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Review Article

Moringa: A multipurpose potential crop – A review

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Moringa oleifera Lam., historically, is regarded as nutrient rich food supplement with immense medicinal and therapeutic values. Literature reveals multipurpose applications of different parts of *Moringa* such as leaves, flowers, pods, seeds and roots. Fruits of *Moringa* are a major source of vitamin C, i.e., 120 mg per 100 g fresh sliced pods. It is used in functional and traditional foods, *e.g*., in making soups, weaning foods, *amala*, biscuits, bread, cake and yoghurt as well as cheese and has the ability to preserve foods. In various medicinal applications, it works as antioxidant, anticancer, anti-inflammatory, antiulcer, antihyperglycemic, antidiabetic and antimicrobial agent and in agricultural uses as animal feed, forage crop, natural plant growth enhancer and bio-pesticide. This review article presents the various uses, of *Moringa* discovered through past years of research in animal and human subjects as well as in other experimental studies, besides, the possibility of including the species for diversity and sustainability.

Keywords: ***Moringa;*** **Drumstick; Nutritional Value; Nutraceutical; Human Health; Agricultural Uses; Food Processing Industry**

Introduction

Moringa oleifera Lam. (Synonymous: *Moringa pterygosperma* Gaertn), a medium-sized tree, is commercially cultivated mainly for its pods, leaves and seeds. The tree is often referred to as a "wonder-tree" due to its multi uses and is also known as "Drumstick-tree and Horseradish tree. In Africa, the tree is known as mother's best friend. In India, it is known by different names in different languages for example: Soanjna (Hindi) Shigru (Sanskrit), Sohanjna (Punjabi), Murungai (Tamil), Sajna (Bengali) Murinna, (Malyalam). All parts of the *Moringa*, *viz*., leaves, seeds, roots, flowers and pods are suitable for human and animal consumption (Leone *et al.*, 2016). From ancient times, it has been a regular component of conventional eatables in India. It is a multipurpose herbal plant and an alternative for medicinal purposes worldwide (Abdull Razis *et al.*, 2014). It is used as potential antioxidant, anticancer, anti-inflammatory, antiulcer, antihyperglycemic, antidiabetic and antimicrobial agent (Abdull Razis *et al.*, 2014; Arora*et al.*, 2013; Babu and Chaudhuri, 2005; Bennett *et al.*, 2003; Bhishagratna, 1991; Hamza, 2010; Verma *et al.*, 2009). It is used in the functional and traditional foods and also has beneficial influence on digestion and has the ability to preserve foods. *Moringa* is cultivated all over the world as a semi-arid crop. This review article will provide necessary baseline data for researchers to comprehend *Moring*'s nutritional content, functional properties, medicinal application and uses in agricultural as well as food processing industry.

Moringa oleifera Lam. (*M. oleifera*) Tree

It is the most widely cultivated species of the genus *Moringa*, which is the only genus in the family Moringaceae (Fig. 1). It is a fast-growing, deciduous tree that can attain a height of approximate 10 to 15

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Fig. 1: Young plantation of *Moringa oleifera* Lam. Intercropped with sweet potato under organic production system

feet. The bark has a whitish-grey colour and is surrounded by thick cork. Young shoots have purplish or greenish-white, hairy bark. This tree has an open crown of drooping, fragile branches with a feathery foliage of tripinnate leaves. The fruit is a hanging, three-sided brown capsule of varying sizes about 20 to 45 cm which holds dark brown, globular seeds. The seeds have three whitish papery wings. The leaves, flowers, pods and seeds, are the foremost parts of this tree.

Varieties, Specialty and Suitability for Cultivation

Moringa is virtuous at reclaiming marginal land and also in controlling soil erosion, besides being suitable for alley cropping and agroforestry systems. Based on soil and climatic conditions, there are commercial varieties of *Moringa*, *viz*., KM 1, PKM 1, PKM 2, GKVK 1, GKVK 2, GKVK 3, Dhanaraj, Bhagya (KDM 01), Konkan Ruchira and Rohit. *Moringa* can be grown as a crop on marginal land with high temperatures and low water availability, where it is hard to cultivate other agricultural crops (Nouman *et al.*, 2014). It can tolerate a wide range of annual rainfall (250 mm-3000 mm) and pH (5.0-9.0) (Palada and Changl, 2003). It grows well in the vicinity of the sandy beds of rivers and streams (The Wealth of India, 1962; Qaiser, 1973). It is a sun and heat-loving crop that does not tolerate freeze or frost and thrives well where the daily temperature ranges between 25 and 35°C. Though, it can survive summer temperatures of up to 48°C for a limited period of time (Price, 2000).

***Moringa* Cultivation**

Moringa grows in almost all type of soils except stiffy clays, however, deep sandy loam soil with pH of 6.5 to 8 is most suitable for cultivating this crop. *Moringa*'s economic cropping period is three years and it can be propagated by seeds (annual *Moringa*), limb cuttings (perennial *Moringa*) during July to October. The crop is highly cross pollinated due to heteromorphic and entomophilous nature, honey bees (*Aphis mellifera*) being the most common pollinators (Arumugam *et al.*, 2017). Seeds @ 500 g/ha can be either sown at a depth of 2.5-3.0 cm in pits of size 45 cm x 45 cm x 45 cm with a spacing of 2 m x 2 m (annual *Moringa*; 2500 plants/ha) 5 m x 5 m (perennial *Moringa*: 400 trees/ha) or raising seedlings in poly bags and transplanted after 35-40 days in the field. FYM @ 10-15 kg and 135:23:45 g of NPK/pit is applied after mixing with top soil. Gap filling may be done within a month of sowing. After pruning, about 45:15:30 g NPK/plant along with 25 kg FYM or compost are applied within a week after cutting back every year.Pinch off the seedlings when they are about 75 cm in height or 60^{h} day after sowing in case of annual *Moringa* to facilitate more branching and medium pinching of shoots at 70 cm from the tip in perennial *Moringa* to regulate flowering and obtain the higher yield. Short duration vegetables like cowpea, okra and tomato can be grown as intercrop. Irrigation before sowing and on the 3rd day after sowing and subsequently at 10-15 days interval may be applied according to soil type. Crop is ready for first harvest after 180 days of sowing. After harvest of main crop, trees are cut back 90 cm from ground level for ratooning. In another 4-5 months, trees will again come for harvest. Likewise, ratoon crops can be taken for 3 years (Arumugam *et al.*, 2017).

Moringa Leaves

The leaves (Fig. 2) are a promising source of K, Mg, Ca, P, Zn, Fe, Cu, Mn and vitamins A, E and C (Arumugam *et al.*, 2017; Leone *et al.*, 2015a; Leone *et al.*, 2015b). Its leaves can be eaten afresh, cooked or stored as dried powder for many months without refrigeration, which do not lose its nutritional value (Singh, 2010; Hsu *et al.*, 2006). Availability of various types of antioxidant compounds in the leaves make a valuable source of natural antioxidants (Anwar *et al.*, 2007) and a good source of nutraceuticals, besides as a functional component (Makkar and Becker, 1996). The biological value of leaves is immense and the boiled leaves exhibited three times more bio-available iron than the raw leaves. Similar results were observed in the powdered *Moringa* leaves (Arumugam *et al.*, 2017). *Moringa* leaves have been reported to be a rich source of carotene, protein, vitamin C, calcium and potassium and act as a good source of natural antioxidants; and thus enhance the shelf-life of fat containing foods (Dillard and German, 2000; Siddhuraju and Becker, 2003). On comparison with standard sources of nutrition, the leaves contained 7 times the vitamin C of oranges; 4 times the vitamin A of carrots; 4 times the Ca of milk; 3 times the K of banana; and 2 times the protein of yogurt. Moreover, the micro-nutrient content is even higher in dried leaves, *i.e*., 10 times the vitamin A of carrots; 17 times the Ca of milk; 15 times the K of bananas; 25 times the Fe of spinach; and 9 times the protein of yogurt. However, vitamin C dropped to half that of oranges (Mahatab *et al.*, 1987; Manzoor *et al.*, 2007; Marcu, 2005; Narasinga *et al.*, 1989; Trees for Life, Moringa Book, 2005). The leaves are highly nutritious and recommended for infants and nursing mothers especially those from developing countries. *Moringa* helps in increasing womens' milk during breast feeding months (Anwar *et al.*, 2007; Estrella *et al.*, 2000; Siddhuraju and Becker, 2003). Alternatively, leaves may also be used as animal fodder (Ponnuswami, 2012).

Fig. 2: Annual *Moringa* with luscious leaves and flowers

Moringa Flower and Pods

The flowers are pleasantly fragrant, yellowish-white in colour (Fig. 2). Fresh or dried flowers are used for making teas (Ponnuswami, 2012) with hypecholesterolemic properties (Gopalakrishnan *et al.*, 2016) and also contains Ca, Kandamino acids. The flowers are said to taste like mushroom when fried (Arise *et al.*, 2014). The flowers act as hypecholesterolemic, and theanti-arthritic agents can cure urinary problems and cold (Fuglie, 2005; Sutalangka *et al.*, 2013). Flowers contain 9 amino acids, sucrose, D-glucose, traces of alkaloids, wax, quercetin and kaempferat; the ash is rich in K and Ca (Ruckmani *et al.*, 1998). They have also been reported to contain some flavonoid pigments such as alkaloids, kaempherol, rhamnetin, isoquercitrin and kaempferitrin (Faizi *et al.*, 1994; Siddhuraju and Becker, 2003).

The fruit is a pendulous, linear, three-sided capsule (referred as a pod, is initially green and tender), and it ripens in about three months after flowering. The pods become brown and dry at maturity and split open into 3 parts longitudinally (Fig. 3). Each pod usually contains 12 to 35 seeds. Pods are believed to be anthelminitic, and are used for infections of the liver and spleen and also in treating articular pains (pain in the joints). The entire young and pliable pod is cooked and eaten or used in the preparation of curries. In older pods which develop tough exterior, the pulp and immature seeds remain edible just before ripening begins. The seeds of edible pods should be white in color. Salads can also be prepared from the pods. A recipe called *Moringa* beans is prepared using very young pods (should be less than 1 cm thick and snap easily) are selected and they are cut into 3 cm long pieces. Thereafter, it is steamed for 10 minutes and then marinated in a mixture of oil, vinegar, salt, pepper, garlic and parsley. Pods are helpful in increasing breast milk in the breastfeeding months (Ponnuswami, 2012).

Fig. 3: (A) *M. oleifera* tree in fruiting

Fig. 3: (B) *M. oleifera* dehisced pod

Moringa Seeds and Oil

Moringa seeds have wings and are about the size of a large pea. A single tree can produce from 15,000 to 25,000 seeds, each weighing, on an average 0.3 g (Foidl *et al.,* 2001) (Fig. 4). The seeds are eaten similar to peanuts in the Malayan Peninsula (Daniell *et al.*,2011). Seeds have a high content of methionine and cysteine, close to that reported for milk and eggs (Oliveira *et al.*, 1999). Therefore, they can be consumed together with legumes which are deficient in sulphur amino acids. Moreover, seeds seem to be free of trypsin inhibitor and urease activity, confirming the high protein digestibility (93%) of *Moringa* seeds (Oliveira *et al.*, 1999; Santos *et al.*, 2005). Powdered seed act as a natural flocculent, able to clarify even the most turbid water. Hence, seed powder can be used as a quick and simple material for cleaning muddy water. The powder joins with the solids in the water and sinks to the bottom. This treatment also removes 90 to 99 per cent of bacteria contained in water, water purification by flocculation, sedimentation, antibiosis and even reduction of Schistosomecercariae titer. Alcohol extract of the seeds showed anti-inflammatory activity in guinea pigs (Mahajan *et al.*, 2009).

Fig. 4: *M. oleifera* seeds

Further, the seeds have attracted scientific interest as *Moringa* seed kernels contain a significant amount of oil (up to 40%) with a high-quality fatty acid composition (oleic acid >70%) and, after refining, possess a notable resistance to oxidative degradation (Anwar *et al.*, 2005). The oil, commercially known as "*Ben oil*" or "*Behen oil*", is aliquid at room temperature and golden yellow in color. Its properties make it suitable for both human consumption and commercial purposes. In fact, *Moringa* oil could be

a good substitute for olive oil in the diet as well as for non-food applications, like biodiesel, cosmetics and a lubricant for fine machinery. Moreover, after oil extraction, the seedcake can be used in waste water treatment as a natural coagulant (Ndabigengesere and Subba Narasiah, 1998) or as an organic fertilizer to improve agricultural productivity (Emmanuel *et al.*, 2011). *Moringa* oil was also used as skin ointments ever since the Egyptian times (Abdull Razis *et al.*, 2014).

Moringa Roots and Gum

A sauce similar to horseradish sauce can be made from the roots when the seedling is only 60 cm tall. The root bark should be completely removed as it contains harmful substances, thereafter the root is ground-up and vinegar and salt are added. However, it should not be consumed in excess (Daniell *et al.*, 2011). It is best to store the sauce in a refrigerator. The gum that is found in the bark can be used to season food (Mulugeta and Fekadu, 2014).

Human Health

Nutritive Properties

Almost all parts of the *Moringa* can be eaten or used as ingredients in traditional herbal medicines. The leaves and pods are commonly eaten in parts of India and Africa (Stohs and Hartman, 2015). The leaves are an excellent source of many vitamins and minerals. 21 g chopped leaves contains 2 g protein, besides, vitamin B_6(19%), vitamin C(12%), Iron: (11%), riboflavin (B_2) (11%), vitamin A (from beta-carotene) (9%), magnesium (8%) of the recommended dietary allowances (NNDSR, 2016). In Western countries, dried leaves are sold as dietary supplements, in either powder or capsule form. Compared to the leaves, the pods are generally lower in vitamins and minerals. However, they are exceptionally rich in vitamin C. 100 g sliced pods contains ~157% of an adult's daily requirement for vitamin C. The diet of people in the developing nations sometimes lack vitamins, minerals and protein. In these countries, *Moringa* can be an important source of many essential nutrients. However, there is one downside, i.e., Moringa leaves may also contain high levels of antinutrients, which can reduce the absorption of minerals and protein (Teixeira *et al*., 2014; Richter *et al*., 2003). Nutrients available in leaf, seed and root are shown in Table 1.

Table 1: Nutrients composition[a]of leaf, seed and root

S.No.	Nutrient	Leaf	Seed	Root
1.	Energy values (Kcal/100 g)	426.12	426.12	384.05
2.	Crude proteins (%)	27.60	28.02	5.02
3.	Crude lipids (%)	20.00	33.78	6.33
4.	Carbohydrates (%)	33.93	28.77	76.75
5.	Ash (%)	11.60	3.03	4.97
6.	Thiamine B1 (mg/100 g)	18.47	-	-
7.	Riboflavin B2 (mg/100 g)	14.82	-	-
8.	Pyridoxine B6 (mg/100 g)	57.29	-	-
9.	Ascorbic acid (mg/100 g)	773.30	94.74	48.13
10.	Niacin B3 (mg/100 g)	50.35	-	-
11.	Calcium (mg/100 g)	13.45	2.84	3.99
13.	Sodium (mg/100 g)	104.06	129.03	514.80
14.	Potassium (mg/100 g)	20.81	-	15.4

[a](Igwilo *et al*., 2017)

Medicinal Properties

Antioxidant Activities

Antioxidants are compounds that act against free radicals in human bodies. High levels of free radicals cause oxidative stress, which may contribute to chronic diseases like heart disease and type 2 diabetes (Kaneto *et al*., 2007; Rodrigo *et al*., 2011). Several antioxidant plant compounds have been found in the leaves of *Moringa (*Arti*et al*., 2009; Chumark *et al*., 2008; Sreelatha *et al*., 2009). In addition to vitamin C and beta-carotene, these include (Amaglo *et al*., 2010; Coppin *et al*., 2013) Quercetin, which is a powerful antioxidant that may help lower blood pressure (Edwards *et al*., 2007; Symonsand Jalili, 2012) too. One study in women found that consuming 7 g of *Moringa* leaves powder every day for three months significantly increased the blood antioxidant levels (Kushwaha *et al*., 2014). *Moringa* leaves extract may also be used as a food preservative, as it increases the shelf life of meat by reducing oxidation (Ahmad *et al*., 2015).

Maintenance of Low Blood Sugar Levels

High blood sugar can be a serious health problem. In fact, it is the main characteristic of diabetes. Interestingly, several studies have shown that *Moringa* may help in lowering blood sugar levels. However, most of the evidence is based on animal

studies. The studies on human are few, and generally of poor quality (Jaiswal *et al*., 2009; Mbikay, 2012; Ndong *et al*., 2007). In a study, on women who consumed 7 g of *Moringa* leaves powder every day for 3 months reduced their fasting blood sugar levels by 13.5 per cent (Kushwaha *et al*., 2014). Another study of a small sample of six diabetic patients found that adding 50 g of *Moringa* leaves to a meal reduced the rise in blood sugar by 21 per cent (William *et al*., 1993). These effects are caused by plant compounds found in *Moringa* leaves, such as isothiocyanates (Waterman *et al*., 2015).

Anti Inflammatory Effects

Inflammation is the body's natural response to infection or injury. It is essential as a protective mechanism, but may become a major health issue when it goes on for a long time. Sustained inflammation is believed to be involved in many chronic diseases, including heart disease and cancer (Libby, 2002). *Moringa* leaf, pod and seeds have been shown to possess anti-inflammatory properties as well, which may also be due to isothiocyanates (Cheenpracha *et al*., 2010; Mahajan and Mehta, 2010; Sulaiman *et al*., 2008). However, the research so far has been limited to test tube and animal studies. It remains to be confirmed if *Moringa* has similar anti-inflammatory effects in humans.

Cholesterol Lowering Effects

High amounts of cholesterol in the blood have been linked to an increased risk of heart disease. Both animal and human studies have shown that *Moringa* may have similar cholesterol-lowering effects (Chumark *et al*., 2008; Ghasi *et al*., 2000; Mbikay, 2012; Mehta *et al*., 2003).

Protect Against Arsenic Toxicity

Arsenic contamination of food and water is a problem in many parts of the world and rice may contain particularly high levels (Rahman and Hasegawa, 2011). Although arsenic in food or water does not cause symptoms of toxicity right away, long-term exposure may lead to health problems. Observational studies indicate that long-term exposure to arsenic may increase the risk of cancer and heart disease (Tapio and Grosche, 2006)**.** Several studies on mice and rats show that the leaves and seeds of *Moringa* may impart protection against some effects of arsenic toxicity (Chattopadhyay *et al*., 2011; Moon *et al*., 2012; Sheikh *et al*., 2014). These studies are promising, however, it is not yet known whether this also applies to humans.

Improving Nutritional Value Through Moringa Supplementation

Food fortification or enrichment is the process of adding nutrients (essential trace elements and vitamins) to food. Many studies have shown the potential use of different parts of *Moringa* in food such as in making soups, weaning foods, *amala*, a stiff dough (Karim *et al.,* 2015; Karim *et al.,* 2013), biscuits, bread, cake, yoghurt (Hekmat *et al.,* 2015) and cheese.

Amala

It is a staple in many parts of Africa including Ghana and Nigeria (Abiodun and Akinoso, 2014; Jimoh and Olatidoye, 2009). It is a starchy gel or stiff dough traditionally prepared from yam (*Dioscorea* spp.) flour (Abiodun and Akinoso, 2014; Awoyale *et al.,* 2010). However, *amala* has also been reportedly prepared from fermented cassava flour or plantain flour (Abulude and Ojediran, 2006; Karim *et al.,* 2015; Karim *et al.,* 2013). The major difference between the stiff dough types is in the appearance and viscoelastic properties. Stiff dough can be made either singly with plantain flour or in combination with yam flour (Abulude and Ojediran, 2006). The *amala* is prepared by reconstituting yam, cassava or plantain flour in boiling water until a smooth paste is formed (Karim *et al.,* 2013). *Moringa* leaves powder (MLP) at varying concentrations of 2.5%, 5%, 7.5% and 10% was reportedly used in the fortification of *amala* prepared from yam flour (Karim *et al.,* 2013). The addition of 10% MLP was found to increase the protein content of *amala* by approximately 4 per cent (Karim *et al.,* 2013). Similarly, Ca, Mg, K, Na and Fe contents of the fortified *amala* increased following the addition of MLP. However, the colour of the *amala* fortified with 10 per cent MLP was poorly rated. Fortification of *amala* with MLP beyond 2.5% was reported to unfavorably affect its sensory properties (Karim *et al.,* 2013).

Ogi

Ogi, also called cereal gruel is regarded as both a weaning or complementary food for infants and a breakfast cereal for adults. It is a fermented cereal porridge made from maize, sorghum or millet. Traditionally, *ogi* is prepared by soaking the cereals grains in water for about 3 days followed by wet milling and sieving to remove bran, hulls and germ (Abioye and Aka, 2015; Ladunni *et al.*, 2013). The filtrate, which is usually white starchy sediment, is fermented for about 2 to 3 days. During *ogi* production, nutrients including protein and minerals are reportedly lost from the grain during sieving. The resulting *ogi* has been shown to be of low nutritional quality (Abioye and Aka, 2015; Akinrele and Bassir, 1967). The addition of MLP to *ogi* was found to considerably improve the nutritionalvalue of maize or millet gruel (Abioye and Aka, 2015; Arise *et al.*, 2014; Olorode *et al.*, 2013). The vitamin A content was also found to increase by approximately 15 fold (Olorode *et al.*, 2013). Other nutrients, such as protein, Ca, Fe and P contents likewise showed significant increase after the addition of MLP (Abioye and Aka, 2015; Olorode *et al.*, 2013).

Biscuits

Moringa seeds (Ogunsina *et al.*, 2010) or leaves (Alam *et al.*, 2014; Dachana *et al.*, 2010; Kar *et al.*, 2013; Manaois *et al.*, 2013) have also been used in wheat biscuit or cookie fortification. It has been reported (Ogunsina *et al.*, 2010) that 20% level of *Moringa* seed flour (MSF) produced wheat cookies with surface cracking pattern and colour similar to that of the control. It can be used to improve nutritional value of bakery products such as cookies up to 9% (based on wheat flour weight) without remarkable effect on its sensory acceptability (Masih *et al.*, 2019). The addition of *Moringa* leaf extract improved the technological properties of wheat flour cookies and influenced positively on its acceptability (Mohamed *et al.*, 2014).

Bread

The addition of *Moringa* powdered flower, seed or leaf in bread dough prepared with wheat flour alone or in combination with other flours has been reported to improve nutritional value of bread (Chinma *et al.*, 2014; Ogunsina *et al.*,2010; Sengev *et al.*, 2013). For instance, the use of wheat flour fortified with 5% MLP was found to increase the protein and crude fibre content of bread, by approximately 54% and 56% respectively (Sengev *et al.*, 2013). Bread prepared with 5% *Moringa* seed powder (MSP) and 95% wheat flour had the best sensory attributes and the proximate analysis showed that *Moringa* seed powder- addition significantly increased the protein (8.55 to13.46%), ash (0.63 to1.76%), fat (7.31 to15.75%) and fiber content (0.08 to 0.62%) of the bread samples, while the moisture (22.90 to 20.01%) and carbohydrates content (57.68 to 46.73%) of the bread decreased. The mineral contents (P, K, Ca and Fe) of the *Moringa* fortified bread also increased considerably. Vitamin A content of the bread samples increased by 50 to 74%, as the proportion of MSP increased in the flour blends (Bolarinwa *et al.*, 2017).

Cake

It has been reported (Kolawole *et al.*, 2013) that upto 20% MLP can be used for the fortification of wheat cake. A more promising alternative for cake fortification may be the use of the seed and flowers of *Moringa* as their colour is not as strong as the leaf, yet they show high nutrient content similar to that of the leaves.

Yoghurt and Cheese

The use of MLP in the fortification of dairy products such as yoghurt and cheese at varying concentration up to about 3% has been reported (He *et al.*, 2010; Hekmat *et al.*, 2015; Kuikman and O'Connor, 2015; Salem *et al.*, 2013). Probiotic yoghurt fortified with 0.5% MLP and 5% sugar was reported to be acceptable to taste panel members (Hekmat *et al.*, 2015). The nutrient content such as fat, ash, protein and carbohydrates of cheese produced from buffalo milk fortified with MLP was found to generally increase with increasing levels of added MLP (Salem *et al.*, 2013). The protein content of the cheese with 1%, 2% and 3% MLP increased by 3%, 5% and 8% respectively. Cheese fortified with 3% MLP reportedly showed higher (3 times) antioxidant properties than the control cheese (Salem *et al.*, 2013). Up to 2% MLP was recommended for use in cheese fortification by these authors, because these levels of MLP had comparable sensory properties with the control. Further, the MLP fortified cheeses were reported to

have good and comparable sensory quality with the control after three weeks of storage.

Soup

Moringa leaves have found applications in preparing soup (Stevens *et al.,* 2013). Evidence of the use of *Moringa* leaves, in making soup, exists in the literature (Babayeju *et al.,* 2014; Chandramouli *et al.,* 2014). *Moringa* was reportedly used in making soups alone or in combination with melon seedand spinach (Babayeju *et al.,* 2014). According to these authors, up to 30% of *Moringa* leaves can be used in making traditional dishes with added spices and melon, as this level of inclusion had ratings next to the control among the studied samples (Babayeju *et al.,* 2014).

Agricultural Uses

Moringaas Animal Feed

Animals like cattle, goat and sheep, rabbits as well as pigs easily eat green leaves and stems of *Moringa*. (Mulugeta and Fekadu, 2014) which increases the cattle's weight gain up to 60% (Aknbamijo *et al.,* 2004), body weight gain, feed and protein intake of Murrah buffalo calves (Aharwal *et al.,* 2018). *Moringa* supplementation resulted in the highest average body weight gain in Bengal goats, besides the nutrient intake and improved digestibility were also observed by animals when *Moringa* leaves were used as a fodder. *Moringa* diet has the highest efficiency of protein utilization, nutrient digestibility and nitrogen utilization (Sultana *et al.,* 2015). The ideal feed combination for pigs is 70% *Moringa*, 10% *Leucaena* and 20% other leaves. MLM can also be included into the feed of fish and poultry. MLM in poultry feed could be particularly used by the small farm holders as natural and healthy feed substitute to synthetic feed supplements (Hermogenes *et al.,* 2014). If a portion of these results could be reproduced at field level, it would be a great boon to people in developing countries. This possibility needs to be investigated further and various aspects examined before the concept could be popularized. *Moringa* leaves also have anti-nutritional factors (ANFs) like tannins which when consumed have adverse effect on the health and productivity of animals. Other anti-nutritional components which have been reported are raffinose and stachyose which produce flatulence (Sahay *et al.,* 2017). MLM as a protein source in fish diets is limited due to presence of high levels of ANFs, particularly saponins and to a lesser extent tannin, phytic acid and hydrogen cyanide (Francis *et al.,* 2001).

Moringaas Honey Bee Forage Crop

Flowers of *Moringa* contain nectar, which is the mainstay of honeybee's life. Since the *Moringa* flowering is almost year round with different intensity, it provides opportunities for honey bees to visit flowers. *Moringa* serves as an alternate forage crop. In north India, when litchi flowering is over then *Moringa* comes to flower. Therefore, *Moringa* can also serve as an excellent forage crop along with litchi, jamun, etc. The honey bees collect nectar from flowers of *Moringa* during pollination and the same is produced into honey, which is highly useful.

Moringaas Natural Plant Growth Enhancer

Moringa leaves extract (MLE) contains K, Ca, carotenoids, phenols and zeatin (Asaolou *et al.,* 2012) which increases yield of onions, bell pepper, maize, soya, coffee, tea, chilli, melon etc., by 25-30% (Mulugeta and Fekadu, 2014), However, foliar spray should be used in addition to other sound agronomic practices. Extract from *Moringa* leaves is a low cost, natural plant growth enhancer that increases plant's tolerance to adverse environmental conditions (El-Hack *et al.,* 2018). Some researchers applied the MLE to various crops and found that spray had a wide range of beneficial effects (Afzal *et al.,* 2012; Asaolou *et al.,* 2012; Azooz *et al.,* 2004; Basra *et al.,* 2011; Desoky *et al.,* 2017; Howladar, 2014; Rady *et al.,* 2015). It was also reported that the plants were firmer, more resistant to diseases, pests (Saavedra Gonzalez and Van Der Maden, 2015) and abiotic stress. The plants had longer life-span; heavier roots, stems and shoots (El-Hack *et al.,* 2018). However, these results need to be confirmed at the field level to have a wider use (Foidl *et al.,* 2001).

Moringaas Natural Pesticide

The damping off disease (caused by *Pythium debaryanum*) among seedlings can be prevented by burying *Moringa* leaves into the soil (Fahey 2005).

Conclusion

Moringa, with emerging awareness regarding its

multiple uses, appears to be a potential crop, as found from various studies in the past years. *Moringa oleifera* consists of antioxidant, anticancer, anti-inflammatory, antiulcer, anti-hyperglycemic, antidiabetic and antimicrobial properties. Besides, its role in agriculture, as animal feed, forage crop, natural plant growth enhancer and bio-pesticide has also been established. High nutrient content, nutraceutical nature and other medicinal uses makes it to be a potential crop. As discussed in the light of scientific findings, *Moringa* can be a potential multipurpose crop to utilize marginal and degraded lands and also to use the unused space in perennial plantations. However, concerted efforts are needed to harness its potential completely.

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