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A COMPOSITIONAL STUDY OF *MORINGA STENOPETALA* LEAVES
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ABSTRACT

Objective: **To investigate nutrient composition in moringa leaves and compare with those of kale (*Brassica carinata*) and Swiss chard (*Beta vulgaris*).**
Design: **Laboratory based study, nutrient composition of fresh and cooked leaves of *M. stenopetala* were analyzed.**
Setting: **Gama-Gofa, south-western Ethiopia.**
***Results*:** **Raw *M. stenopetala* leaves contain 9% dry matter as crude protein, about 3-fold lower than in kale and swiss chard. *M. stenopetala* leaves contain higher percentage of carbohydrate, crude fiber and calcium compared to both raw and cooked kale and swiss chard. Vitamins are present at nutritionally significant levels averaging 28mg/100g of vitamin C and 160 µg/100g of ß-carotene. Minerals such as potassium, iron, zinc, phosphorus and calcium also exist in significant concentrations with the average values of 3.08 mg/100g iron and 792.8 mg/100g calcium.**
Conclusion: **Although the nutrient composition of *M. stenopetala* leaves in most cases is lower compared to kale and swiss chard they can be a good source of nutrients in dry season potentially when other vegetables are scarce. However, the presence of small amount of cyanogenic glucosides in *M. stenopetala* leaves may have a health risk in areas of high incidence of endemic goitre as an exacerbating factor if consumed more for a long period of time.**

INTRODUCTION

Moringa stenopetala, indigenous to Southern Ethiopia and Northern Kenya, is a member of the single genus family *Moringaceae*. The tree is popularly known as *Shifara* or *Shalchada* in *Ethiopia. Moringa stenopetala* is widely cultivated in Southern Ethiopia especially in Gamu-Gofa, Sidama, Konso and the adjoining provinces. A German geographer in 1938(1) observed the use of leaves from *M. stenopetala* as cabbage in the Konso highlands, south of Lake Chamo for the first time. Cultivation of the tree in compounds, on terraces and marketing of the leaves is, however, also practiced by several other tribes of Southern Ethiopia(2). Even today these leaves are an important vegetable during the dry season, not only for Konso, Gamo and Burji in Ethiopia but also for minorities from the same tribe in the Marsabit area of Northern Kenya(3). *Moringa stenopetala* is also known as vegetable tree. The Njemb tribe, living in Kenya, utilises this tree as medicinal plant(4). In southern Ethiopia it is used as kale or cabbage for human consumption and animal feed. Over five million people depend on this plant as a vegetable source. In Gamu-Gofa, immature leaves of *M. stenopetala* are part of the staple diet of the population. *Kurkurfa,* a paste prepared from *M. stenopetala* and cereals such as sorghum, maize, millet and barley is perceived as a delicacy among the population of Gamu-Gofa.

Besides its fast growing, drought resistance and resistance to insect and pests character, it offers many advantages to subsistence farmers(5). One plant of *M. stenopetala* is able to support a large family for several years. Apart from being cultivated traditionally as cabbage tree and planted as ornamental tree, unripe and mature seeds of the *Morigaceae* family are used as foodstuff and spices in many Asian and African countries and also consumed in drinks prepared in folk medicine(5).

The bark of *M. stenopetala* is used as condiment, having a horseradish taste. Elsewhere in the world villagers for their pods and leaves prize *M. stenopetala* trees. *Moringa stenopetala* leaves can also be eaten in salads and are important in regions where vegetables are scarce. Seeds of the *Moringaceae* family contain 40% by weight of high quality oil that is of equal value

both for cooking oil and as the main ingredient for soap manufacture(6,7).

Information available on the chemical composition of *M. stenopetala* leaves particularly its potential as a food or a feed resource is lacking. Therefore, the purpose of the present study is to provide information on the chemical composition of this non-conventional vegetable food, determine its nutritional quality and compare its nutrient content with those of kale *(Brassica carinata)* and Swiss chard *(Beta vulgaris).*

MATERIALS AND METHODS

Plant material: The leaves of *M. stenopetala* were collected from Gamo-Gofa, southern Ethiopia in August, 1998 and identified by Dawit Abebe of Ethiopian Health and Nutrition Research Institute (EHNRI). A voucher specimen (Herbarium No. 1119) has been deposited at the Herbarium of the Department of Drug Research (EHNRI, Ethiopia).

Moringa consumption: Fifty households were randomly selected for a dietary survey. Their dietary intake was estimated using a 3-day weighed record in which food quantities were weighed immediately prior to eating or by weighing duplicate portions, using a Salter kitchen scale. Dietary contribution of cooked *M. stenopetala* to the recommended daily allowance (RDA) for children and adults were then derived. Adults were regarded as moderately active with average age of 23-50 years was assumed. Finally the contribution of cooked *Moringa* to total intake of energy and nutrients was estimated by dividing intake from *Moringa* by total intake.

Chemical analysis: Fresh *M. stenopetala* leaves cooked without spices according to the traditional way of cooking were collected from households in Gamo-Gofa and were transported to the Ethiopian Health and Nutrition Research Institute (EHNRI) in ice-boxes. All samples were kept in a freezer. Part of the cooked and fresh leaves was freeze dried and stored at 4°C until analysis. Minerals and proximate analysis were conducted in the Ethiopian Health and Nutrition Research Institute.

The leaves of *M. stenopetala* were washed with cold deionized water to clear them from dirt and other foreign matter, then cut into approximately 2.5cm, segments using a stainless steel knife to avoid damaging the colour of the plant by oxidation of the pigments in the presence of metal content. The material obtained was stored in a freezer at 4°C before drying (at 55°C for at least 24 hours) and grinding (to less than 0. Imm size) it into flours. Dry matter content was determined by drying 2.0g flesh samples at 100±2°C for 24 hours. Flours obtained from the raw and cooked *M. stenopetala* leaves were analyzed for their proximate, chemical composition, as well as for minerals, neutral detergent fiber and ash content. Ash was gravimetrically obtained by furnace combustion at 600°C(8).

Potassium and sodium were determined by flame photometer using Allen's method(9). Calcium, iron and zinc concentrations in the ash were analysed utilising a flame atomic absorption spectrometer (Varian Model Spectra 20 Plus, Australia) except for phosphorus, which was estimated according to the method of Allen(9). Total nitrogen was determined by digestion of the dried ground sample in a Tecator Digestion System, followed by distillation and titration in a Kjeltec Auto 1030 Analyzer (Tecator AB, Hoganas, Sweden). Crude protein was calculated by multiplying Kjeldahl nitrogen by 6.25.

Fat was extracted with petroleum either using the Soxhlet method(8). Crude fiber (CF) was obtained using the neutral detergent fiber method(8).

Ascorbic acid was determined by the photometric adaptation of the 2,6-dichlorophenol indophenol method using a Bausch and Lomb Spectronic 20 at 520nm. Extraction was done with 3% metaphosphoric acid(10,11).

Carotenoids analysis: Carotenoids from fresh and cooked samples were measured with the HPLC following the procedure of Epler *et al* (11). HPLC with Diode Array Detection (HPLC-DAD) Jasco ternary gradient unit LG 980-02, with degasser and MD-910 multiwavelength detector driven by BORWIN chromatography software has been used. The chromatographic separation was performed on a Superspher RP18 column (250mmx4mm) from Merck (Darmstadt Germany) at ambient temperature. The HPLC separation of carotenoides was achieved by gradient conditions. Crystalline carotenoids (Sigma) were used as standards. The correlation coefficient for carotenoids concentrations versus its peak area was 0.995 and intercept was close to zero. Carotenoid content was expressed in terms of retinol equivalent (RE).

Determination of cyanogenic glucoside content: Cyanogenic glucoside content of the freeze-died samples was assayed at Botanisches, Institut der Technischen Universitat Braunschweig, Germany, following the method of Adridge(12). In brief, the freeze-dried leaf material (0.719g) was extracted with 10ml methanol for 24 hours. The extract was centrifuged at 2500rpm for 10 minutes and the residue was re-extracted with 1ml methanol and centrifuged again. The combined residues were evaporated to dryness and dissolved in 2ml water using an ultrasonic bath. The water solution was then centrifuged and 57 µl of the clear supernatant incubated with 300µl of ß-glucosidase and 430µl buffer using Thanberg tubes to prevent loss of HCN. Following 16 hours of incubation, 400µ1 1M NaOH was added to liberate HCN from hydroxynitriles. The basic solution was then neutralized with 400µl 1M HCL and made up to 5ml. The HCN content was then measured by a Merck spectrophometer at 595 nm using the Merck-Test "Spectroquant Cyanide" (585_E=131.600 l/mol x cm).

Statistical analysis: Statview 4.01 (Abacus Concepts, Inc. Berkley, CA, USA) was used to determine the mean and the standard error of mean (SEM) for each leaf component. A difference in composition among cooked and raw samples was determined by analysis of variance (ANOVA) and tested Fisher's protected least significant difference (PLSD).

RESULTS

Kjeldahl nitrogen values were used to calculate protein content factor 6.25. *Moringa stenopetala* leaves contain significantly less ($p < 0.01$) protein than kale and Swiss chard (Table 1). The protein content of raw and cooked *M. stenopetala* leaves were 9% and 11%, in dry weight, respectively. In contrast the protein content of kale and Swiss chard is comparable to values reported for amaranth leaves(13).

Table 1

Proximate composition of M. stenopetala leaves, kale and Swiss chard (g/100g, dry weight basis)[1]

Variant	Carbohydrate %	Protein %	Fat %	Crude fiber %	Ash %	Energy Kcal
M. stenopetala leaves						
Cooked	49.8±12.7	10.6±0.7	5.45±0.6	20.8±2.4	13.4±0.6	290.6±1.62
Range	(40.5-51.3)	(8.7-12.1)	(3.7-7.0)	(19.3-23.8)	(11.0-17.8)	(222.1-359.6)
M. stenopetala Leaves						
Raw	51.8±2.6	9.0±0.7	5.8±1.4	20.8±3.3	12.6±1.1	295.4±2.75
Range	(47.1-58.3)	(7.0-11.9)	(4.0-7.0)	(19.1-24.2)	(9.1-14.2)	(248.4-343.8)
Kale						
Raw	39.5±0.2	25.5±0.1	6.7±0.1	12.5±0.2	15.8±0.3	323.3±1.1
Range	(34.1-47.2)	(23.2-26.3)	(5.7-8.3)	(10.1-14.4)	(13.8-16.9)	(316.3-332.0)
Kale						
Cooked	40.7±0.3	24.6±0.3	6.9±0.1	13.2±0.1	14.6±0.2	261.2±1.4
Range	(26.3-46.4)	(21.2-27.8)	(4.8-8.2)	(11.4-15.8)	(11.2-15.9)	(290.2-310.6)
Swiss chard						
Raw	31.8±0.2	25.9±0.1	4.7±0.1	12.9±0.3	24.7±0.4	273.1±0.2
Range	(24.1-41.3)	(23.7-27.3)	(3.7-5.1)	(10.0-14.7)	(21.3-28.8)	(251.5-293.3)
Boiled	38.9±10.1	22.8±0.4	4.5±0.1	11.8±0.2	20.0±0.3	287.3±0.9
Range	(30.6-46.8)	(19.5-24.5)	(4.4-6.4)	(10.3-15.7)	19.0-22.8)	(246.0-304.4)

[1]Mean ± SEM for three composite samples

Table 2

Mineral content of raw and cooked samples (mg/100g, dry weight basis)[1]

Variant	Na	K	P	Ca	Fe	Zn
M. stenopetala leaves						
Cooked	243.7±2.5	311.9±3.6	56.7±14	665.7±87	2.89±2.2	0.45±0.1
Range	(213-371)	(289-393)	(51.3-61.7)	(618-784)	(2.2-4.7)	(0.38-0.61)
M. stenopetala leaves						
Raw	403.5±21	453.0±11.0	65.6±13	792.8±92	3.08±0.8	0.53±0.8
Range	(381-470)	(413-532)	(61.2-68.7)	(678-897)	(2.6-4.8)	(0.48-0.56)
Kale						
Cooked	326.2±32	404±56	45.3±17	260±13	4.2±0.7	0.51±0.3
Range	(291-376)	(354-508)	(39.8-50.3)	(213-341)	(3.3-5.1)	(0.47-0.62)
Kale						
Raw	550±51	806.2±38	64±9	194±43	7.2±0.2	0.61±0.10
Range	(431-674)	(789-904)	(57-71)	(189-203)	(6.9-8.7)	(0.53-0.71)
Swiss Chard						
Raw	810.6±43	1315±93	68±5	417.5±14	5.60±0.1	0.35±0.2
Range	(713-895)	(1298-1404)	(38-83)	(372-481)	(2.9-6.6)	(0.29-0.55)
Swiss Chard						
Boiled	432±23	785±65	41±2	385±10	5.4±0.2	0.38±0.3
Range	(386-492)	(821-1053)	(36-48)	(277-394)	(3.1-6.4)	(0.33-0.51)

[1]Mean±SEM for three composite samples

Compared with kale, *M. stenopetala* leaves are lower in fat content but significantly higher ($p<0.05$) than Swiss chard (Table 1). With respect to crude fiber, both raw and cooked *M. stenopetala* leaves had, on average, a significantly higher ($p<0.05$) content than kale and Swiss chard. The crude fiber content in the raw *M. stenopetala* leaves is similar to that of cooked *M. stenopetala* leaves. Both raw and cooked *M. stenopetala* leaves and kale had significantly lower ($p<0.01$) ash levels than the corresponding Swiss chard.

The carbohydrate content of the raw and cooked *M. stenopetala* leaves was significantly higher than in kale and Swiss chard (Table 1). However, in the cooked samples the carbohydrate levels were lower than in the corresponding raw samples.

The mineral composition of *M. stenopetala* leaves as compared with kale and Swiss chard is given in Table 2. Potassium concentration was highest in both raw kale and Swiss chard. In contrast, raw *M. stenopetala* leaves contained similar concentration of phosphorus but higher calcium compared with kale and Swiss chard. A similar trend in mineral levels was observed in Amaranth leaves(13). Raw *M. stenopetala* leaves had higher zinc concentrations, comparable level with kale and higher zinc content than the Swiss chard. The iron concentration in raw *M. stenopetala* leaves is more than 1.8 fold lower compared to raw kale and Swiss chard. The ratio of Ca to P in both cooked and raw leaves of *M. stenopetala* is 1:0.09, which is far lower than the recommended Ca:P ratio of 1:1(14). *Moringa stenopetala* leaves thus appear to be a good source of Ca but poor source of phosphorous.

The calcium levels in the raw leaves in this study are significantly higher than those values reported for amaranth leaves(13). The high Ca level in *M. stenopetala* leaves suggests that oxalic acid would occur as the insoluble Ca salt in the leaves.

The process of cooking the leaves was carried out by first washing and then decanting, leading to a significant decrease in the recovery of minerals. Cooking marginally reduced the content of minerals to a varying degree. In the cooked samples, the highest loss was observed for sodium and potassium the least for iron. Despite their low protein content *M. stenopetala* leaves can be considered as a potential mineral source.

Antioxidants, such as carotenoids and vitamin C, may contribute to the beneficial effects of vegetable consumption. Many epidemiological studies have indicated that an increased intake of vegetables is associated with a decreased risk of certain cancers(15). An alternative source of vitamin A is ß-carotene, available easily through green leafy vegetables.

Table 3 presents the concentration of ascorbic acid, carotenoids and cyanogenic glucoside in raw and cooked *M. stenopetala* leaves. Vitamin C and 3-carotene are present at nutritionally significant levels, averaging 28 mg/100g of vitamin C and 160 µg/100g of ß-carotene, fresh weight. α-Carotene, ß-cryptoxanthin, zeantin and lutein were similarly determined in *M. stenopetala* leaves (Table 3). The concentration of ascorbic acid in raw *M. stenopetala* leaves is eight-fold less than in amaranth leaves(13). Such vegetables often lose their carotene and ascorbic acid content through cooking processes. In the present study, ascorbic acid content in cooked *M. stenopetala* leaves decreased by about ten-fold probably due to oxidation of the vitamin C in these leaves during cooking. Decanting of cooking water may have also contributed to the significant decrease in ascorbic acid since such a process is usually practiced in households. Carotenes are stable during ordinary cooking although some loss may occur at temperatures above 100°C when oil or butter is used. However, the carotene content of cooked *M. stenopetala* leaves was reduced by only 11%.

Table 3

Carotenoid, vitamin C and cyanogenic glucoside of M. stenopetala leaves

Variable	Raw leaves	Cooked leaves
Vitamin C (mg/100g)	28.07±7.3	2.12±0.9
ß-Carotene (µg/100g)	160.0	121.0
α-Carotene (µg/100g)	54.0	35.7
P- Cryptoxanthin (mg/100g)	37.5	28.3
Zeanthin (µg/100g)	25.5	21.1
Lutein (µg/100g)	650.0	558.0
Retinol equivalent (RE)	34.04	–
Cyanogenic glucoside (mg/100g)	88.8	79

Similar to the mature seeds of *Moringa oleifera* and *Moringa stenopetala*, the raw leaves of *Moringa stenopetala* contain isothiocyanates (cyanogenic glucoside) (16). The seeds of both *moringa* species contain 4(α-L-rhamnosyloxy) benzyl isothiocyanate(5). The isothiocyanates also occurring in the genera *Brassica* (cabbage) are hydrolyzed in the presence of enzymes to hydrocyanic acid, toxic to human and which is readily metabolized to thiocyanate (SCN), a known goiterogenic substance(17). Isothiocyanates in low-iodine diets depress the iodine uptake by the thyroid significantly causing hyperactivity and hyperplasia of this gland(18). In a previous study conducted in Southern Ethiopia, significant association between the prevalence of goitre and frequency of *Moringa stenopetala* leaves consumption has been observed(19). Although the concentration of cyanogenic glucoside determined in the present study is less than that expected to cause goitre, excess and frequent consumption may cause hypothyrodism since it is widely grown and consumed by the population living in areas of incidence of endemic goitre. In the present study, the cyanogenic glucosides are reduced by 11% only in cooked leaves mid may cause a health hazard (Table 3).

Table 4

Contribution of cooked M. stenopetala leaves to energy and nutrients intake

	Proportion of requirement for children[a]	Contribution of *M. stenopetala* to total make (%)	Proportion of requirement for adults[b]	Contribution of *M. stenotepala* to total make (%)
Energy,Kcal	1300	17.2	2400	18.2
Protein, (gm)	23	35.7	56	24.6
Vitamin C (mg)	45	3.6	60	3.2
Vitamin A (μgRE)	400	5.8	1000	4.53
Iron, (mg)	15	14.7	10	43.5
Calcium (mg)	800	64.1	800	125
Zinc (mg)	10	3.5	15	4.5
Phosphorus (mg)	800	5.5	800	10.8

[a]1-3 years of age, 13kg body weight. [b]23-50 years of age, 70kg body weight.

The major uses of the recommended daily allowances (RDA) as nutrition standard is assessing the nutritional adequacy of diets from knowledge of food composition and food intake. Table 4 presents the results of the dietary survey. The proportion of total energy intake derived from protein, fat and carbohydrate was 2.6, 3 and 13% for adults and 3.3 and 12% for children, respectively. The average consumption of *M. stenopetala* leaves was 0.150 kg day^{-1} for adults and 0.076 kg day^{-1} for children, providing 19.2 % of energy for adults and 17.2 % for children. The intake of energy was thus very low compared to the percentage requirement. The intakes of protein (29.5 and 37%), vitamin A (4.5 and 6%), iron (43.5 and 15%), zinc (4.5 and 3.5%), phosphorus (11 and 6%) for adults and children, respectively, were also below the requirement. Calcium only exceeded the requirements (124 and 124%). All vitamin A came from the leaves as provitamin A.

DISCUSSION

The general conclusion we obtained from this study is, prevailing food security and nutritional importance of traditional food plant given less attention in developing countries. *Moringa stenopetala* is one of the major drought resistant vegetable plants in low and middle lands of Ethiopia. This plant has various benefits to Ethiopian subsistence agricultural community as a source of daily diet and local medicinal value. Besides its characteristic fast growing, drought resistance and resistance to insect and pests, it offers many advantages to subsistence farmers(5). A single plant of *M. stenopetala* is able to support a large family for several years. Apart from being cultivated traditionally as cabbage tree and planted as ornamental tree, unripe and mature seeds of the *Morigaceae* family are used as foodstuff and spices in many Asian and African countries and also consumed in drinks prepared in folk medicine(5).

The analytical results presented clearly indicate the potential of *M. stenopetala* as a possible additional source of nutrients such as vitamin C and carotenoids like ß-carotene, α-Carotene, ß-cryptoxanthin, zeantin and lutein. *Moringa stenopetala* leaves contain an equal amount of vitamin A as carrot roots, and are richer in vitamin C than tomatoes, radishes, carrots and peas. Their protein content is equivalent to peas and calcium and phosphorus amounts are higher than in many other vegetables.

Although the nutrient composition of *M. stenopetala* leaves in most cases is lower compared to kale and swiss chard, the plant may be a good source of nutrients in dry season when other vegetables are scarce. In addition to being an important source of nutrients the seeds of *M. stenopetala* are priced as condiment with their characteristic horseradish taste. Seeds of the *Moringaceae* family contain 40% by weight of high quality oil that is of equal value both for cooking oil and as the main ingredient for soap manufacture.

The seeds of *M. stenopetala* contain antimicrobial properties attributed mainly to benzyl isothiocyanate. However, isothiocyanate have been known to act as goitrogenic factor(18). In a study conducted in Southern Ethiopia, significant association was noted between the prevalence of goitre and frequency of *M. stenopetala* leaves consumption(19). In line with this a known goitrogenic factor, cyanogenic glucoside was determined in *M. stenopetala* leaves in the study. Although the concentration of cyanogenic glucoside determined in the present study is less than that expected to cause goitre, excess and frequent consumption may exacerbate hypothyroidism since it is widely grown and exclusively consumed during drought by the population living in areas of incidence of endemic goitre.

The effect of cooking on nutrient composition was also assessed. The concentration of ascorbic acid in raw *M. stenopetala* leaves is eight-fold less than in amaranth

leaves(13). Such vegetables often lose their carotene and ascorbic acid content through cooking processes. In the present study, ascorbic acid content in cooked *M. stenopetala* leaves decreased by about ten-fold probably due to oxidation of the vitamin C in these leaves during cooking. Decanting of cooking water may have also contributed to the significant decrease in ascorbic acid since such a process is usually practiced in rural households. Carotenes are stable during ordinary cooking although some loss may occur at temperatures above 100°C when oil or butter is used. However, the carotene content of cooked *M. stenopetala* leaves was reduced by only 11%. This suggests that attention must be given to minimise loss of important nutrients during cooking.

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