



Moringa olifera: Nutrient Dense Food Source and World's Most Useful Plant to Ensure Nutritional Security, Good Health and Eradication of Malnutrition

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Authors' contributions

This work was carried out in collaboration between all authors. Author VPS designed the study, managed the literature search and wrote the first draft of the manuscript. Authors AA and SA have commented and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Moringa (*Moringa olifera* Lam.), belonging to the family Moringaceae, is a plant native to the Indian sub-continent and has become naturalised in tropical and sub-tropical areas around the world. Traditionally, the leaves, fruits, flowers, and immature pods of this tree are eaten in many countries. It is an economically important, multipurpose tree with immense nutritional value, containing all essential vitamins and minerals.

In view of the high nutritional and nutraceutical values the aim of this study was to compile a comprehensive review on the functional nutrients of Moringa with their respective health benefits and its significant potential to address malnutrition.

The majority of the research articles reviewed showed that Moringa leaves have very dense nutritional values, with highest number of antioxidants, and is rich in vitamins A, B, C, D, E and K. Apart from vitamins, the plant is also very rich in mineral content and contains Calcium, Iron, Potassium, Magnesium, Manganese and Zinc.

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Every part of Moringa tree is nutritious. Taking Moringa leaf as a vegetable, juice or in the form of dried powder can help in curing a number of deficiencies and diseases. Regular consumption of its leaf, in various forms, can control blood pressure, blood sugar and anemia, enhance mental alertness and bone strength. Further studies on recommended daily intake and scientific consensus on therapeutic benefits are needed.

Keywords: Antioxidants; malnutrition; micronutrients; miracle tree; *Moringa olifera*; super food.

1. INTRODUCTION

Over the past decade momentum around nutrition has been steadily building. With the naming of 2016-2025 as the United Nations Decade of Action on Nutrition, more and more people have begun to recognise the importance of addressing malnutrition in all its forms. In 2015, the UN Sustainable Development Goals enshrined the objective of “ending all forms of malnutrition”, challenging the world to think and act differently on malnutrition- to focus on all its faces and work to end it, for all people, by 2030 [1]. The State of Food Security and Nutrition in the World 2017 report indicated that, after steadily declining for over a decade, global hunger is on the rise again in 2016. Hunger statistics are going in the wrong direction and 2 billion people lack key micronutrients like iron and Vitamin A [2]. According to the report by FAO, globally 815 million people were undernourished in 2016, up from 777 million in 2015 [3]. The highest number of the undernourished live in Asia (520 million), followed by 243 million in Africa and 42 million in Latin America. In India, 190.7 million people are undernourished and 38.4% of children under five are stunted due to long-term nutritional deficiency, while 51.4% of women of reproductive age are anemic. Nutritional deficiency may also affect mental development, school performance and intellectual capacity.

The regions most burdened by under nutrition in Africa, Asia, Latin America, and the Caribbean share the ability to grow and utilize an edible plant, *Moringa (Moringa oleifera Lam.)*, commonly referred to as “The Miracle Tree” due to its nutritional benefits, medicinal properties and ability of environmental conservation [4,5,6]. *Moringa* is considered one of the world’s most useful trees, as almost every part of the *Moringa* tree can be used for food, medication or industrial purposes [7]. This tree has the potential to improve nutrition, boost food security and foster rural development [8]. *Moringa* belongs to the family Moringaceae, comprising 13 species

of which *Moringa olifera* is more widely cultivated [9]. Commonly known as the drumstick tree or horseradish tree, it is a short to medium-sized tree native to the sub-Himalayan tracts of India. *Moringa* can be grown in any tropical and subtropical regions of the world with a temperature around 25-35°C. It requires sandy or loamy soil with wide range of pH (5-9) and a net rainfall of 250-3000 mm [10]. Since this plant naturally occurs in varying habitats, is naïve to expect a great magnitude of variation in the concentration of chemical ingredients in different part of the tree. But some studies indicated that *Moringa* tree grown at different geographical locations differs in nutrient composition [11,12,13]. A comparative study by Asante et al. [13] indicates that leaves of *Moringa* tree grown in Savannah were less nutritious than leaves from semi-deciduous region. Difference between the nutritional compositions of leaves from different locations could be due to the influence of soil characteristics, climate and environmental factors [14,15]. But *Moringa* grown in any geographical areas is an economically important, multipurpose tree with immense nutritional value and has significant potential to address malnutrition.

Leading health and wellness experts at the Sterling Rice Group [16], and the popular wellness blog, Well+Good have identified *Moringa* as the superfood of 2018. According to Well+Good editors, 2018 is all about *Moringa*. It has twice the protein of spinach and three times as much iron, says nutritionist (and Well+Good Council member) Kimberly Snyder [17].

The leaves of *Moringa* are highly nutritious and as such are highly recommended for infants and nursing mothers especially those from developing countries or areas prone to cases of malnutrition, since both groups are at risk of nutritional deficiencies. Infants are in the critical stage of their development, while pregnant women and breast-feeding mothers need a constant supply of nutrients to ensure healthy children. *Moringa* is referred to as “Mother’s Best Friend” because of its utilization to increase

woman's milk production it is indeed a "Natural Gift of Nature" [18,19].

Moringa is widely distributed throughout Africa, Saudi Arabia, Southeast Asia, the Caribbean Islands and South America. Traditionally, the leaves, fruits, flowers, and immature pods of this tree are eaten; they are used as a highly nutritive vegetable in many countries, particularly in India, Pakistan, the Philippines, Hawaii, and some African nations [20,21,22]. In developing nations, Moringa is used as an alternative to imported food supplements to treat and combat malnutrition, especially among infants and nursing mothers [23]. The history of Moringa dates back to 150 B.C. Historical proofs reveal that ancient kings and queens used Moringa leaves and fruit in their diet to maintain mental alertness and healthy skin. Ancient Maurian warriors of India were fed with Moringa leaf extract on the warfront [23]. For hundreds of years, traditional healers also have prescribed different parts of Moringa for treatment of hypertension, diabetes, cancer treatment, skin

diseases, respiratory illnesses, ear and dental infections, water purification, and have promoted its use as a nutrient dense food source [4,24]. Preparation of Moringa based spice with 20% inclusion of Moringa leaf could be recommended for use as spice for cuisines. This will promote the consumption of Moringa especially by those averse to raw consumption of Moringa leaves [25]. The leaves of Moringa have been reported to be a valuable source of both macro and micronutrients and are now found growing within tropical and subtropical regions worldwide, congruent with the geographies where its nutritional benefits are most needed. Trees for Life, an NGO based in United States of America have promoted the nutritional benefits of the Moringa plant around the world. According to this organization Moringa grows in countries where malnutrition rate is high (Fig. 1) [26]. Several other NGOs like ECHO (Florida, USA), Church World Service (Indiana, USA), GIANT (Georgia, USA), Helen Keller International (Guinea), and Santé et Nature (Congo) are also active in promoting the use of Moringa [27].

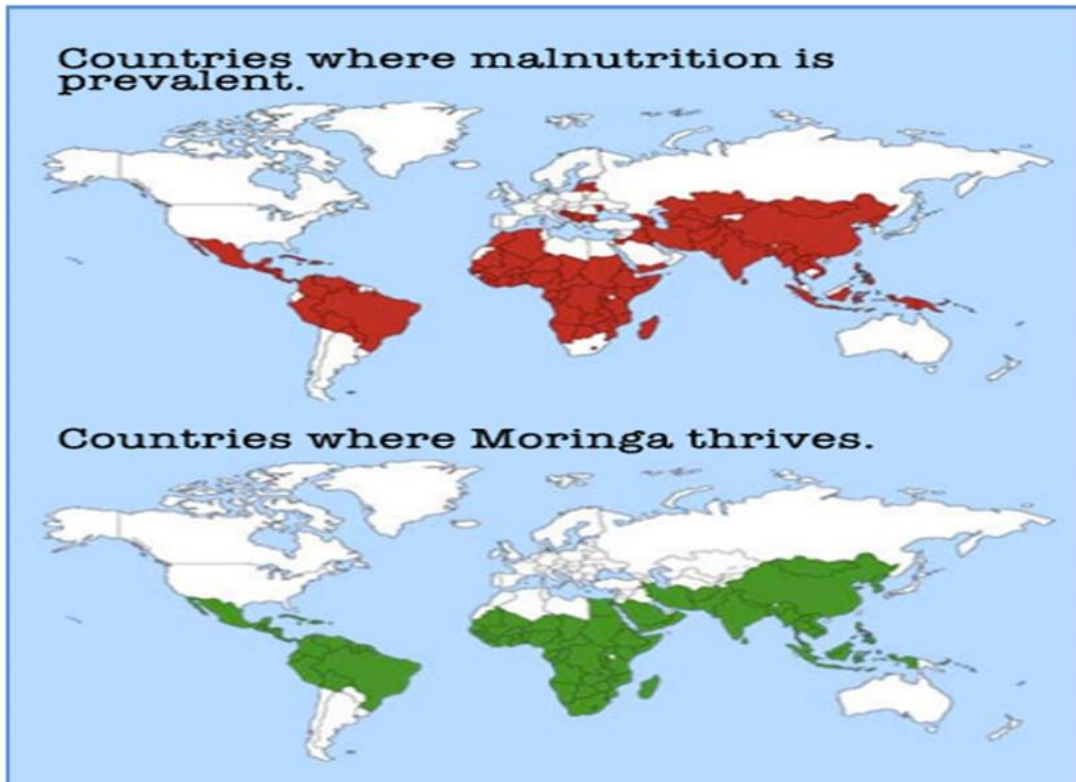


Fig. 1. Countries with 3-35% malnourished population and countries where Moringa grows naturally

2. NUTRITIONAL BENEFITS

Essential nutrients cannot be synthesized by the body and therefore must be provided through diet. A large number of reports on the nutritional quality of Moringa now exist in both scientific and popular literature, highlighting every part of Moringa is nutritious and an alternative medicine that is fast becoming popular in the West region. Studies have shown that Moringa leaves are rich sources of minerals, vitamins and amino acids, beta carotene, anti-inflammatory nutrients and omega 3 and 6 fatty acids [8,28-30]. As commonly known, most vegetables lose their nutrients upon cooking. However, it was observed that Moringa leaves whether fresh, cooked or stored as dried powder for months without refrigeration, did not lose its nutritional value [8]. Three non-governmental organisations (Trees for Life, Educational Concerns for Hunger and Church World Service, Senegal) have advocated the use of Moringa as a form of natural nutrition for the tropics [4].

In southern parts of India, leaves are fed to infants and children since their high content of beta-carotenes could help to prevent the development of blindness by Vitamin A deficiency [31], a common and widespread nutritional disorder amongst children and pregnant women in many developing countries. Besides being an excellent source of Vitamin A, Moringa leaf is also rich in vitamins B, C, proteins and minerals and acts as a good source of natural antioxidants [32]. It also contains a high content of amino acids such as methionine and cysteine [23].

Recent studies have demonstrated the potential bioactive properties of Moringa leaves and also shown the enrichment of carotenoids, tocopherols along iron bioavailability in animal models [33]. A study by Teixeira et al. [34] showed that whole leaf flour of Moringa contained 28.7, 7.1 and 44.4% of crude protein, fat and carbohydrate, respectively, with 3.0 and

103.1 mg/100 g of calcium and iron, respectively. The protein profile revealed 3.1, 0.3, 2.2, 3.5 and 70.1% levels of albumin, globulins, prolamin, glutelin and insoluble proteins, respectively. Ethanolic extract from Moringa leaves showed antioxidant activity that was stable in pH 4 and 9; when the extract was stored in the dark at 5°C and 25°C during a 15 day period, it did not show any significant change in its antioxidant property. Therefore, this plant extract is a potential source of dietary antioxidants [35]. It can also enhance the shelf-life of fat containing foods due to the presence of various types of antioxidant compounds such as ascorbic acid, flavonoids, phenolics and carotenoids [18,36]. Moringa contains all the essential amino acids needed for normal body functioning and must be replenished daily [4,37]. According to Igwilo et al. [37] different parts of Moringa are rich in essential amino acids, while the highest amount is reported in the leaves; thus leaves could be a good amino acid supplement.

The fresh Moringa leaves provide significant quantities of the key nutrients required for a healthy diet. These quantities are several times greater in Moringa leaves than the nutrients found in other fruits and vegetables [4]. Trees for Life's often-reproduced illustration (Table 1), shows that "gram-for-gram, Moringa leaves contain more vitamin A than carrots, more calcium than milk, more iron than spinach, more vitamin C than oranges, and more potassium than bananas," and that the protein quality of Moringa leaves rivals that of milk and eggs [24]. Since the dried Moringa leaf powder is concentrated, it contains even more of these essential nutrients with the exception of vitamin C (Table 1) [38]. Moringa has also been receiving increasing attention from the food processing industries. According to the Global Facilitation Unit (GFU), 2008, African companies manufacturing cereals are interested in adding Moringa leaf powder to enrich their products with a low cost, local source of vitamins and minerals.

Table 1. Comparison of nutrient level of Moringa leaves with other nutrient rich fruits, vegetables and products

Fresh leaves	Dried leaf powder
4 times the Vitamin A in carrots	10 times the Vitamin A in carrots
7 times the Vitamin C in oranges	1/2 the Vitamin C in oranges
¾ Iron of Spinach	25 times the Iron in Spinach
3 times the Potassium in bananas	15 times the Potassium in bananas
4 times the Calcium in Milk	17 times the Calcium in Milk
2 times the Protein in Yogurt	9 times the Protein in Yogurt

3. HEALTH BENEFITS

Moringa is a great indigenous source of highly digestible proteins, calcium, iron, vitamin C, K and A [18]. In addition, it contains vitamin B complex, chromium, copper, magnesium, manganese, phosphorus and zinc [39]. It is a complete food in itself. Thurber and Fahey [27] stated that Moringa leaves are a rich protein source which can be used by doctors, nutritionists and community health conscious persons to solve under nutrition problems.

Moringa helps in controlling different health complications such as diabetes, anemia and high blood pressure. An extract from the Moringa leaf has been shown to be effective in lowering blood sugar levels within 3 hours ingestion, though less effectively than the standard hypoglycemic drug, glibenclamid [40], it could be regarded as a more natural alternative. Moringa leaves contain isothiocyanates that attenuate *in vivo* inflammation [41]. Due to antioxidant properties the regular intake of Moringa leaves through diet can protect normal as well as diabetic patients against oxidative damage [42]. According to Omabe et al. [43] Moringa not only has anti-diabetic and non-cytotoxic properties, but it is also associated with significant anion gap acidosis in alloxan induced type-2 diabetic rats. Moringa leaf juice is known to have a stabilizing effect on blood pressure [44]. This is due to presence of nitrile, mustard oil glycosides and thiocarbamate glycosides in Moringa leaves which were found to be responsible for the blood pressure lowering effect [45,46].

The crude extract of Moringa leaves has a significant cholesterol lowering action in the serum of high fat diet fed rats which might be attributed to the presence of a bioactive Phytoconstituents, notably β - sitosterol [31]. Moringa fruit has been found to lower the serum cholesterol, phospholipids, triglycerides, low density lipoprotein (LDL), very low density lipoprotein (VLDL) cholesterol to phospholipid ratio, atherogenic index lipid and reduce the lipid profile of liver, heart and aorta in hypercholesteremic rabbits and increased the excretion of fecal cholesterol [47].

Moringa was found to have a group of unique compounds containing sugar and rhamnase, which are uncommon sugar-modified glucosinolates [24,48]. These compounds were reported to demonstrate certain chemo-preventive activity, by inducing apoptosis [49].

The aqueous leaf extract was able to inhibit the proliferation of human tumor cells in a dose dependent manner as well as inducing cellular apoptosis [50,51]. It can also regulate thyroid hormone and can be used to treat hyperthyroidism [52]. Phytosterols and phenolic compounds present in Moringa leaves extract promote wound healing activity [53].

In the Philippines, Moringa is known as mother's best friend because of its utilisation to increase woman's milk production [18,54]. Moringa leaves have certain quality as alactagogum (i.e. increasing breast milk secretion) [4,54,55] as it contains aphytosterol compound which help in increase of milk production in breastfeeding mothers [56]. Moringa flour is one foodstuff used in the process of making dried noodles as a food improvement that can enhance the productivity of mothers' breast milk. A study conducted on impact of noodles enhanced by Moringa, fed to the rat, is able to increase the productivity of breast milk of female rats [57].

Moringa leaves help prevent anemia. Results of the metabolic (anaemia) study by Madukwe et al. [58] revealed, true to literature reports, use of dry Moringa leaf powder provides effective treatment of anemia [24]. This evidently is because of its content of quality protein, iron and vitamins A and C. Moringa is a good source of vitamin A and its deficiency impairs numerous functions. As a result, its absence has many health consequences, to which infants, young children and pregnant women appear to be at greatest risk [59]. Anemia can result from vitamin A deficiency in children and women, likely due to multiple apparent roles of vitamin A in supporting iron mobilization and transport, and hematopoiesis [60]. In 2002, West [61] estimated that 127 million preschool-age children were vitamin A deficient in the developing world, of whom 4.4 million have xerophthalmia (including night blindness, Bitot's spots, and corneal xerophthalmia). These estimates showed that nearly half of the world's children with xerophthalmia resided in South and South-East Asia, of whom over 85% live in India. Eating Moringa leaves, pods and leaf powder, which contain high proportions of vitamin A, can help to prevent night blindness and eye problems in children. The Food and Nutrition Unit in the Ministry of Agriculture in Malawi, recently identified nutrient-rich Moringa as a potential solution to vitamin A deficiency [62]. The Wealth of India [63], reported that Moringa leaves has purgative properties and also serves as an

antidote to piles, fevers, sore-throat, bronchitis, catarrh, eye and ear infections, as well as healing sores, a reliever of headaches and leaf juice has the capacity to reduce swelling of an inflammation.

Moringa seeds also have several medicinal properties. They contain specific protein fractions for skin and hair care. Two new active components for the cosmetic industry have been extracted from Moringa seed oil cake. They protect the human skin from environmental influences and combat premature skin aging. With dual activity, antipollution and conditioning/strengthening of hair, the Moringa seed extract is a globally acceptable innovative solution for hair care [64]. Moringa seed and flower oil called Moringa oil or ben oil has anti-inflammatory compounds that help relieve the pain and swelling caused by arthritis, rheumatism and joint pain [19,21]. Essential oil from Moringa leaves and extract from seeds showed anti-fungal activities against dermatophytes such as *Trichophyton rubrum*, *Trichophyton mentagrophytes*, *Epidermophyton floccosum* and *Microsporum canis* and thus can be used in the future for development of anti-skin disease agents [64]. The phytochemicals derived from Moringa seed extracts are effective mosquito vector control agents and the plant extracts may be used for further integrated pest-management programmes [32]. Bark of Moringa has been used to cure dental caries/toothache, common cold, external sores/ulcer, anti-tumor, snake bite, scorpion bite, headache and scurvy [24]. The ancient traditional medicine of India called Ayurveda has long recognized use of almost all parts of the Moringa tree for treating various illnesses such as inflammation, anemia, bronchitis, asthma, diarrhea, headache, gout, joint pain, rheumatism, hysteria, cholera, heart complaints, fevers, respiratory disorders, digestive disorders, intestinal worms, and diabetes, swelling, skin infections, in the indigenous system of medicine [65-67].

4. MORINGA FIGHTS MALNUTRITION

Moringa has high nutritional potential because its leaves contain a high concentration of nutrients, and phenolic constituents, mainly flavonoids and phenolic acids, which represent a good source of natural antioxidants [68]. The World Health Organization (WHO) has been promoting the Moringa plant as an alternative to imported food supplements to treat malnutrition in poor countries [69]. Daily consumption of Moringa in

the form of juice, fresh leaves or dried leaf powder can contribute significantly to meeting the needs of nutrients and reduce the risks of malnutrition in pregnant women, lactating mothers and young children. Moringa is reported to prevent malnutrition because of the high protein and micronutrient content of the leaves [70]. In Senegal, village women use Moringa leaf powder in their foods for development of growth and improving overall health of children, pregnant women recovered from anemia and had babies with higher birth weights and lactating mothers increased their milk production [71]. Traditionally, a tea made by boiling Moringa flowers is used by lactating mothers to stimulate the flow of breast milk. A 100g portion of fresh leaves gives a woman three times her daily requirements of vitamins A and C, about half her daily requirement of calcium, and significant quantities of iron and protein.

Regular use of Moringa leaf powder has been shown to increase the nutritional status of the subject. Research done by Zongo et al. [72] in Burkina Faso, shows that children who are malnourished given Moringa leaf powder have increased weight than those not given Moringa leaf powder. Research conducted by Srikanth et al. [73] in India with Moringa leaf powder fed to children showed significant weight gain among children with grade I and grade II Protein Energy Malnutrition (PEM). It was found that 70% children with grade II PEM improved to grade I and 60% children with grade I PEM had shown significant improvement in their nutritional status. As nutrient supplement, adding one large spoonful (8 g) of dried Moringa leaf powder to any complementary foods three times each day will ensure that a child is getting a nutrition-rich diet. Technical bulletin of USAID identifies how dried Moringa leaf powder contributes to the recommended daily allowances of young children and women for key nutrients given in Table 2 [74].

According to Dr. Lowell Fuglie, the West Africa representative of the Church World Service who used the Moringa tree as a base for a nutrition programme, for a child aged 1-3 years, a 100 g serving of fresh cooked leaves would provide all his daily requirements of calcium, about 75% of his Iron and half his protein needs, as well as important amounts of potassium, vitamin B and all the essential amino acids [4]. As little as 20 g of leaves would provide all the vitamins A and C requirement of a child [4,39].

Table 2. Recommended daily allowances of nutrients to nursing mothers and child

Nutrients	% Recommended daily allowance	
	Nursing Mothers (6 large spoonful/ day)	Child, 1-3 Years (1 large spoonful, 3 times/day)
Vitamin A	143	272
Vitamin C	9	22
Iron	94	71
Calcium	84	125
Protein	21	42
Potassium	22	41
Magnesium	54	61

In 1995 to stop classroom hunger and improve the nutritional status of children the Government of India launched National Programme on Nutritional Support to Primary Education (NP-NSPE) commonly known as the Mid day Meal Programme. Under the scheme cooked 'Mid-Day Meals' with 300 calories and 8-12 grams of protein were given to children in school. But providing a balanced and nutritious diet to the children is still a challenge in rural area. Moringa packed with nutritional potential and readily available in all geographical locations in India, can be used as low cost substitute to address malnutrition in children by adding Moringa leaf powder in the mid day meal.

5. CONCLUSION AND FUTURE PROSPECTS

Several scientific studies have proved that Moringa is the most nutrient rich plant yet discovered and the only plant on planet with 96 nutrients and 46 antioxidants. It is rare for a single plant to contain as many essential nutrients and furthermore in high quantities those found individually in several other types of fruits and vegetables. This tree has in recent times been advocated as an outstanding indigenous source of highly digestible protein, calcium, iron, vitamins and carotenoids, and has the potential to be used as nutritional supplements and save millions of lives in poor countries where malnutrition is prevalent because of its high nutritional value. Since this plant naturally occurs in varying habitats have less possibility of great magnitude of variation in the concentration and composition of chemical ingredient in leaves and other part of the tree. However the effect of soil characteristics and environmental factors affecting the nutrient levels of leaves and other parts of *Moringa oleifera* grown across the globe require further studies.

Moringa provides a rich and rare combination of nutrients, amino acids, antioxidants, anti-aging and inflammatory properties used for nutrition and healing. Use of Moringa leaves helps in controlling different health complications such as anemia, high blood pressure, lowering blood sugar level and has great anti-diabetic and anti-cancer properties. However, double blind researches are less prevalent to further substantiate these properties of Moringa. More studies are needed to substantiate the primary mechanisms of Moringa as anti-diabetic and anti-cancer agents.

In view of its multiple uses, the Moringa plant needs to be promoted and widely cultivated around the world where climatic conditions favour its optimum growth. Leaves, pods and flowers of Moringa can be used as a dietary supplement as cooked vegetables or dried, turning them into powder for use in several food preparations. In recent years there has been growing awareness about benefits of Moringa tree that can meet nutritional needs and take care of medicinal requirement of growing population but still under utilised. Further studies on recommended daily intake and more human trials for scientific consensus on its curative benefits are needed on this potential super food of the future.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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