Moringa oleifera a potential tree for nutrition security in sub-Sahara Africa

Armachius James and Vumilia Zikankuba

Horticultural Research and Training Institute (HORTI)-Tengeru,
P.O.Box 1253, Arusha, Tanzania.
Corresponding author: Armachius James Email: armachiuss@gmail.com

ABSTRACT

Moringa oleifera popularly known as 'Moringa' is a widely distributed plant in the tropics and sub-tropics countries. It is a highly valued plant which serves multipurpose use due to its wide range of minerals, vitamins and antioxidants content. Almost all parts of the tree are useful either as food or medicine especially to indigenous people in their traditional medicine systems. Flowers, immature pods, seeds and leaves are rich sources of vitamins, minerals, proteins and other important phytochemicals. The leaves and seeds contain proteins and essential amino acids, which are important for human nutrition. Seeds provide protein electrolytes that can be used in water purification. Coupled with that, Moringa leaves and seed possess a wide range of biological applications, such as tissue and organ protection, analgesic, antiulcer, antihypertensive and immunomodulation actions. Moringa contains a lot of antioxidants such as, polyphenols, flavonoids and glucosinolates claimed to be important to human health. In this review, nutritional and anti-nutritional aspects of Moringa are elaborated.

Keywords: Moringa, nutrition, sub-Sahara Africa, Micronutrients, Malnutrition, hidden hunger

{Citation: Armachius James and Vumilia Zikankuba. *Moringa oleifera* a potential tree for nutrition security in sub-Sahara Africa. American Journal of Research Communication, 2017, 5(4): 1-14} www.usa-journals.com, ISSN: 2325-4076.

INTRODUCTION

Moringa oleifera is a most cultivated tropical species of monogeneric family, *Moringaceae*, it is native to India, Pakistan, Bangladesh and Afghanistan (Bichi, 2013). Generally, Moringa performs better in the tropics and sub-tropics countries (Kumar, Prabhu, Ponnuswami, Lakshmanan, & Nithyadevi, 2014; Leone, Spada, et al., 2015). The major producer of Moringa is India, whereby similar species are cultivated in Africa, tropical America, Sri Lanka and Malaysia (Bichi, 2013; Kumar et al., 2014). *Moringa oleifera* is known by several other names such as Benzolive, Drumstick tree, Mother's Best Friend, Miracle tree, Horseradish tree, Kelor, Marango, Mlonge, Mulangay, Saijhan and Sajna depending on a community and region (Abdull, Ahmad, Ibrahim, & Kntayya, 2014; Leone, Spada, et al., 2015). 'The horse radish tree' name for Moringa was due to the taste of its roots (Alhakmani, Kumar, & Khan, 2013; Gopalakrishnan, Doriya, & Kumar, 2016).

Unlike other vegetables, Moringa tree grow fast and tolerates harsh weather such as draught, high temperatures and light frost (Kumar et al., 2014; Leone, Spada, et al., 2015). Although, it is not a commercial crop, Moringa interest communities due to its multipurpose application and guaranteed yield throughout the year (Leone, Spada, et al., 2015; Saavedra & Maden, 2015; Santos et al., 2015). Every part of this tree is edible, from the leaves, flowers, immature pods, stems, all the way down to its roots (Abdull et al., 2014; Offor, Ehiri, & Njoku, 2014). The roots, barks and flowers possess antimicrobial properties and are widely used in traditional medicine by Indian and African communities (Gopalakrishnan et al., 2016; Stohs & Hartman, 2015). Moringa tree can be used locally to treat malnutrition and a number of illnesses effectively (Kasolo, Bimenya, Ojok, Ochieng, & Ogwal-Okeng, 2010).

Globally, diets are shifting towards consumption of high calories processed food and animal fats leading to poor nutrition (Steyn & Mchiza, 2014; Sundaram, 2014). At the same time, diet for majority in developing countries, lacks micronutrient rich food sources such as fruits and vegetable leading to high incidences of micronutrient deficiencies (Joy et al., 2014; Kamga, Kouame, Atangana, Chagomoka, & Ndango, 2013). Micronutrient deficiencies, which is also known as hidden hunger represent a public health challenge to global burden of diseases (Burchi, Fanzo, & Frison, 2011; Dhakar, Maurya, Pooniya, Bairwa, & Gupta, 2011). Hidden hunger affects about 2 billion people globally (von Grebmer et al., 2014). Consequently, contributing to low productivity, poor healthy, stunting, reduced economic growth, poor cognitive potential and persistence poverty in most countries (Gibson, 2012; UNICEF, 2013). Mbwana, Kinabo, Lambert, and Biesalski (2016), reported high consumption of cereals with little or without vegetables a contributing factor to high micronutrients deficiencies in Tanzania. Muthayya et al. (2013) and Ruel-Bergeron et al. (2015), reported multiple micronutrients deficiencies in the same population widely affected by iron, vitamin A, zinc, iodine, folate, and other B group vitamins. As the result, sub-Sahara Africa communities are facing a double burden of malnutrition; lack of both macronutrients and micronutrients which are also associated with a quick rise of overweight, obesity and diet related chronic diseases in all age groups (Freire, Silva-Jaramillo, Ramírez-Luzuriaga, Belmont, & Waters, 2014; Steyn & Mchiza, 2014). Clearly then, Moringa is a readily available solution to the problem of malnutrition and hidden hunger in sub-Sahara Africa. In this article, nutritional and anti-nutritional composition of *Moringa oleifera* leaves, pods and seeds are reviewed.

NUTRITIONAL ASPECTS OF MORINGA

Leaves

Moringa leaves are good source of micronutrients and are concentrated with protein (Moyo, Masika, Hugo, & Muchenje, 2011; Olson et al., 2016). They contain high amount of β-carotene and minerals (**Table 1)**. The leaves are exceptionally excellent source of β-carotene, vitamin C, calcium, iron, potassium, magnesium, selenium, zinc and a good balance of all the essential amino acids (Gidamis, Panga, Sarwatt, Chove, & Shayo, 2003; Ojiewo, Tenkouano, & Yang, 2010).

Moringa leaf proteins range from 29.1 to 35.3 g/100g dry weight (Olson et al., 2016). The protein contains essential amino acids higher than the level recommended by the Food and Agriculture Organization (FAO) reference protein, with patterns comparable to those in soybeans (Aregheore, 2012; Makkar & Becker, 1997). El Sohaimy, Hamad, Mohamed, Amar, and Al-Hindi (2015), confirmed that, Moringa leaves has high amount of essential amino acids; Methionine, leucine, isoleucine, histidine, phenylalanine, valine, threonine, arginine and lysine compared to cereals and legume **(Table 2)**. In addition to essential amino acids, the proteins in Moringa leaves have different biological and functional properties, including, trypsin inhibitors, lectins, chitin binding proteins and proteases (Santos et al., 2015). Moringa leaves can be eaten as fresh, cooked and stored as dry powder for several months without losing their nutritional value (Ebert, 2014). Dried Moringa leaves powder are used as alternative food source to combat malnutrition, especially in children and women in Asian and western African countries (Kasolo et al., 2010; Moyo, Masika, Hugo, & Muchenje, 2013; Thurber & Fahey, 2009). According to De Pee and Bloem (2009), Moringa leaves powder in combination with peanut paste has been useful as nutritional supplement to treat malnourished children aged 6 -59 months in Niger. Also, use of Moringa leaves powder in the diet successfully prevented and cured malnutrition among pregnant women, nursing mothers and children in Senegal, Burkina Faso and Uganda (Dhakar et al., 2011; Kasolo et al., 2010; Zongo, Zoungrana, Savadogo, & Traoré, 2013). Furthermore, women recovered from anemia, increased milk production and their babies were born with normal birth weight after being administered with *Moringa oleifera* leaves extract in their meals, in Indonesia (Iskandar, Hadju, As' ad, & Natsir, 2015). In addition, Moringa leaves are often used to complement modern medicines in Acquired Immune Deficiency Syndrome (AIDS) and Human Immunodeficiency Virus (HIV) related illness (Aregheore, 2012). Moreover, Moringa leaves has proven anti-diabetic effect in clinical trials conducted in India (Arun Giridhari, Malathi, & Geetha, 2011).

Pods and Seeds

Moringa immature green pods can be consumed raw or cooked as green beans and contains essential amino acids, minerals, vitamins and are rich in fiber (Dhakar et al., 2011; Sánchez-Machado, Núñez-Gastélum, Reyes-Moreno, Ramírez-Wong, & López-Cervantes, 2010). Moringa seeds contain 155 sodium, 479 potassium, 220.10 magnesium , 203.85 calcium, 31.03 iron, 8.08 zinc and 3 manganese, all in mg/kg (Abiodun, Adegbite, & Omolola, 2012). Protein and oils in Moringa seeds are at 18.92 and 2.74 g/100g, respectively (Nweze & Nwafor, 2014). The oil is rich in essential fatty acids and is stable to rancidity (Latif, Anwar, Hussain, & Shahid, 2011; Pandey, Pradheep, Gupta, Nayar, & Bhandari, 2011). Likewise, seed extracts and oil have positive hepato-protective, anti-inflammatory, antioxidants, anti-fibrosis and skin protection properties in experimental animals (Dubey, Dora, Kumar, & Gulsan, 2013). Moringa seed oils are also, used in skin and hair cosmetics preparations such as moisturizer and conditioner (Fernandes et al., 2015; Ogunsina et al., 2014).

Table 1: Selected micronutrients concentration in *Moringa oleifera* leaves (mg/100g)

Minerals	Composition (g/100g)	References
Magnesium	1.9 - 528.65	Nweze and Nwafor (2014),
Calcium	2.97 - 2244.25	Aye (2016),
Potassium	4.16 - 1745.0	Moyo et al. (2013),
Iron	0.85 - 318.61	Olagbemide and Philip (2014),
Zinc	0.16 - 10.62	Teixeira, Carvalho, Neves, Silva, and
Copper	0.07 - 3.38	Arantes-Pereira (2014),
Sulphur	137 - 936.37	Leone, Fiorillo, et al. (2015),
manganese	5.98 - 12.16	Dhakar et al. (2011),
β-Carotene	3.73 - 19.19	Olson et al. (2016), and
		James and Matemu (2016).

ANTI-NUTRITIONAL FACTORS

Anti-nutritional factors are compounds synthesized by the plant which reduce nutrient utilization from plants or plant products, and determine the use of particular plant as food for human (Gemede & Ratta, 2014). They are synthesized through normal metabolism pathways in plant as secondary metabolites intended for own plant defense (Itkin et al., 2013). They affect digestibility, bioavailability and utilization of nutrients mainly proteins, minerals and vitamins in food and reduce their nutritive values (K. O. Soetan, Akinrinde, & Adisa, 2014). Some have beneficial and some have deleterious toxic biological responses to human nutrition and health (Gilani, Xiao, & Cockell, 2012; K. Soetan & Oyewole, 2009). Anti-nutritional factors in plant includes tannins, oxalates, phytates, saponins, lectins, trypsin and protease inhibitors, alkaloids, coumarins, gossypol and cyanogenic glycosides (Gemede & Ratta, 2014; Gilani et al., 2012).

Moringa leaves contain 21 g/kg phytate, 10.5 g/kg oxalates and negligible amount of tannins, saponins, trypsin and amylase inhibitors and no detectable cyanogenic compounds (Makkar & Becker, 1997; Teixeira et al., 2014). Moringa leaves have low level of anti-nutritional factors compared to other leaf vegetables and produce no toxic effect on consumption (Stohs & Hartman, 2015; Teixeira et al., 2014). The low level of anti-nutritional factors compared to

Amaranthus spp, spinach, Ethiopian mustard and other *Brassica spp* vegetables contribute to the acceptability and wide use of *Moringa oleifera* as the leaf vegetable (Amalraj & Pius, 2015; Aregheore, 2012; Verkerk et al., 2009).

Table 2: Amino acid profile in *Moringa oleifera* leaves and seeds (mg/100g)

	Leaves	**Seed**
Amino acid	**Concentration in mg/100g**	
Lysine*	63.13	312
Histidine*	29.56	1930
Valine*	62.34	1080
Leucine*	94.36	3830
Isoleucine*	46.98	4230
Threonine*	48.35	3020
Alanine	4.93	5160
Aspartic acid	13.76	1570
Serine	3.13	3060
Proline	1.86	2180
Glutamic acid	18.03	17870
Glycine	2.31	2370
Arginine*	7.65	8280
Cysteine	2.15	1680
Tyrosine	2.03	1970
Methionine*	0.43	310
Phenylalanine*	3.42	3270

Key: asterisk * = indicate essential amino acids

Adopted from El Sohaimy et al. (2015) and Ijarotimi, Adeoti, and Ariyo (2013).

However, anti-nutritional factors are mostly affected by processing methods, like blanching, drying, fermentation and de-fatting which results in reduced or deactivated activity (Devisetti, Sreerama, & Bhattacharya, 2016; Ijarotimi et al., 2013; Indriasari, Wignyanto, & Kumalaningsih, 2016). On the other hand, Moringa seeds contain alkaloids, phytates, tannins, oxalates and saponins approximately at 291, 175, 131, 110 and 33 mg/100g, respectively (Ijarotimi et al., 2013). The roots contain 45 mg/100g tannins, 17.08 mg/100g oxalates, 4.20 mg/100g saponins, 0.07 mg/100g phytates and 2.72 mg/100g cyanogenic glycosides (Igwilo et al., 2014).

WATER TREATMENT AND PURIFICATION

The role of clean water for achieving food and nutrition security for better human health cannot be underestimated. Water play a great role to food and nutrition security through its linkage to all economic access to food; from agriculture through food preparations to nutrient bioavailability. According to Mabhaudhi, Chibarabada, and Modi (2016), agriculture, food and nutrition outcomes can be achieved if, there is proper linkage with water that is, available and accessible. Consumption of turbid water has resulted into potential human health problems in developing countries such as, water borne diseases outbreak (WHO & UNICEF., 2013). Water turbidity removal is extremely important as it reduces problem associated with turbid water (Kansal & Kumari, 2014). Turbidity can effectively be removed by coagulation process which leads to sedimentation for easy separation (Bichi, 2013; Thakur & Choubey, 2014).

The main chemicals used to aid coagulation are Aluminium sulphate ($Al_2(SO_4)_3$) and Ferric sulphate ($Fe_2(SO_4)_3$) (Deeba et al., 2015). These coagulants are positively charged, whereas colloidal particles causing water turbidity are negatively charged (Kansal & Kumari, 2014). Coagulants and colloidal particles form flocs during water treatments that settles by sedimentation under gravity leaving turbid water clear or with reduced turbidity (Jiang, 2015). In most of developing countries, chemical flocculants are expensive and not locally available leading to research for potential biological coagulants such as *Moringa oleifera* seeds (Kansal & Kumari, 2014). Moringa seeds provide coagulation effect at low cost and low risk to human health and environment (Deeba et al., 2015). Dried ground Moringa seeds coagulates debris in water due to their active soluble protein component which is a natural cationic polyelectrolyte (Pritchard, Craven, Mkandawire, Edmondson, & O'neill, 2010). The powder binds colloidal particles and bacteria in water to form agglomerated particles or flocs which settles by gravity forming clarified water (Kansal & Kumari, 2014). Therefore, used as an alternative water treatment and purification method in developing countries (Ferreira et al., 2011; Pritchard et al., 2010).

Studies conducted mainly on river water in African countries, including Nigeria, Rwanda, Malawi, Egypt and Sudan indicated turbidity and color reduction over 90% and microorganisms such as *Escherichia coli* over 95% (Bichi, 2013; Nkurunziza, Nduwayezu, Banadda, & Nhapi, 2009; Pritchard et al., 2010). Moringa seed extracts can reduce fecal coliforms, *Staphylococcus aureus* in water from rivers and wells (Ferreira et al., 2011). In the laboratory experiment Dasgupta, Gunda, and Mitra (2016), reported efficiency of Moringa seed powder to remove bacteria up to 99.5%. Also, Nkurunziza et al. (2009), mentioned that Moringa seed powder can reduce heavy metals such as Manganese, Iron, Copper, Chromium and Zinc in water. Bichi (2013), presented several research results conducted in Sudan and England that proved total hardness removal in water treated with Moringa seed powder.

However, the coagulation process using Moringa seeds powder works better at pH 6.5-9, while alkalinity favors the clarification (Pritchard et al., 2010; Thakur & Choubey, 2014). Water pH is an important parameter that determines the coagulating capacity, because it affects the degree of ionization and solubility of adsorbate (Sivakumar, 2013). At the same time, high temperatures increase Moringa seed powder coagulating power and it is affected by temperature below 15°C (Pritchard et al., 2010). Therefore, for better results using *Moringa oleifera* seed powder or extract for water treatment: pH, contact time and temperature should be controlled and monitored (Alsharaa, Basheer, Adio, Alhooshani, & Lee, 2016; Muthuraman & Sasikala, 2014). Bringing all together, Moringa as an underutilized plant can bring a multidisciplinary approach to addressing water and nutrition in agriculture interventions particularly in rural sub-Saharan Africa communities.

CONCLUSIONS

Moringa can be used to supplement dietary micronutrients, reduce and prevent micronutrient deficiencies, especially among children and women of reproductive age in sub-Sahara Africa. Many of the benefits of Moringa leaves and seed are attributed to micronutrients and antioxidants forming an important part of healthy, nutritious and balanced diet. On the other hand, availability of pure drinking water has become a challenging agenda in developing countries due to poor land use and management. Water contamination; Surface water polluted by sewage, industrial water discharge and run off from land clearing and agriculture activities, while ground water polluted by waste dumping site can be reduced by use of Moringa seed powder or extract. Research and extension efforts should be directed towards harnessing the potential of the Moringa tree which is underutilized in sub-Sahara African countries. And therefore, promoting use and incorporation of *Moringa oleifera* leaves, flowers, immature pods and seeds into diet is inevitable for its nutritional and health benefit to the people of the sub-Sahara Africa region in bringing in dietary diversity.

ACKNOWLEDGEMENT

The authors acknowledge the ministry of agriculture, livestock and fisheries, Tanzania through Horticultural Research and Training Institute (HORTI)-Tengeru for material and technical support in accomplishment of this review.

CONFLICT OF INTEREST

The author declares no competing interest.

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