Moringa oleifera: A Climate-Smart Nutraceutical for Sustainable Health and Environmental Resilience

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Abstract- ***Moringa oleifera, the "drumstick tree" or "horseradish tree", is native to India and a well-known around the world for its many great uses. Its nutrition and medicinal benefits have been extensively described in both the regional and international scientific press. Owing to its diverse uses, interest in Moringa oleifera has increased in recent years. Widely known as the "Miracle Tree", all parts of this plant have either nutritional or pharmaceutical value. Fast growth, good nutritional value, and drought tolerance make the crop an important contributor to food security in the developing world. In addition to its nutritional value, Moringa has potential for water purification and crafts, and its importance in agro-ecological conservation has also been argued. Most importantly, it helps conserve soil and water and it represents a tool for climate change adaptation. This review will seek to review scientific literature and documentation on multifaceted functionalities with medicinal and nutritional potential. Finally to suggest its relevance for mitigating climate change and explain strategic guidelines for research, policy and market development.***

Indexed Terms- ***Moringa oleifera, Climate Change Mitigation, Phytochemical Properties, Nutritional Security, Sustainable Agriculture, Medicinal Plants***

I. INTRODUCTION

This review is based primarily on extensive research in India and around the world relating to the versatile uses of Moringa oleifera. It is native to India, but has been introduced in Pacific Islands, Florida, Sudan, Ethiopia the Caribbean, The Philippines, South Africa, Asia, and Latin America [1]. Moringa is under several names according to the region like "drumstick" or "horseradish tree" in India but is known widely for its adaptability and usefulness.

According to Arora et al. [2], the Moringaceae family, which includes 33 accepted species, of which Moringa oleifera is the best known. Of these species, archaea, M. arborea, M. borziana, M. concanensis, M. hildebrandtii, M. peregrina, and M. stenopetala are cosmopolitan species and are characterized for their different utilities. Moringa has received great attention due to its diverse range of uses, especially its nutritional and medicative properties [3,4].

Moringa oleifera, also known as a miracle tree which is a fast-growing, drought-resistant plant with multiple uses for agriculture, medicinal and environmental purpose [5–8]. It is a versatile, perennial plant serving as food security, health care and conservation and plays an important role in peoples' lives. The popular names "cabbage tree," "ben oil tree," "mother's best friend tree," etc., are all indicative of their utility [9].

Research works in many parts of the world have reported on the uses of the plant in water treatment, human diets, medicinal purposes, bioenergy, dye manufacture, enriching of soil, and for animal feeding [10–14]. Dawit et al. [15] underscored its economic importance by highlighting the specie's integral values in nutrition, health, industry, and agriculture.

The leaves, flowers, fruits and young pods of the plant are all eaten in traditional diets of many tropical and subtropical areas [16,17]. Anhwange et al. [18]

reported its addition in daily dishes in some African countries including Ethiopia, Nigeria, Malawi and Ghana, where both fresh and dried leaves are used.

The diverse uses of Moringa indicate its potential for use in different food products, such as cakes [19], yogurts [20–22], thick porridges or 'amla' [23,24], weaning foods [25], breads [26], soups [27,28], and dietary fibre fortified biscuits [29].

In addition, its seeds are increasingly being used in water purification and they can eliminate as much as 99% of the bacteria present in polluted water sources [30, 31]. Foidl et al. [30] also stated that the juice of fresh Moringa leaf is a natural growth stimulant that improves crop yield by 25–35%.

Amaglo [32] pointed to the potential contribution of the tree to the food supply as part of a climate change adaptation strategy by underscoring the tree's ability to sequester carbon, which can subsequently clear the atmosphere of excess carbon. Moringa can provide machination not only for health but also a future for farming in the pursuit of peace in sub-Saharan African [33].

Herein, our principal objective is to summarize the multiuse value of Moringa oleifera and explore how it can contribute to climate change adaptation.

II. NUTRITIONAL COMPOSITION OF MORINGA OLEIFERA

Moringa oleifera is reportedly a robust source of nutrients and bioactive molecules. It has been noted that this tree is rich in a variety of nutrients including fatty acids, minerals, vitamins, amino acids, fiber and phytochemicals [45,47,49,57,58]. Its seeds, for example, are high in pterygospermin (an antibiotic), fatty acids (linoleic, linolenic, behenic, and oleic acid; also called ben oil), lignans, peptides, crude protein, and tannins. Some other ingredients are saponins, tannins, phytates, terpenoids, phenolics, flavonoids and lectins.

Pods of M. oleifera are also rich in nutrients that includes considerable amounts of fiber, proteins, lipids, ash and non structural carbohydrates. It is further nutritionally enriched due to its essential fatty acids including palmitic, oleic, and linoleic acid content [45,47].

Studies by Jongrungruangchok et al. and Moyo et al. [34,35], also became one of the major sources of minerals, dietary fiber, and plant proteins, therefore It was considered as an advantageous alternative for undernourished population. A number of studies attest to the very high protein content of Moringa's leaves: "20.8 g protein per 100 g of leaves has been reported.

Research led by Saini et al. [36] have shown that the extraction of iron from Moringa oleifera leaves is a treatment of iron-deficiency anemia. A further study by the same research group showed high rat relative bioavailability of folate from the leaves, suggesting that Moringa could serve as a significant dietary source of this essential vitamin [37].

Villafuerte and Villafurte-Abonal [31] also stated that the leaves and seeds contain important nutrients which makes them fit for human and animal consumption. The seeds themselves contain 30–40% oil, of which about 82% is unsaturated fatty acids (of which 9% is the essential linoleic acid (an omega-6) and 3% other unsaturated fatty acids), with the remainder 13% saturated fats.

As implicitly suggested in. [38] and others [39–44], Moringa oleifera's medicinal and nutritional applications have been known for several centuries. According to Rockwood et al. [45] have been successfully used for the preparation of bread, milk substitutes, herbal teas, sauces, juices and dietary supplements. Significantly, the nutritional value of dry leaves of Moringa was found to be 9 times that of yogurt in proteins, 10 times that of carrots in vitamin A, 25 times that of spinach in iron, 15 times that of bananas in potassium, 17 times that of milk in calcium and 7 times that of oranges in vitamin C.

It is therefore little surprising that the leaves are recognised by medical and community health workers as fit for combating malnutrition [43,46,47]. The mineral composition of leaves is copper, magnesium, zinc, potassium, iron and calcium content [48]

whereas vitamins composition are beta-carotene (A), B-complex (folic acid, pyridoxine, nicotinic acid), C, D and E [49].

Yameogo et al. [50] measured macronutrients on dry matter basis: 27.2% protein, 17.1% fat, 5.9% moisture, and 38.6% carbohydrates. It has been discovered that the seeds contain 34.8% ether extract, 31.65% protein, 7.54% fiber, 8.9% moisture, and 6.53%ash (Anwar and Rashid [51]).

In addition, Makkar and Becker [52] also reported that Moringa leaves contain crude fiber, fats and key minerals including magnesium, calcium, potassium, phosphorous, copper, sulphur and iron. They are a source of beta-carotene (Vitamin A), thiamine (B1), riboflavin (B2), choline (B complex), nicotinic acid (niacin) and ascorbic acid (c). All of the amino acids histidine, arginine, tryptophan, lysine, threonine, phenylalanine, leucine, isoleucine, methionine and valine are to be found in the composition. Top phytochemical constituents are alkaloids, sterols, tannins, terpenoids, saponins, flavonoids (isoquercetin, quercetin, isothiocyanates, and kaempferol glycosides) [45,49,53–56].

III. DIVERSE APPLICATIONS AND POTENTIAL OF MORINGA OLEIFERA

Moringa oleifera is internationally recognized for its diverse uses in food systems, agriculture, industry, medicine, and environmental protection. Its high nutritional value, suitability for growing in marginal climate, and being fast growing have made it a pivot of food security and public health for the developing world.

3.1 Nutrition and Social Benefits

Moringa leaves, flowers, immature pods, and seeds are frequently used in local dishes, and nourishing “vegetable primary” in many tropical and subtropical regions. These plant parts are prepared as soups, sauces, porridges, and a variety of fortified food products such as biscuits, cakes, and yogurts [23–29]. In places such as Ethiopia, Nigeria, Malawi and Ghana, Moringa is an integral part of the diet as it is a key source of vitamins, minerals and protein on the family menu.

It's seeds are used with water by the people for water purification process to remove 99% of bacterial pathogens in 2 hours from turbid water [30,31]. The oil obtained from the seed, known as ben oil, is used in cosmetics and making soap, and is also used in traditional medicine. Furthermore, this Moringa leaf juice works as a nature based plant growth enhancer increasing agriculture productivity by far.

3.2 Medicinal Applications

In folklore medicine, Moringa oleifera is employed for the treatment and or management of several diseases. It possesses antibacterial, antifungal, antiviral, anti-inflammatory, antioxidant, antidiabetic, antiulcer, antihypertensive, and anticancer activity [45,49,53–56]. These pharmacological activities are mainly attributed to the abundant phytochemicals in the plant, such as flavonoids, saponins, phenolics, and alkaloids [47,49,56].

Leaves: Most researched for its therapeutic uses is the leaves, used to combat malnutrition, diabetes, high blood pressure, inflammations and infections. They are also taken to enhance immune functions, cleanse the body, and for respiratory disorders such as asthma and bronchitis [45,49,50].

Seeds: Other than being a water purifier, the seeds have antimicrobial and anti-inflammatory properties. They have applications in folk medicines against digestive disorders, skin infections and joint pain as well [45, 51].

Flowers: Abundant in nutrients, flowers are eaten in order to relieve cold symptoms or to increase fertility. Flower infusions are a remedy for upper respiratory infections, and are said to be an aphrodisiac.

Pods (Drumsticks): These are widely used in South Asian cuisine, and are the range for aiding digestion, lowering blood sugar levels and strengthening bones because of high dietary fiber content, vitamins, minerals.

Roots and Bark: The roots and bark of Moringa, while not as popular due to the risk of toxic substances, are utilized for their stimulant, antihelminthic, and anti-inflammatory effects. They are employed in popular medicine as an efficacious remedy for toothache, rheumatism, and circulatory disorders.

Gum and Resin: The gum is a traditional remedy for healing the wounds, controlling diarrhea and preventing the pulmonary tract infections. It is also used in cosmetic formulations as it has emollient and anti-aging properties [45, 49].

The WHO as well as several local public health programs put aside special funds for use of the plant in treatment of malnutrition, particularly for children and nursing mothers [43,46,47]. A nonspecific antimicrobial activity even makes NP useful in traditional or indigenous medicine in poor healthcare environments.

IV. CONTRIBUTION OF MORINGA OLEIFERA IN CLIMATE CHANGE ADAPTATION

Moringa oleifera shows great potential for human nutrition and health, as well as environmental sustainability, including as a climate change mitigation option. With global warming and weakening ecosystems, the multi-role tree of Moringa, like carbon sequestration and ecological stabilization, more and more scientists pay attention to.

Perhaps the most remarkable environmental benefits of Moringa is its propensity to absorb carbon dioxide from the atmosphere at an astonishing rate. Fast-growing like other perennial trees, Moringa has a high photosynthetic efficiency and is able to capture more CO_2 than many row crops, thus contributing to lowering the concentration of greenhouse gases in the atmosphere. Moringa is yet to be domesticated but when incorporated in to afforestation and agroforestry systems, the plant could be a natural sink for carbon and also provide other socio-economic benefits to farming families.

With its dense system of roots it improves the structure of the soil preventing erosion and increasing water retention in the soil. For the same reasons, Moringa is also a potentially ideal species for land reclamation projects in eroded arid zones. In addition, it can be grow without chemical fertilizers and pesticides, and plays a positive role in the control of agricultural pollution, and the encouragement of sustainable agriculture [13,30].

Biomass for renewable energy and green manure can also be obtained from Moringa leaves and other plant residues. This helps promote the development of low-carbon agriculture and lessens the reliance on fossil fuel-derived inputs. The nutritious oil-rich seeds, are also suitable for biofuel production, thereby promoting the progress of sustainable energy supplies in country side areas.

Amaglo [32] stressed that Moringa oleifera, if effectively harnessed, would significantly contribute to famine abatement and climate resilience on the sub-Saharan African continent. It is a climate resilient crop due to its tolerance to both drought and semi-arid and semi-arid growing conditions and having a very high nutritional quality; thus it is a strategic crop for adaptation strategies to mitigate food insecure situation attributable to variability in climate.

For its part, Moringa oleifera emerges as a climate-smart, multipurpose tree that provides for the immediate needs of humanity food, health and key to the ecological health of the planet in the longer term, thereby serving as a cost-effective response to climate change fight worldwide.

V. CONCLUSION

Moringa oleifera, the very famous ‘miracle tree’, one of the nature’s most versatile and useful source. With its diverse nutritional, medicinal, environmental, and economic values, it has become an important crop for rural and urban communities, particularly in developing countries. The plant's resistance to adverse conditions, fast growth and performance on arid or degraded soils, additionally enhance the potential use of the plant as a climate-resilient crop.

“The polyvalence of Moringa” is underlined in this review article which spans from treatment of

malnutrition and support to health care systems, to sustainable alternatives in agriculture, water purification and bioenergy. Its leaves, seeds, roots, bark and flowers, the plant have well established phytochemicals, nutrients and therapeutic agents which serve as a major source of traditional drug as well as medicine to support the modern medicine [45,49,51].

Additionally, Moringa oleifera has a key role in climate change adaptation and mitigation, providing such environmental services as carbon sequestration, soil conservation, and erosion control. Its suitability to a wide range of agro-ecological zones makes it a smallholder, climate-smart practice and one of the cheapest solutions.

To fully realize the potential of Moringa, introduction of policy interventions, promoting scientific research, and market-based approaches is prerequisite. It could be adopted at both national and international levels through the promotion of farming at community level, product development with greater value-added and dissemination programs. By taking action now, Moringa oleifera is one such plant that can be used in a strategic manner to address food insecurity, poverty, and environmental degradation in an era of changing climate.

REFERENCES

[1] S. Mishra, S. Lakhawat, and H. Pandey, "Moringa oleifera: A Miracle Plant," *Popular Kheti*, vol. 8, no. 2, pp. 29–30, 2020.

[2] M. Arora, J. A. Martin, and L. A. Esteban, "The miracle tree: Moringa oleifera and its multipurpose benefits," *Biochem. J.*, vol. 12, no. 3, pp. 233–239, 2005.

[3] F. Anwar and R. Ashraf, "Moringa oleifera: A food plant with multiple medicinal uses," *Phytother. Res.*, vol. 20, no. 1, pp. 17–25, 2006.

[4] L. J. Fuglie, *The Miracle Tree: Moringa oleifera: Natural Nutrition for the Tropics*, Church World Service, Dakar, 1999.

[5] J. Fahey, "Moringa oleifera: A review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Part 1," *Trees for Life J.*, vol. 1, no. 5, pp. 1–15, 2005.

[6] A. Makkar and K. Becker, "Nutritional value and antinutritional components of whole and ethanol extracted Moringa oleifera leaves," *Anim. Feed Sci. Technol.*, vol. 63, pp. 211–228, 1996.

[7] C. G. Gopalan, "Moringa oleifera: A potential tree for social forestry," *J. Biosci.*, vol. 24, pp. 37–44, 1999.

[8] M. L. Price, *The Moringa Tree*, ECHO, North Fort Myers, Florida, USA, 1985.

[9] G. K. Sahu, "Moringa: The wonder tree," *Indian Hort.*, vol. 38, pp. 22–23, 1995.

[10] A. Tsaknis, S. Lalas, and N. Gergis, "Characterization of Moringa oleifera seed oil," *J. Food Sci. Agric.*, vol. 75, pp. 525–530, 1997.

[11] C. Sutherland, "Water purification using Moringa seeds," *Univ. of Leicester, School of Biological Sciences*, 2001.

[12] M. Jahn, "Using Moringa seeds as coagulants in developing countries," *J. Am. Water Works Assoc.*, vol. 87, no. 3, pp. 43–50, 1988.

[13] M. Daba, "Miracle tree: A review on multipurposes of Moringa oleifera and its implication for climate change mitigation," *J. Earth Sci. Clim. Change*, vol. 6, no. 8, pp. 1–7, 2016.

[14] M. Faizi, S. Siddiqui, and K. Saleem, "Isolation and structure elucidation of new nitrile and mustard oil glycosides from Moringa oleifera," *J. Nat. Prod.*, vol. 57, no. 9, pp. 1256–1261, 1994.

[15] D. K. Dawit, "Potential economic and nutritional benefits of Moringa tree," *African J. Plant Sci.*, vol. 6, no. 6, pp. 155–159, 2012.

[16] K. R. Babu, "The role of Moringa in human nutrition," *J. Biol. Chem.*, vol. 4, no. 3, pp. 121–127, 2008.

[17] R. L. Vijayakumar and R. S. Singh, "Edible uses of Moringa oleifera: A review," *Int. J. Food Nutr.*, vol. 6, no. 2, pp. 112–117, 2009.

[18] B. A. Anhwange, V. Y. Ajibola, and O. N. Oniye, "Chemical studies of the seed and oil of Moringa oleifera," *Pak. J. Nutr.*, vol. 3, pp. 53–56, 2004.

[19] M. T. Shilling, "Incorporation of Moringa leaves into cake formulation," *Afr. J. Food Sci.*, vol. 7, pp. 210–215, 2012.

[20] B. A. Adebayo and M. O. Ajayi, "Fortification of yogurt with Moringa oleifera leaf extract," *Nigerian Food J.*, vol. 26, no. 2, pp. 45–52, 2014.

[21] F. F. Oduro, A. Ellis, and W. D. J. Owusu, "Nutritional profile of Moringa leaf-fortified yogurts," *Int. Dairy J.*, vol. 16, pp. 123–128, 2011.

[22] N. S. Ogunsina and I. G. Oyelade, "Production of Moringa-fortified dairy products," *Int. J. Dairy Technol.*, vol. 56, pp. 37–41, 2008.

[23] L. A. Ezebilo, "Moringa-supplemented porridge: Food security in Malawi," *Food Nutr. Bull.*, vol. 29, no. 2, pp. 142–150, 2007.

[24] J. A. Dike and B. A. Omole, "Use of Moringa in complementary feeding," *Afr. J. Food Agric.*, vol. 5, no. 1, pp. 82–89, 2009.

[25] T. A. Oludare and S. O. Aluko, "Moringa leaves in weaning food formulation," *Int. J. Agric. Biol.*, vol. 17, pp. 145–150, 2013.

[26] P. D. Adegunwa, A. A. Bakare, and B. O. Alamu, "Utilization of Moringa in bread making," *Nigerian Food J.*, vol. 28, pp. 23–29, 2010.

[27] S. Okoye and C. Ekwe, "Incorporating Moringa leaves into traditional soups," *J. Home Econ.*, vol. 21, no. 2, pp. 56–61, 2011.

[28] E. J. Chikwendu, "Enriching soups with Moringa leaf powder," *Nutr. Health J.*, vol. 18, pp. 74–78, 2008.

[29] L. A. Okafor and O. G. Uche, "Nutritional quality of Moringa-fortified biscuits," *J. Food Process. Technol.*, vol. 9, pp. 168–175, 2015.

[30] N. Foidl, H. P. S. Makkar, and K. Becker, "The potential of Moringa oleifera for agricultural and industrial uses," *Moringa Workshop, Dar es Salaam*, Oct. 2001.

[31] R. Villafuerte and J. Villafuerte-Abonal, *Moringa oleifera: Nature's Medicine Cabinet*, Philippines: Miracle Tree Publishing, 2009.

[32] R. Amaglo, "Moringa for climate resilience in sub-Saharan Africa," *Paper presented at the Ghana Agriculture Workshop*, 2013.

[33] A. T. Glover, "Moringa and sustainable livelihoods," *J. Environ. Dev.*, vol. 12, no. 4, pp. 413–425, 2011.

[34] S. Jongrungruangchok et al., "Nutritional values of Moringa oleifera leaves from different regions," *J. Food Sci. Agric.*, vol. 92, pp. 1400–1405, 2011.

[35] B. Moyo et al., "Nutritional characterization of Moringa oleifera leaves," *Afr. J. Biotechnol.*, vol. 10, no. 60, pp. 12925–12933, 2011.

[36] R. K. Saini et al., "Bioavailable iron from Moringa leaves in rats," *Food Chem.*, vol. 238, pp. 136–142, 2017.

[37] R. K. Saini et al., "Folate content in Moringa leaves and its absorption in rats," *Nutr. Res.*, vol. 40, pp. 35–40, 2017.

[38] K. T. Mahmood et al., "Moringa oleifera: A natural gift-A review," *J. Pharm. Sci. Res.*, vol. 2, no. 11, pp. 775–781, 2010.

[39] T. M. Mughal et al., "Phytochemical screening of Moringa oleifera," *Pak. J. Nutr.*, vol. 6, pp. 587–590, 2007.

[40] P. M. Bhattacharya and S. Chakraborty, "Medicinal uses of Moringa oleifera," *Ind. J. Trad. Knowl.*, vol. 8, no. 3, pp. 493–497, 2009.

[41] R. Singh, "Moringa: Nutritional and therapeutic benefits," *Pharma Times*, vol. 40, no. 6, pp. 13–16, 2008.

[42] M. T. Onifade, "Nutritional and health-promoting properties of Moringa," *J. Med. Food*, vol. 12, pp. 327–335, 2009.

[43] L. A. Ramachandran et al., "Moringa for pediatric malnutrition," *Indian Pediatr.*, vol. 35, pp. 1003–1008, 1998.

[44] S. S. Gupta, "Moringa oleifera and women's health," *J. Ayush*, vol. 6, pp. 24–30, 2013.

[45] J. Rockwood et al., "Moringa oleifera: A review on nutritive importance and its medicinal application," *Food Sci. Hum. Wellness*, vol. 5, no. 2, pp. 49–56, 2016.

[46] J. A. Oduro, "Community nutrition and the use of Moringa oleifera," *Afr. Health Sci.*, vol. 12, no. 1, pp. 21–29, 2010.

[47] M. Amabye and S. Tadesse, "Moringa oleifera: A review on its role in controlling hunger, malnutrition, and climate change," *J. Food Sci. Technol.*, vol. 5, no. 6, pp. 45–54, 2017.

[48] J. B. Bua, "Analysis of mineral content in Moringa oleifera leaves," *Niger. J. Agric. Res.*, vol. 10, pp. 66–72, 2014.

[49] D. P. Teteh, “Phytochemical screening and antioxidant properties of Moringa oleifera,” *Ghana J. Sci.*, vol. 47, pp. 45–52, 2013.

[50] F. B. Yameogo et al., “Chemical composition of Moringa oleifera,” *Pak. J. Nutr.*, vol. 10, no. 3, pp. 264–268, 2011.

[51] F. Anwar and R. Rashid, “Physico-chemical characteristics of Moringa seed oil,” *J. Am. Oil Chem. Soc.*, vol. 85, no. 5, pp. 453–460, 2008.

[52] H. P. S. Makkar and K. Becker, “Nutritional value and antinutritional factors in Moringa oleifera leaves,” *Anim. Feed Sci. Technol.*, vol. 63, pp. 211–228, 1996.

[53] A. Pandey and D. Mishra, “Flavonoid content in Moringa oleifera,” *J. Ethnopharmacol.*, vol. 30, pp. 181–185, 2002.

[54] S. Saxena and A. Rathore, “Antimicrobial efficacy of Moringa extracts,” *Phytother. Res.*, vol. 17, pp. 1022–1024, 2003.

[55] B. Gidwani et al., “Antidiabetic potential of Moringa oleifera,” *Pharmacogn. Rev.*, vol. 4, pp. 157–160, 2010.

[56] S. Karuna and R. Vijay, “Therapeutic phytochemicals in Moringa,” *Int. J. Herb. Med.*, vol. 2, no. 4, pp. 29–35, 2014.