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Chemistry and Significance of Moringa oleifera, a Miracle Tree- A Review

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All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

Abstract

A cost-effective option for nutrition and illness prevention is Moringa oleifera. Recent clinical investigations support the advantages of this fast-growing tree, which has been traditionally commended for treating over 300 medical ailments. It is also well-known for its pharmacological and agricultural uses. Though lack of knowledge prevents ideal growing, moringa products–particularly seeds and leaf powders–are highly sought after worldwide. Clinical research supports its beneficial effects on immunological function, bio-toxicity, and nutritional absorption, providing treatments for a range of illnesses. Promoting the growth of moringa in developing nations opens up economic opportunities, lessens reliance on food aid, and generates foreign cash through exports. As a "Miracle" plant, moringa is a priceless gift from nature that offers a host of advantages at a minimal cost.

KEYWORDS

Moringa oleifera; Miracle tree; Medicinal value; Phytochemicals; Economic opportunities

INTRODUCTION

The genuine diploid tree Moringa oleifera, which has 28 chromosomes (2n=28) according to Gharsallah et al., (2023), is commonly regarded as the "Miracle Tree" and the most widely grown tree of its kind. Its birthplace is in the north-eastern region of India, amid the foothills of the Himalayas. This remarkable superfood has been used for over two millennia; references to its use may be found in Indian Ayurvedic books from as early as 150 BC. According to Khalid et al., 2023, these historical manuscripts show the tree's amazing efficacy in treating over 300 medical ailments, including kidney stones, heart disorders, asthma, and TB. Advancing to contemporary times, the remarkable healing properties of Moringa have been scientifically substantiated. A comprehensive study conducted by John Hopkins University confirmed Moringa's ability to alleviate over 300 different disease conditions (Hamza et al., 2005). Prominent among the family Moringaceae and the order Brassicales, Moringa oleifera is known for several noteworthy traits, the most important of which are its remarkable drought resilience and remarkable pace of development. This botanical wonder distinguishes itself as a robust and adaptable species within the plant world by its capacity to grow and survive even in a dry environment (Fahey et al., 2005).

According to Fahey et al., (2005), moringa has garnered interest. from all around the world because of its many uses, which include medical applications, dietary supplements, industrial applications, and water purifying qualities. As highlighted by Lamidi et al. in 2017, nearly every component of the human nourishment is made from the moringa tree., animal feed, and, most importantly, for its remarkable therapeutic benefits. According to Jongrungruangchok et al. (2010), this deliberate moringa tree planting is practiced in several developing nations, including South Africa, to improve food and nutritional security among economically disadvantaged households. According to Kumssa et al. (2017), the dried nutritious leaf powder made from moringa is used as a meal fortifier. This is especially important during dry seasons when the availability of green leafy vegetables is restricted. Moreover, studies on the use of moringa in the treatment of Diabetes like Type 1 and Type 2 have shown promise. It is known that even at greater doses, moringa powder intake is safe in the case of insufficient production of insulin is a hallmark of Type 1 diabetes. Moringa leaves are rich in nutrients and serve as a non-dairy source of calcium, boosting energy levels and alleviating tiredness and fatigue. The high iron content in moringa leaves helps reduce weakness and drowsiness. Furthermore, moringa leaves are packed with immune-boosting phytonutrients that strengthen the immune system and aid in fighting off infections. The combination of vitamins A, C, and iron in moringa supports a healthy and active immune system. Chlorogenic acid, a pigment present in moringa, helps stabilize blood sugar levels after meals, combats inflammation, promotes heart health, and provides benefits for digestive disorders, among other health advantages (Lamidi et al., 2017).

VERNACULAR NAMES

The adaptable plant moringa goes by many names, which reflects the diversity of its languages and cultures. In English, it's known as the Ben tree, the Drumstick tree, or the Horseradish tree. Saguna or Sainjana is the Hindi name for it, whereas Subhanjana is the Sanskrit term. It is called Sojne Danta in Bengali, among other local names. Moreover, Moringa is important in the conventional Ayurvedic system under several names such as Haritashaaka, Tikshnagandhaa, Raktaka, and

Akshiva. This variety of names highlights how well-known the plant is and how many distinct ways it is used in many cultures and medical traditions.

CULTIVATION AND PRODUCTION

Most moringa tree farming takes place in semiarid, tropical, and subtropical climates, which are often found in USDA hardiness zones 9 and 10. Although the moringa tree can grow in a wide variety of soil types, its ideal pH range is between 4.5 to 8.0. It does, however, prefer neutral to slightly acidic circumstances. Well-drained, sandy, or loamy soil is very favorable for its development; nevertheless, waterlogged soil should be avoided since the roots might rot. Strong affinities for warm, sunny climates are shown by moringa, which grows best in settings with plenty of warmth and sunshine. MP et al.'s research from 2021 shows that moringa is not resistant to frost or very low temperatures, despite its flexibility.

The cultivation of Moringa oleifera involves two primary methods of development, sowing and cutting. In regions like India, Indonesia, and certain parts of West Africa, vegetative propagation is commonly employed, while in Sudan, traditional practices favor the use of seeds. The process of germination for moringa seeds usually takes two weeks, during which they can swell up to a maximum depth of 2 cm. A critical stage in nursery planting is when the seedlings are ready for transplantation, which usually happens three to six weeks after germination, and they have grown to a height of around thirty centimeters. The number of seeds per kilogram varies, from 3000 to 9000, depending on the Moringa type, and the germination percentage consistently ranges from 80-90%. For moringa seeds to remain viable, ideal storage conditions must be maintained. This entails maintaining a steady 3°C temperature as well as a balanced moisture content of 5% to 7%. Seed viability may suffer if these suggested storage criteria are not followed. For example, the germination rate noticeably decreases when exposed to high relative humidity and ambient temperature. According to a 2015 research by Leone et al., the germination rate can drop to as low as 7% in such unfavorable circumstances after only three months of storage. These results highlight how crucial careful storage methods are to preserving the life of Moringa seeds for productive growing.

When planting hardwood cuttings which are usually taken from mature trees during the rainy season and have a diameter of 4 to 16 centimeters burying about three-quarters of the soil-cutting promotes the growth of roots, which take several months to reach a significant size. This tree grows rather quickly; in just three months, it reaches a height of three meters. In a few years, it will naturally reach a height of ten or twelve meters. Remarkably, the tree exhibits tremendous regeneration, taking on a bushy form and actively resprouting following cutting or trimming. This trait adds to its reputation as a robust and quickly spreading species by making it especially resilient and adaptive. (Ramachandran et al., 1980).

A low-density plantation is advised to maximize seed production since it improves yields. These plantations usually have dimensions of 2.5 x 2.5 meters or 3 × 3 meters and are organized in a triangle configuration. It is estimated that each pod has around 26 seeds, each of which has a diameter of about 1 cm. On the outside of the pod, three pale, papery leaflets encircle these seeds. Remarkably, a single tree may yield an astounding number of seeds between 15,000 and 25,000 each weighing an average of 0.3 grams. Certain Moringa cultivars blossom early and produce pods in as

little as six months. Some types, meanwhile, can need more than a year to get to this point of seed output. It's also important to remember that branches may produce new pods within six months of pruning, which supports a continual and sustainable cycle of seed production. The adaptability and productivity of Moringa plantations are improved by the timeliness of blooming and seed production being flexible (Leone et al., 2015).

NUTRITIVE PROPERTIES

An absolute goldmine of vital nutrients and antinutrients may be found in every section of the Moringa oleifera plant. Among these, M. oleifera leaves are particularly plentiful in important minerals (calcium, potassium, zinc, magnesium, iron, and copper), as Kasolo et al. (2010) have thoroughly demonstrated. The whole range of nutrients found in Moringa oleifera includes several vitamins, including beta-carotene (which is a precursor to vitamin A), a variety of B vitamins, including pyridoxine, folic acid, and nicotinic acid, as well as vitamins C, D, and E (Mbikay et al of 2012). Because of its extensive botanical variety, Moringa oleifera is a potent supporter of dietary diversification and nutritional well-being. Its wide range of vitamins and minerals not only increases dietary intake but may also provide health advantages. Including Moringa oleifera in diets becomes a comprehensive way to use its nutritious potential for general health and wellness. A wide range of phytochemicals, including tannins, sterols, terpenoids, flavonoids, saponins, anthraquinones, alkaloids, and reducing sugar, are abundant in Moringa oleifera. Furthermore, as the 2013 study by Berkovich et al. pointed out, it has anti-cancerous substances such as glucosinolates, isothiocyanates, glycoside compounds, and glycerol-1-9-octadecanoate. Because of their low-calorie content, moringa leaves are a good addition to any diet for those who are struggling with obesity. According to a 2008 study by Owusu et al., the fibrous pods of the moringa plant have beneficial qualities for treating digestive problems and may even be able to prevent colon cancer. According to studies, immature pods have a protein level of about 20.66% and a fiber content of about 46.78%. Moreover, the amino acid content of the pods is 30%, the leaves are 44%, and the flowers are 31%. Remarkably, Sánchez et al., (2010) found that the concentrations of palmitic, linolenic, linoleic, and oleic acids in immature pods and flowers are comparable. The diverse composition highlights the nutritional value and possible health advantages linked to different sections of the Moringa oleifera plant.

Moringa is rich in key elements that are important for development and growth, especially calcium, which is important for human growth. For example, if you compare 8 ounces of milk to 1000 mg of calcium found in moringa leaves, you would find that moringa powder has more than 4000 mg (Azlan et al., 2023). Moringa powder presents a beneficial option for treating anemia and may be used in place of iron pills. Interestingly, moringa leaf powder has a large 28 mg of iron, while beef only has 2 mg (Marrufo et al., 2013). According to studies, moringa has a higher iron content than spinach (Fuglie et al., 2005). Sustaining a sufficient amount of zinc in the diet is essential for both the healthy development of sperm cells and the production of DNA and RNA. Moringa oleifera leaves meet the daily requirement for zinc in the diet by containing about 25.5–31.03 mg of zinc per kilogram (Barminas et al., 1998).

Linoleic acid, linolenic acid, and oleic acid are examples of polyunsaturated fatty acids (PUFAs) that help regulate cholesterol levels. According to studies, moringa seed oil has about 76% PUFAs, making it a better option than olive oil (Lalas et al., 2002). Notably, the nutritional composition of moringa varies according to geography. Studies reveal that iron and vitamin C are more common in the cool-dry season, although vitamin A is more plentiful in the hot-wet one (Yang et al., 2006). The significant influence of location, climate, and environmental variables on the nutritional content of the Moringa tree accounts for these discrepancies in results (Moyo et al., 2011).

ECONOMIC SIGNIFICANCE AND EXPORT POTENTIALITY

India holds the distinction of being the largest producer of Moringa oleifera, commonly known as drumstick. Every part of the plant possesses remarkable medicinal and nutritional properties. India fulfills over 80% of the global demand for moringa products, making it the largest contributor to production at 41%. Western Africa follows at 33%, with Malesia and the Philippines at 12%, China at 8%, and Venezuela contributing about 6% (Peddi et al., 2018). With a growth rate of 26-30%, the export of moringa leaves is a significant industry in Tamil Nadu, Andhra Pradesh, Karnataka, and Odisha. Important importers of moringa leaves include the USA, Germany, China, Canada, and other European nations (Azlan et al., 2023). Farmers may receive a benefit of 2.99 rupees for every rupee they spend, according to the benefit-cost ratio chart. Drumstick is therefore considered economically advantageous due to its cheap investment cost and quick returns within the same year (Zirmire et al., 2018). In 2015, India exported 14.6 crore worth of moringa leaves, compared to 11.61 crore in 2014. In January and February of this year, the export value was 2.5 crore. The export market is increasing at a rate of 30% or more, especially with the growth of its value-added products. The application of moringa leaves in nutraceutical, pharmaceutical, and cosmetic industries contributes to the increasing value of these leaves year by year.

Indian in origin, moringa trees are currently grown in Ghana, the Philippines, Nigeria, Kenya, Rwanda, Cambodia, Niger, Mozambique, and Haiti, among other nations. With an annual growth rate of 9%, the projected value of the worldwide market is currently 27,000 crores. At the moment, private organizations are receiving assistance from the Agricultural and Processed Food Products Export Development Authority (APEDA) to set up the required infrastructure. APEDA-registered exporter from Telangana intends to send about 40 metric tonnes of powdered moringa leaf to the United States (Alavilli et al., 2022).

CHEMICAL COMPOSITIONS

Leaf Oil

When hydrodistillation is used on Moringa oleifera leaves, a unique light-yellow oil is produced that has 29 different components and is distinguished by a wide range of chemicals. It should be noted that the main ingredients in the essential oil that is extracted using the Soxhlet method are nonacosane (18.6%), 1,2,4-trimethylbenzene (16.9%), and heptocosane (7.4%). Interestingly, Marrufo et al. (2013) report that the same main constituents, including nonacosane, heptocosane, and pentacosane, are also extracted using Supercritical Fluid Extraction. Whichever technique of extraction is used, the fatty acid makeup of the oil stays very much the same. One research found that oil extracted by solvent extraction had somewhat lower levels of stearic and myristic acid than oil

extracted by cold press. The seed oil is defined as having a high oleic content and a significant ratio of monounsaturated to saturated fatty acids. Notably, the seeds' restricted amount of polyunsaturated fatty acids increases their stability and resistance to oxygen. These observations are based on research done in 2019 by Alberto et al.

Root Powder Solution

Analysis of the roots of Moringa plants has demonstrated a significant concentration of dissolved chemical components, which offers information on the variety of micronutrients that the plant contains. Different micronutrients showed significant concentrations when dissolved in water; in decreasing order, potassium, phosphorus, sulfur, magnesium, sodium, and calcium emerged as the most common elements. Furthermore. After a thorough examination, it was discovered that moringa roots included a variety of components outside of the widely known micronutrients. These elements are lead, antimony, uranium, vanadium, tin, aluminum, arsenic, boron, cadmium, mercury, cobalt, chromium, molybdenum, nickel, and selenium. Interestingly, Nweze et al. (2014) found that these components were noticeably missing from water that had been treated with moringa. This data highlights the intricate molecular makeup of moringa roots and highlights the plant's potential utility in nutrient-rich applications.

USES OF Moringa oleifera

Among the many nutritional advantages of Moringa oleifera, it is particularly noteworthy. As Kasolo et al. (2010) thoroughly documented, the leaves of M. oleifera are especially notable for their rich mineral content, which includes calcium, potassium, zinc, iron, and copper. Apart from minerals, these leaves are a rich source of several vitamins, which include beta-carotene (Vitamin A), different types of B vitamins, and significant levels of C, D, and E. Moringa leaves specifically include folic acid, pyridoxine, and nicotinic acid under the category of Vitamin B (Mbikay et al., 2012). Furthermore, a wide range of phytochemicals, such as sterols, terpenoids, flavonoids, tannins, saponins, anthraquinones, alkaloids, and reducing sugars, are abundant in moringa leaves. Compounds with the ability to prevent cancer, such as glycosides, glucosinolates, isothiocyanates, and glycerol-1-9-octadecenoate, have been found. This was clarified by Berkovich et al. in 2013. This thorough nutritional profile highlights the many health advantages that Moringa oleifera provides, indicating that it is a great supplement to a diet rich in nutrients and well-balanced. In contemporary dietary recommendations, nutritionists endorse the inclusion of Moringa leaves due to their low caloric content. The fibrous nature of Moringa pods renders them valuable for addressing digestive issues. Additionally, they are recognized for their potential in treating and preventing colon cancer, as indicated by Owusu et al in 2008.

Pharmaceutical Applications

According to Mughal et al. (1999), moringa oleifera has been known for its remarkable medical qualities for a very long time. These systems include Ayurveda and Unani. Indigenous medicine has used several components of the Moringa plant, including the roots, leaves, bark, gum, fruits or pods, flowers, seeds, and seed oil, because of their varied nutritional and therapeutic properties (Akinyeye et al., 2014). These ancient custom highlights the diverse range of medicinal benefits that the plant's constituent parts provide, adding to the plant's respected standing in conventional medicine.

Antimicrobial & Anthelmintic Effects

The detection of moringa's inhibitory effects on a variety of bacteria has proven its antimicrobial characteristics. According to recent studies, when taken at a regular dose, the aqueous extract of moringa efficiently inhibits the pathogenic activities of bacteria, including Staphylococcus aureus, Bacillus subtilis, Escherichia coli, and Pseudomonas aeruginosa (Saadabi et al., 2011). Moreover, Nwosu and Okafor (1995) observed that the leaf extract of moringa has shown effectiveness against fungus, especially in preventing the development of Basidiobolus haptosporus and Basidiobolus tantrums. In addition, green algae, E. Coli, Herpes Simplex virus type 1 (HSV 1), and Poliovirus type 1 (Sabin vaccine) are among the microorganisms against which the aqueous methanolic extract and fixed oil of moringa have antibacterial activities. These results highlight moringa's broad-spectrum antibacterial capabilities and demonstrate how powerful it is against viruses, fungi, and bacteria. It is well known that Moringa oleifera has antifungal properties, especially when it comes to inhibiting Aspergillus niger. Significant research on Aspergillus oryzae, Aspergillus terreus, and Aspergillus nidulans has been done by Kekuda et al. (2010). Pterygospermin, a substance found in moringa, has been shown to have strong antifungal and antibacterial effects. Rao et al. (1946) clarified this. Spirochin and Anthonine, which are found in the roots of the Moringa plant, are highly efficient against a variety of bacteria. Nwosu and Okafor (1995) revealed that anthonine had strong inhibitory effects against Vibrio cholerae. These results highlight Moringa's broad range of antimicrobial potential, which includes both antifungal and antibacterial qualities.

Anti-Diabetic Properties

Empirical data indicates that moringa may have potential benefits for managing Type 1 and Type 2 diabetes. People with Type 1 diabetes struggle to produce enough insulin, a hormone that is essential for controlling normal blood glucose levels. On the other hand, insulin resistance, which often results from beta cell malfunction, is a hallmark of Type 2 diabetes. This condition impairs the body's ability to correctly sense glucose levels and raises blood glucose levels (Lestari et al., 2022). Research has shown that moringa oleifera can effectively cure insulin-resistant Type 2 diabetes as well as Type 1 diabetes produced by streptozotocin. In one study, moringa seed powder was given to rats who had been given STZ-induced diabetes, which caused their blood glucose levels to drop quickly. Moreover, serum antioxidant enzyme levels increased in rats given 500 mg of moringa seed powder per kilogram of body weight. This implies that, as shown in the study by Mbikay et al. (2012), the antioxidants found in moringa may help minimize reactive oxygen species (ROS) generated in beta-cells owing to STZ induction.

Anticancer Properties

Cancer is a common illness, and inadequate treatment is thought to be the cause of one in seven fatalities. It will be the primary cause of death worldwide in 2020, with around 10 million fatalities attributed to it. Factors including alcohol use, radiation exposure, tobacco use, high body mass index, inadequate intake of fruits and vegetables, and inactivity can be linked to around one-third of cancer-related fatalities. The World Health Organisation (WHO, 2020) reports that colon, rectal, lung, breast, and prostate cancers are the most common malignancies. Because of its safe, dependable, and natural qualities, moringa oleifera shows great promise as an anticancer agent. According to studies, moringa efficiently inhibits the proliferation of cancer cells by acting as an anti-

neoproliferative agent (Tiloke et al., 2013). Its capacity to produce reactive oxygen species in cancer cells is thought to be the cause of its anti-proliferative effects on the disease. Cells undergo apoptosis in response to reactive oxygen species increase; this process is further reinforced by the overexpression of caspase 3 and caspase 9, which are essential elements of the apoptotic pathway (Tanga et al., 2022).

Properties of Antioxidant

Naturally occurring substances, especially polyphenols, are essential in lowering oxidative tissue damage. As shown by Pamok et al. in 2012, this is accomplished by either scavenging free radicals or indirectly enhancing cellular activity. The abundance of polyphenols and antioxidants found in the moringa tree has been acknowledged in research by Sreelatha and Padma (2009) and Verma et al. (2009).

In research, higher concentrations of enzymatic and non-enzymatic antioxidants were found in extracts taken from both mature and young Moringa oleifera leaves. According to Sreelatha and Padma's 2009 report, the mature and tender leaves showed a considerable decrease in DPPH (2,2-diphenyl-1-picrylhydrazyl) radicals in the DPPH free radical test. Additionally, a thin-layer chromatography (TLC) examination revealed the presence of several substances. The extract's remarkable antioxidant qualities were highlighted by a qualitative examination that found many components in both mature and young leaves, including phenolics, flavonoids, and trace levels of alkaloids (Siddhuraju and Becker, 2003).

Anti-tumour Properties

According to a study, moringa possesses a bioactive substance called niazimicin that inhibits the growth of tumors in mice in stages two and three. Several test compounds showed substantial anti-tumor-promoting characteristics in the in vitro screening findings, particularly 4-(α-4-L- rhamnosyloxy) benzyl isothiocyanate, niazimicin, and β-sitosterol-3-O-β-D-glucopyranoside. In vivo, niazimicin demonstrated a 50% delay in the promotion of tumors, as reported by Guillén et al., in 1999.

Anti-Inflammatory Properties

The plant Moringa possesses significant anti-inflammatory qualities, which are especially apparent in the n-butanol extract that is extracted from its seeds. According to Mahajan et al.'s 2009 report, its anti-inflammatory effect was evaluated about ovalbumin-induced airway inflammation in guinea pigs. According to Muangnoi et al. (2011), the anti-inflammatory properties of bioactive chemicals derived from moringa, such as isoleucine, leucine, lysine, methionine, phenylalanine, tryptophan, and valine, suggest that inflammation-related chronic illnesses may be lessened.

Anti-Asthmatic Properties

Historically, the alkaloid found in the moringa plant, known as moringine, was noted to have actions similar to ephedrine and was considered for the treatment of asthma. According to Panchal et al. (2011), this alkaloid can relax bronchioles. Furthermore, the seed kernels of the moringa plant have demonstrated encouraging outcomes in the management of bronchial asthma, as indicated by Agarwal and Mehta (2008).

Moringa Oleifera Skin Care Benefits

In contemporary times, the desire for an attractive appearance is prevalent, leading many to explore various cosmetics and chemical products. Moringa is recognized for its potential to address skin issues and promote flawless and perfect skin. Moringa leaves, containing 30 different antioxidants, play

a role in eliminating unwanted toxins from the body. The sulfur present in moringa leaves is rich in collagen, aiding in skin health. Additionally, moringa leaves are employed by beauticians as a skin toner, and the paste is used as a scrub for exfoliation, contributing to a glowing and radiant face, as noted by Widiastini et al. (2021).

The Uses of Moringa Oleifera in Nutraceuticals

With a wealth of more than 90 vitamins and minerals, moringa oleifera is a nutritional powerhouse. This broad spectrum includes vitamins A through K as well as 46 potent antioxidants, 36 anti-inflammatory substances, and important fatty acids (omega 3, 6, and 9). This remarkable plant exhibits impressive energy-boosting capabilities, providing 420 kJ of energy with just 100 grams of leaves and 100 grams of pods. Moringa is also rich in carbohydrates, with more than 8.28% in 100 grams of leaves and 8.53% in 100 grams of pods. Additionally, both moringa pods and leaves contain dietary fiber, with 3.2% and 2%, respectively, in every 100 grams. Moringa leaves surpass average daily protein requirements, with an astonishing 9.8% protein content in 100 grams. Moringa seeds and fresh pods also contain a significant amount of oleic acid.

In terms of vitamins, moringa leaves encompass a comprehensive range, providing substantial amounts of Vitamin A (7564 IU or 252% of daily intake in 100 grams), Vitamin C (86% in 100 grams of leaves and 235% in 100 grams of pods), and moringa oleifera is also a rich source of several B-complex vitamins, such as riboflavin, thiamine, folate, pantothenic acid, niacin, and pyridoxine. It is also a good source of zinc, iron, selenium, phosphorus, sodium, magnesium, calcium, and copper, among other important minerals. According to Viotti et al. (2019), these minerals are essential for boosting several areas of health, including skin health and hair development.

AGRICULTURAL USES

Plant Pathogenic Properties

Because of their strong fungicidal properties, the roots, pods, and leaves of the moringa plant are used as a biological fungicide in addition to being mostly used as fodder. Applying varying quantities of Moringa oleifera root extract was shown to significantly reduce pathogenic plant fungi's linear growth, spore or sclerotia germination, and dry weight of mycelia. In particular, the root extract prevents fungi such as F. oxysporum, F. solani, A. solani, and A. alternata from growing linearly. Moreover, at a 25% concentration, fungi like R. solani, S. rolfsii, and M. phaseolina show notable growth reductions of 94.2%, 90.0%, and 87.4%, respectively (Raid et al., 2014). Likewise, tests on harmful plant fungi have demonstrated that different doses of moringa leaf extract can reduce the pathogens' dry mycelia weight, spore or sclerotia germination, and linear development. Moringa leaf extract specifically reduces the linear growth of A. solani, A. alternata, R. solani, S. rolfsii, and M. phaseolina and inhibits the growth of F. oxysporum and F. solani at a 50% concentration. Moreover, all fungal mycelia development is gradually inhibited by the extract from moringa pod covers (Abdalla et al., 2014).

In addition, the extract made from 80% ethanol-soaked moringa leaves contains elements that promote growth, including hormones of the cytokinin type. According to Makkar & Becker's 1996 study, this extract can be used as a foliar spray to promote plant development, ward off illnesses, and simultaneously ward off insect infestations.

Agro-Industrial Uses

Because the leaves of Moringa oleifera may produce more nodules and root weight, their ethanolic and aqueous extracts are used as biofertilizers. According to Howladar et al. (2014), this impact is explained by the presence of plant hormones such as zeatin and gibberellin. Furthermore, the moringa seed oil is used in cosmetics as an emollient, conditioner, and moisturizer for the skin. According to Aney et al. (2009), it is a component of many skincare products, including soaps, salves, lotions, and sunscreens. Additionally, moringa seed oil serves as a food fortifying and preservative, as highlighted by Bijina et al. (2011).

According to Sharma et al. (2009), moringa seed oil is thought to have a high viscosity index, low-temperature characteristics, and lubricity, making it a viable source of biodiesel for automobiles. Moringa leaves and stems possess fodder potential and can grow easily with minimal water requirements, particularly in dry seasons (Nouman et al., 2014). These plant parts contain approximately 23% and 9% protein with digestibility rates of 79% and 57%, respectively (Velázquez et al., 2016). Supplying moringa to ruminants enhances milk productivity, as noted by Mahmood et al. in 2010. In poultry, it improves growth, food digestion, and egg production, and in rabbit diets, moringa leaves contribute to weight gain (Abbas et al., 2013). For growing pigs, it has been found to improve digestibility from 50% to 65.8% (Garcia & Macias, 2014).

Water purification

Moringa seeds serve as coagulants and possess antimicrobial properties. The seeds and their proteins are water-soluble, and the paste derived from moringa seeds contains positively charged ions. Contaminants with negative charges, such as silt and clay, are drawn to substances with positive charges and bond to each other, settling to the bottom. Additionally, some bacteria bind with the positive ions of moringa. When particles aggregate and settle, the rate at which unwanted microorganisms thrive in water is reduced. Generally, one seed kernel is sufficient to purify one liter of water, as mentioned by Widiastini et al. (2021). About 30 - 42% of moringa seeds are oil, and the high-protein press cakes act as a naturally occurring, non-toxic polypeptide to help settle organic matter and mineral particles during the purification process. According to research done in 2001 by Foidl et al., this protein is also useful for cleansing vegetable oil and helping fibers settle in the juice and beverage sectors.

The ability of moringa to clot plant seeds is strong and capable of removing turbidity and heavy metals from water. Studies indicate that moringa seeds exhibit effective pesticide removal activity. In a research study, different doses of Profenofos 500 EC pesticide were applied to pesticide-free potato piles, and a submersion in moringa seed solution proved to be the most effective method, removing 52.9% of Profenofos. This was followed by the vegetable bath method, which removed 47.3%. Neither method altered the taste of food, but the moringa seed method was significantly more cost-effective than other treatments, as highlighted by Mondal et al. (2019).

ESTIMATION OF PHYTOCHEMICALS IN Moringa oleifera

Analysis By GC/MS

Gas Chromatography-Mass Spectrometry (GC/MS) was used to identify the phytocomponents in the aqueous extract of moringa leaves, as shown in Figure 2. The investigation turned up 25 peaks that represented different biomolecules. Prominent ingredients with high peak percentages are butyl 2-pentyl ester, 2-isopropoxyethyl propionate, 4 H-Pyran-4-one, 1,3-Dioxolan-2-one, 4,5-dimethyl, and carbonic acid. Furthermore, substances with appropriate percentages of peak area were found, including butanedioic acid, 2-hydroxy-2-methyl, Azetidin-2-one 3,3-dimethyl4-(1-aminoethyl), 1,3-Dihydroxyacetone dimer, and beta-D-glucose. It is noteworthy that extracts from the moringa plant seldom contain 2-hydroxy-2-methyl butanedioic acid (2-hydroxy-2-methyl), as noted by Igwe et al. in 2015.

Optimization of UPLC & MS Condition

The solution's charged analytes exhibit enhanced detection sensitivity when employing the Electrospray Ionization (ESI) mode, as depicted in Figure 3. Due to the numerous hydroxyl groups in phenols, they tend to generate charged entities. To optimize sensitivity, both the negative (ESI-) and the positive (ESI+) ionization modes were used. Consequently, the signal associated with the most substantial product was identified as the quantifier (Yang et al., 2020).

During the UPLC-DAD analysis of moringa essential oil, Figure 4 reveals the presence of two main peaks. These peaks correspond to luteolin, identified based on elution times. While important antioxidant components of Moringa oleifera including kaempferol, crypto-chlorogenic acid, isoquercetin, and astragalin are conspicuously lacking in this investigation, quercetin is present in the hydro-alcoholic extract. It is uncommon for essential oils to contain polyphenols, but their presence is neither frequent nor exceptional (Marrufo et al., 2013).

Isolation of Volatile Oil

After being pulverized in a blender to produce 100 grams of dry sample leaves, the leaves were hydro-distilated for three hours. After that, the extracted oil was dissolved in n-hexane, dried over anhydrous sodium sulphate, and kept under nitrogen in a dark, temperature-controlled environment until the testing and analysis day. According to Mohamed et al. (2021), the oil extracted from the dry material had a yellow hue.

CONCLUSION

The Moringa oleifera plant is a noteworthy substitute that is both economical and dependable for treating and preventing various illnesses in addition to offering vital nourishment. In India, growing Moringa trees is an affordable and accessible hobby. The study concludes that Moringa oleifera exhibits pharmaceutical, nutraceutical, plant pathogenic, water purification, and livestock-promoting properties. However, the full range of its benefits remains largely unknown to farmers, and cultivation practices may not be optimal. Moringa leaves, abundant in nutrients and serving as a non-dairy source of calcium, contribute to increased energy levels and relief from fatigue. Their richness in iron helps combat weakness and drowsiness. Additionally, the leaves are packed with immune-boosting phytonutrients, strengthening the body's defenses against infections. The oils from Moringa seeds and leaf powders are in high demand, being sold both online and offline, often at premium prices.

In agriculture, Moringa is employed for its bioactive compounds, acting as an antifungal and antibacterial agent. Farmers cultivating Moringa for export find lucrative returns, with some reporting selling prices three times higher than cultivation costs. This has translated into substantial profits for private companies dealing in Moringa seeds, leaf powder, kernels, pods, and value-added products, contributing to significant revenue generation.

Clinical studies involving humans have demonstrated that Moringa exhibits positive effects on nutrient bioavailability and bio-toxicity. It has been shown that moringa strengthens the immune system, helping the body fight against conditions including HIV/AIDS, AIDS-related illnesses, TB, diabetes, hypertension, and high blood pressure. Moreover, the antioxidant qualities of moringa aid in the fight against illnesses including cancer, Alzheimer's disease, and heart disease. There is a compelling case for poor countries to actively promote the cultivation and utilization of Moringa rather than relying solely on food aid from wealthier nations. The widespread adoption of Moringa could not only address nutritional needs but also create opportunities for earning foreign exchange through exports. This stands in contrast to the expenditure of foreign exchange on imports. Moringa emerges as a truly "miraculous" plant, offering numerous benefits to humanity at an exceptionally low cost, and it should be recognized as a valuable gift from nature.

Information on the quality control of chemical pollutants is conspicuously lacking, such as pesticides, and biological contaminants for both domestic use and the export of Moringa products to foreign countries. Consequently, there is an opportunity for further development of analytical methods specifically focused on chemical contaminants like metals and pesticide residues.

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