents reported by Babayemi [23] for *Pennisetum purpureum* are similar with those of whole fresh pods (118 vs. 115 g/kg DM); but higher than those found in *Panicum maximum* (79 g/kg DM). The CP contents observed in whole fresh pod were similar to those of *Centrosema pubescens* (165 vs. 160 g/kg DM) but lower than those of *Pueraria phaseoloides* (220 g/kg DM) as reported by Babayemi [23].

The CP content of seeds-removed dried-pods of *M. stenopetala* as reported by Melesse et al. [11] was much lower than those observed in the present study for both whole and seeds-removed fresh pods. The CP values observed in whole fresh pods of *M. stenopetala* were comparable to those reported by Melesse et al. [24] for the same Moringa species; but slightly lower than those of alfalfa hay as reported by Bueno et al. [25]. The CP values found in whole fresh pods are comparable to those of coarse type of wheat bran reported by Kiran and Krishnamoorthy [26].

In the present study, the average CP values observed in whole and seeds-removed fresh pods (165 and 119 g/kg DM, respectively) are well above the range of 70-80 g/kg DM as suggested by Van Soest [27] to be the critical limit below which intake of forages by ruminants and rumen microbial activity would be adversely affected. In general, it can be concluded that both whole and seeds-removed fresh pods might be considered as an alternative protein supplements when compared to the low quality roughages fed ruminants.

The fat values reported by Melesse et al. [11] for seeds-removed dried-pods of *M. stenopetala* are in good agreement with those of seeds-removed fresh pods. The low fat content in seeds-removed fresh pods compared to whole fresh pods in the present study might be explained by the removal of the seed, which is reported to be rich in fat [11]. Kiran and Krishnamoorthy [26] reported low fat content of solvent extracted soya bean and sunflower meals than those observed in whole fresh pods of both Moringa types. The variation among data in literature could be due to the age of leaves at harvest, soil type and fertility, as well as agro-ecology in which the trees were growing. According to Maasdorp et al. [28], plant species/variety, soil, climate, grazing, plant fraction and stage of maturity at sampling affect the nutritive value of forages.

Melesse et al. [11] reported high plant cell wall structures for seeds-removed dried-pods of *M. stenopetala* as compared to the present study. Similarly, Makkar and Becker [12] reported higher values of NDF, ADF and ADL for *M. oleifera* seed hulls than those of whole fresh pods of *M. oleifera*. The NDF and ADL values for whole fresh pods of *M. oleifera* and seeds-removed fresh pods of *M. stenopetala* as obtained in the present study find similarity with those reported for alfalfa hay [25]. The NDF and ADF values reported by Anele et al. [29] for Nigerian multi-purpose tree species were generally lower than those found in fresh pods of the current study. However, the cellulose content for alfalfa hay reported by Bueno et al. [25] was comparable with those of the whole fresh pods of *M. stenopetala*. In both whole and seeds-removed fresh pods, the values for fiber fractions (NDF, ADF, ADL, cellulose and hemicelluloses) are within the range that can be utilized by the ruminant animals without any known adverse effects on DM and nutrient intakes.

Mineral compositions

Minerals are essential in animal feeding and human nutrition. More than 100 mg of major minerals and less than 100 mg of minor minerals are needed daily by human bodies [30]. Mineral composition of a plant plays significant role its nutritional, medicinal and therapeutic values. The Ca content in whole fresh pods of *M. stenopetala* was comparable to that of Melesse et al. [11, 24] for seeds-removed dried-pods of the same Moringa specie and Anjorin et al. [31] for lamina part of *M. oleifera*. However, the Ca values of both Moringa species in the current study were higher than those reported by Anjorin et al. [31] from a year old pods of *M. oleifera*. On the other hand, contents of Mg and K in whole fresh pods in the present study were much higher than those found by Melesse et al. [11] for seeds-removed dried-pods and by Anjorin et al. [31] for pods of *M. oleifera*. The contents of P and Na in whole and seeds-removed fresh pods of the present study are generally higher than those reported by Nurfeta et al. [32] for leaf lamina fraction of *Ensete ventricosum*. Moreover, the contents of P, Mg, K and Na reported by Nurfeta et al. [32] for leaf midrib, pseudostem and corm fractions of *Ensete ventricosum* were lower than those found in whole and seeds-removed fresh pods of both Moringa species. Similarly, the contents of Fe, Cu and Zn in the current study were generally higher than those of Nurfeta et al. [32] reported for midrib, pseudostem and corm fractions of *Ensete ventricosum*. Differences in mineral composition of a plant could be as a result of variation in edaphic factors and agro climatic conditions. Reedy and Bhatt [33] confirmed a variation in the minerals content of green leafy vegetable cultivated on soil fortified with different chemical fertilizer. It was reported by Aslam et al. [34] that mineral content in the leaves and seeds of Moringa varied in Pakistan with location.

CONCLUSIONS

This study suggested that fresh pods of *M. stenopetala* and *M. oleifera* could be used as sources of home grown supplements of protein for low quality crop residues, especially during the dry season for ruminants. The fresh pods might be also useful source of macro and trace minerals in monogastric animals such as poultry and human nutrition. It is recommended further investigations on vitamin and amino acid profiles and anti-nutritional factors of fresh pods.

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