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Review Article

Use of *Moringa oleifera* as a complementary food fortificant

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ABSTRACT

Moringa oleifera Lam (*Moringaceae*) is a highly valued plant, distributed in many countries of the tropics and subtropics. *Moringa oleifera* grown and used in many countries around the world is a multi-purpose tree with medicinal, nutritional and socio-economic values. Most plant parts of the Moringa are edible. It is already established the medicinal uses of M. Oleifera leaves by different local communities of world and identified several phytochemicals present in *M. oleifera* extracts. Malnutrition causes a great deal of human suffering and is associated with more than half of all deaths of children worldwide. Malnutrition severely affects the socio-economic development of a nation because a work force that is stunted both mentally and physically may have a reduced work capacity. Thus nutrition plays an important role in the reproduction of poverty from one generation to the next. Not only is the *M.oleifera* tree extraordinary in that all parts of the tree are edible, but the most amazing aspect of the tree is its exceptionally high nutritional value. Moringa tree can be utilized in treating the malnutrition in a local and cost-effective manner. Present review focuses on the potential benefits of M. oleifera in treatment of malnutrition.

INTRODUCTION

Drumstick (*Moringa oleifera*) is universally known as the miracle plantfor life. The Moringa plant derives this name basedon its uses, particularly with reference to medicinal and nutritional properties. It is a plant native to the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan (Fahey, 2005). *M. Oleiferais* the most widely cultivated among the 13 species of the Moringaceae family and it is exceptionally nutritious with a variety of uses. Almost all the parts of this miracle tree have been found to be very useful. Leaves are used as forage, tree trunk for making gums, flower nectar in honey and powdered seeds for water purification (Fuglie, 1999) (Fig.1). M. Oleifera leaf has been used as an alternative food source to combat malnutrition, especially among children and infants (Anwar et al., 2007).The leaves of *M.Oleifera* have also been found to contain high amounts of total phenols, proteins, calcium, potassium, magnesium, iron, manganese and copper (Hekmatet al., 2015). *M. Oleifera* leaves are also good sources of phytonutrients such as carotenoids, tocopherols and ascorbic acid (Saini et al., 2014b). *M. Oleifera* leaves are reported to contain substantial amounts of vitamin A, C and E (Hekmatet al., 2015). These nutrients are known to strong antioxidants when combined with a diet and also responsible for immuno suppressive effects. In many parts of the world including Africa, the use of *M.Oleifera* as a food fortificant is on the increase. For instance, both fresh and dried Moringa leaves are included in meals in African countries such as Ghana, Nigeria, Ethiopia, East Africa and Malawi (Agbogidi and Ilondu, 2012). Several scientific study and research indicates the potential use of different parts of M. *Oleiferain* food applications such as in making several types of weaning foods (Arise et al., 2014), amala, (Karim et al., 2015),herbal biscuits (Alamet al., 2014), bread (Chinmaet al., 2014), cake (Kolawoleet al., 2013) and yoghurt (Hekmatet al., 2015).

Nutritional value of different parts of *Moringa oleifera*

M.oleifera, native of the western and sub Himalayan tracts, India, Pakistan, Asia Minor, Africa and Arabia (Mughal et al., 1999) is now distributed in the Philippines, Cambodia, Central America, North and South America and the Caribbean Islands (Morton, 1991). In India and Pakistan, it is locally known as 'Sohanjna' and is cultivated all over the country (Anwar et al., 2005). A number of medicinal properties have been reported to various parts of this highly esteemed tree (Table 1).M. Oleifera tree is a plant rich in a number of nutrients such asproteins, fibre and minerals (Moyo et al., 2011) that play important role in human nutrition. Yang et al.,(2006) worked with four cultivars of Moringa and reported that *M. oleifera* had the highest amount of b-carotene, ascorbic acid, a-tocopherol and iron. The fresh leaves of *M. Oleifera* have been found to be good sources of carotenoids such astrans-lutein (approx. 37 mg/100 g), trans-b-carotene (approx.18 mg/100 g) and trans-zeaxanthin (approx. 6 mg/100 g)(Saini et al., 2014d). M. *oleifera* leaves have also reported to contain significant amount of essential amino acid with high contents of alpha linoleic acid (Moyo et al., 2011). The leaves of moringa are known for excellent source of dietary antioxidants(Saini et al., 2014d,). According to Yang et al. (2006) and Nkukwana et al. (2014a) *M. oleifera* leaves have significantly higher antioxidant contents when compared to fruits such as strawberries known for high antioxidant contents. A recent study showed that iron from *M. Oleifera* is very useful to overcome iron deficiency and modulate the expression of iron-responsive genes in compare to conventional iron supplements (Saini et al., 2014a). Saini et al.(2016) reported that the relative bioavailability of folate from *M. Oleifera* leaves using rat model was very high (approx.82%) indicating that the M. Oleifera leaves can be a potential source of dietary folate. Many of the reported nutritional benefits of M. Oleifera suggest that it can serve as a functional ingredient in the food and allied industries.

Role Moringaoleiferain food fortification

Drumstick (M.*oleifera*) is well known for its nutritional and health benefits and is being recommended for malnourished people all over the world. Moringa leaves are sold in Ghana in the form of dry powder, and it is used as a nutritional supplement to minimize the malnutrition and related ailments (Vanajakshiet al., 2015). Food fortification involves the addition of essential nutrients such as vitamins and minerals to staple foods for improvement of their nutritional value. Fortifications can effects to rapidim provements in the micronutrient status of a population at are a reasonable cost. According to several reports, food fortification can take several forms such as mass fortification, targeted fortification and market-driven fortification. Whatever the purpose of fortification, it is pertinent to note that the food to be fortified (food vehicle) and fortificant must be compatible. The fortification with moringa components is reported that it readily available, accessible and well absorbed into the food without causing a significant change in the sensory attributes of the fortified food (Allen et al., 2006). The use of M. *Oleifera* to improve the nutritional value of staple foods in many parts of the world including Africa may not necessarily fall under fortification or enrichment. As previously defined, fortification which is sometimes used interchangeably with enrichment involves the addition of specific micronutrients to staple foods to improve the overall nutritional value of the targeted population.

Food fortification and Micronutrient malnutrition

Micronutrient malnutrition has many adverse effects on human health, not all of which are clinically evident. Even moderate levels of deficiency can have serious detrimental effects on human function. Thus, in addition to the obvious and direct health effects, the existence of MNM has profound implications for economic development and productivity, particularly in terms of the potentially huge public health costs and the loss of human capital formation. The control of vitamin and mineral deficiencies is an essential part of the overall effort to fight hunger and malnutrition. Actions that promote an increase in the supply, access, consumption and utilization of an adequate quantity, quality and variety of foods for all populations groups should be supported.

Food fortification refers to the addition of micronutrients to processed foods. In many situations, this strategy can lead to relatively rapid improvements in the micronutrient status of a population, and at a very reasonable cost, especially if advantage can be taken of existing technology and local distribution networks (Misra and Misra, 2014). Since the benefits are potentially large, food fortification can be a very cost-effective public health intervention. However, an obvious requirement is that the fortified food(s) needs to be consumed in adequate amounts by a large proportion of the target individuals in a population. It is also necessary to have access to, and to use, fortificants that are well absorbed yet do not affect the sensory properties of foods. In most cases, it is preferable to use food vehicles that are centrally processed, and to have the support of the food industry. Fortification of food with micronutrients is a valid technology for reducing micronutrient malnutrition as part of a food-based approach when and where existing food supplies and limited access fail to provide adequate levels of the respective nutrients in the diet (Dhakaret al.,2011).

Foods fortification at the household level

In many countries efforts are under way to ways of adding micronutrients to foods at the household level, in particular, to complementary foods for young children. In effect, this approach is a combination of supplementation and fortification, and has been referred to by some as complementary food supplementation (Nestelet al., 2003). The efficacy and effectiveness of several different types of products, including soluble or crushable tablets, micronutrient-based powder ("sprinkles") and micronutrient-rich spreads are currently being evaluated (Table 2). Developments of micronutrient-dense fortified spreads have been found to be very popular with children (Briend, 2001). Fortification of foods at the community level is also still at the initial experimental stage. One such approach involves the addition of a commercial micronutrient premix, available in sachets, to small batches of flour during the milling process (CARE International Zimbabwe, 2000). The major challenges to local-scale fortification programmes include the initial cost of the mixing equipment, the price of the premix, achieving and maintaining an adequate standard of quality control and sustaining monitoring and distribution systems.

Table 1: Medicinal uses of different parts of *Moringa oleifera*.

S.No.	Plant part	Medicinal Uses	References
1.	Seed	• Seed extract exerts its protective effect fractions isolated from the acetate phase of the ethanolic extract of Moringa pods	Lalas and Tsaknis, 2002
2.	Leave	• Antilithic, rubefacient, vesicant, carminative, antifertility, anti - inflammatory, stimulant in paralytic afflictions. • Act as a cardiac/circulatory tonic, used as a laxative, abortifacient, treating rheumatism, inflammations, articular pains, lower kidney pain and constipation	Morton, 1991; Fuglie, 2005
3.	Root	• Antilithic, rubefacient, vesicant, carminative, antifertility, anti - inflammatory, stimulant in paralytic afflictions. • Act as a cardiac and circulatory tonic, used as a laxative, abortifacient, treating rheumatism, inflammations, articular pains, lower kidney pain and constipation	Padmaraoet *al*., 1996; Dahot, 1988
4.	Flower	• High medicinal value as a stimulant, aphrodi siac, abortifacient, cholagogue. • Used to cure inflammations, muscle diseases, hysteria, tumors, and enlargement of the spleen • Lower the serum cholesterol, phosphol ipid, triglyceride, VLDL, LDL cholesterol to phospholi pid ratio and atherogenic index D ecrease lipid profile of liver, heart and aorta in hypercholesteraemic rabbits and increased the excretion of faecal cholesterol	Bhattacharya *et al.,* 1982; Dahot, 1988;
5.	Stem bark	• Rubefacient, vesicant and used to cure eye diseases and for the treatment of delirious patients, • Prevent enlargement of the spleen and formation of tuberculous glands of the neck, to destroy tumours and to heal ulcers. • The juice from the ro ot bark is used as a pain killer, and has anti-tubercular activity	Siddhuraju and Becker, 2003
6.	Gum	• Used for dental caries, relieve headaches, fevers, in testinal complaints, dysentery and asthma. • Sometimes used as an abortifacient, and to treat syphilis and rheumatism	Fuglie, 1999

Table 2: Fortification at the household level (Zlotkinet al., 2001;Briend, 2001).

Product	Specificity and use
Micronutrient powder (sprinkled onto food)	Contain several micronutrients, including iron, encapsulated to minimize adverse interactions between micronutrients and sensory changes to t he food to which they are added Available in sachets
Soluble micronutrient (dissolved in water and use as a drink)	Suitable for young children Tested by WHO
Crushable micronutrient tablets (for adding to foods)	For infants and young children Tested by UNICEF
Fat-based spread (fortified with micronutrient)	Popular with children Can be produced locally

Nutritive properties of *Moringa oleifera* suitable in food fortification

The leaves of M. *Oleiferaare* rich in minerals like calcium, potassium, zinc, magnesium, iron and copper (Kasolo, et al., 2010). Vitamins like beta-carotene of vitamin A, vitamin B complex (such as folic acid, pyridoxine and nicotinic acid), vitamin C, D and E also present in rich amount in M. Oleifera(Mbikay, 2012). Phytochemicals such as tannins, sterols, terpenoids, flavonoids, saponins, anthraquinones, alkaloids and reducing sugar are present. Anti-cancerous agents like glucosinolates, isothiocyanates, glycoside compounds and glycerol-1-9-octadecanoate also reported in different part of Moringa(Berkovichet al., 2013). Moringa leaves have a low calorific value and can be used in the diet ofthe obese. The pods are fibrous and are valuable to treat digestive problems and thwart colon cancer (Oduro, et al., 2008). Some research also reported that immature pod contains around 46.78% fiber and around 20.66%protein content. Pods have 30% of amino acid content, the leave shave 44% and flowers have 31%. The immature pods and flowers showed similar amounts of palmitic, linolenic, linoleic and oleic acids (Sánchez-Machado, et al., 2010).Moringapowder can be used as a substitute for iron tablets, hence as a treatment for anemia. It has been reported that moringacontains more iron than spinach (Fuglie, 2005). M. *Oleiferal* eaves show around 25.5–31.03 mg of zinc/kg, which is the daily requirement of zinc in the diet (Barminas and Charles, 1998).Several research report indicate that moringa seed oil contains around 76% PUFA, making it ideal for use as a substitute for olive oil (Lalas and Tsaknis, 2002, Fuglie, 2005,Yang, et al., 2006).

Chemistry of *Moringa oleifera*

Moringa oleifera is rich in the simple sugar, rhamnose and a fairly unique group of compounds called glucosinolates and isothiocyanates (Bennett et al., 2003). The stem bark contain two major alkaloids, namely moringine and moringinine (Kerharo, 1969). Vanillin, β-sitosterol,

β-sitostenone, 4-hydroxymellin and octacosanoic acid have been isolated from the stem of M. *oleifera* (Faiziet al., 1994a). The moringa flowers contain nine amino acids, sucrose, D-glucose, traces of alkaloids, wax, quercetin and kaempferat (Ruckmaniet al., 1998). Moringa leaves act as a good source of natural antioxidant due to the presence of various types of antioxidant compounds such as ascorbic acid, flavonoids, phenolics and carotenoids (Anwar et al., 2005). The high concentrations of several useful compounds such as ascorbic acid, oestrogenic substances and β-sitosterol, iron, calcium, phosphorus, copper, vitamins A, B and C, α-tocopherol, riboflavin, nicotinic acid, folic acid, pyridoxine, β-carotene, protein present in moringa leaves and pods make it a virtually ideal dietary supplement (Makkar and Becker, 1996).

Processing of Moringa for development of complementary food

During processing most plants lose their nutritive properties. When compared, the nutritive content of raw, germinated and fermented moringa seed flour, it was found that phytochemicals were higher in raw seed flour and amino acid content was atits peak in fermented and germinated seed flour (Ijarotimiet al., 2013; Mishra, et al., 2012). This is supposed due to result of the biochemical activities during germination and microbial activity during fermentation. However, some studyis under progress for observe the effect of boiling, simmering and blanching to seethe retention of nutrient content of moringa leaves. The presence of phytate and otheranti-nutrients can reduce the bioavailability of certain nutrients and processing can hence be done for maximum utilization of required nutrients from the seeds and leaves (Sallau, et al., 2012). Yang et al.(Yang,et al.,2006) reported that boiling increased the availability of iron andantioxidant content. Hence, the processed moringa seed flour canbe used to treat malnutrition problems. However, some studies have shown that children refuse to take in moringa due to its slight bitter taste (Nambiarand Parnami, 2014). M. Oleiferahave also been incorporated into chocolates.A recent report tested different percentages of moringa in the chocolate fortification and found that, 20% moringaincorporation in cocoa powder was ideal. Such studies have shown the potential for developing protein andminerals-rich flour based and spread based food products for malnourished children(Abou-zaid and Nadir, 2014). Several such moringa fortifications are possible to ensure intake of adequate amounts of nutrients in children.

Moringa can also be preserved for a long time without loss ofnutrients. Drying or freezing can be done to store the leaves. Yang et al. (2006) reported that a low temperature oven used to dehydrate the leaves retained more nutrients except vitamin C than freeze-dried leaves. Preservation by dehydration improves the shelf life of moringa without change in nutritional value. An overdose of moringa may cause high accumulation ofiron. High iron can cause gastrointestinal distress and hemochromatos is. Hence, a daily dose of 70 g of moringa is suggested to be good and prevents over accumulation of nutrients (Asiedu-Gyekye, et al., 2013).

Conclusion and future prospects

The research on M. *Oleifera* is yet to gain importance in India. It is essential that the nutrients of this wonder tree are exploited for a variety of purposes. M. *Oleifera* has great anti-diabetic andanti-cancer properties. M. *Oleifera* plant is indeed a miracle plant with enormous potentials yet to be fully explored in food application. The different parts of *M. Oleifera* leaf powder, *M. Oleifera* seed powder, *M.Oleifera* flower powder are now used in various food applications. Development of food fortified with different forms of moringa must be determined for in-vivo and in-vitro digestibility properties, nutrient bioavailability and phytochemical contents of fortified products in future research. Although, many of the reviewed studies reported improvement in the nutritional value of foods fortified with *M. Oleifera*. The demand for snacks and beverages in the market is huge. Hence Moringa fortification in foods and beverages to eradicate malnutrition has a many advantage. The tree as a native to India and can be utilized for great source of income for the nation if properly utilized in development of several functional foods and beverages.

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