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REVIEW ARTICLE

Archaeobotanical Elucidation of *Moringa oleifera*: It's Biological, Ethnopharmacological and Phytochemical Activities

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Abstract

Moringa oleifera (family Moringaceae) was originally first found in India now it has been cultivated in various regions of the world. The architecture of a plant is an endogenous morphological growth pattern through which the plant develops its shape. Analysing plant architecture is important for the understanding of plant growth, and branching patterns. A high source of natural phytochemical compounds is present in *Moringa*, and plant parts have high nutritional value. *Moringa* is used in animal feeding systems to fight malnutrition in India and Africa. The potency of *Moringa* is evaluated for its effectiveness on rats and humans, among other animals. It is a safe, affordable, and effective pharmacological and dietary option. *M. oleifera* is a fantastic food crop with clear economic, medicinal, and nutritional advantages. *Moringa* contains Alkaloids, vincristine, vinblastine, kaempferitrin, isoquercitrin, kaempherol, polyphenols and flavonoids that may be present in *Moringa*. *Moringa* leaves contain vitamin C and beta-carotene which act against free radicals. Quercetin acts as an antioxidant property and chlorogenic acid, polyphenol act as an antioxidant and anticancer activity. The presence of 4-L-rhamnosyloxybenzyl isothiocyanate is responsible for showing the antibacterial activity of the root. *Moringa* is used as a superfood supplement and has immune booster properties. Ethnopharmacological activity of *Moringa* includes antibacterial, anti-inflammatory, antioxidant, antidiabetic, analgesic, chronic periodontitis, antipyretic, cardio protecting, anti-asthmatic, antispasmodic, promoting breast milk production, biogas production and water filtration properties. Numerous studies have shown that it can control physiological processes, as well as both prevent and treat illnesses. Nowadays researchers developed *Moringa oleifera* leaf nanoparticles that show antidiabetic and antiproliferative activity against human cancer lines and others. In clinical or human studies, lower doses of *Moringa* were not associated with any negative effects or toxicities.

Keywords: Architecture of Plant, Biogas Production, Ethnopharmacology, Phytochemical Compounds, Superfood Supplement

1. Introduction

A plant, *Moringa* originally first found in India. It's a drought-resistant, fast-growing perennial that adapts well to a variety of environments and farming systems. In the Moringaceae family, it is still thought to be neglected. *Moringa* have high nutritional value. It is also known as a magical tree. For a very long time, almost all tree parts are edible[1,2].

According to Fuglie, the *Moringa* tree is used for a variety of purposes, including the manufacture of biomass, animal food, biogas, products for home cleaning, consuming plans to combat starvation, especially in African countries, as blue dye, for constructing barriers, agricultural fertiliser, green waste, for collecting gum and honey juice, different medicines, floral plantations, as a biological insecticide

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for plant dampness off, rope making, and purifying water[3].

Almost all sections of the plant have exceptional medicinal and pharmacological capabilities. All of these characteristics make it a one-of-a-kind biomaterial for food and other applications. In the Indian subcontinent, numerous preparations of *Moringa* leaves, flowers, and fruits are utilised for a variety of uses. It is used to treat cardiovascular disease, diabetes, anticancer properties, anti-inflammatory effects, and immune-boosting effects[4].

Moringa oleifera has 12 different species. The etiology of *Moringa* is cylindrically shaped, leaves are tri-pinnate and have an open crown of delicate, drooping branches. They are formed in clusters of 10–25 cm in length on slender, hairy stems. Flowering occurs 6 months after planting. Flowering happens once in April and once in May in milder climates[5,6].

1.1 *Moringa* as a Superfood

Superfoods are foods that are high in nutrients and consequently beneficial to one's health. A superfood is high in vitamins, antioxidants, minerals, or other nutrients while being low in calories. Major health benefits are highlighted in Figure 1.

1.2 Some of the Advantages of *Moringa* Include

- High nutrients
- May reduce inflammation
- Positive effects on cholesterol
- Natural energy booster
- Rich in antioxidants
- May lower blood sugar levels
- May protect against arsenic toxicity

For all of these reasons, *Moringa* is also called a superfood.

Synonym: Sajna, Horseradish tree, Mulangay etc.

1.3 Worldwide Spread of *Moringa oleifera*

Arabia, Madagascar, Kenya, northeastern and southern Africa, and India are among the places where Moringa oleifera may be found[7]. since it was distributed in rural South African communities for growing in 2006. 0.75-hectare parcel of land is used by commercial farmers in the Limpopo region to sell *M. oleifera* leaves[8].

1.4 Processing of *Moringa*

Plants lose their nutritional value when they are treated. While fermented and germinated seed flour both have a high quantity of amino acids, raw *Moringa*

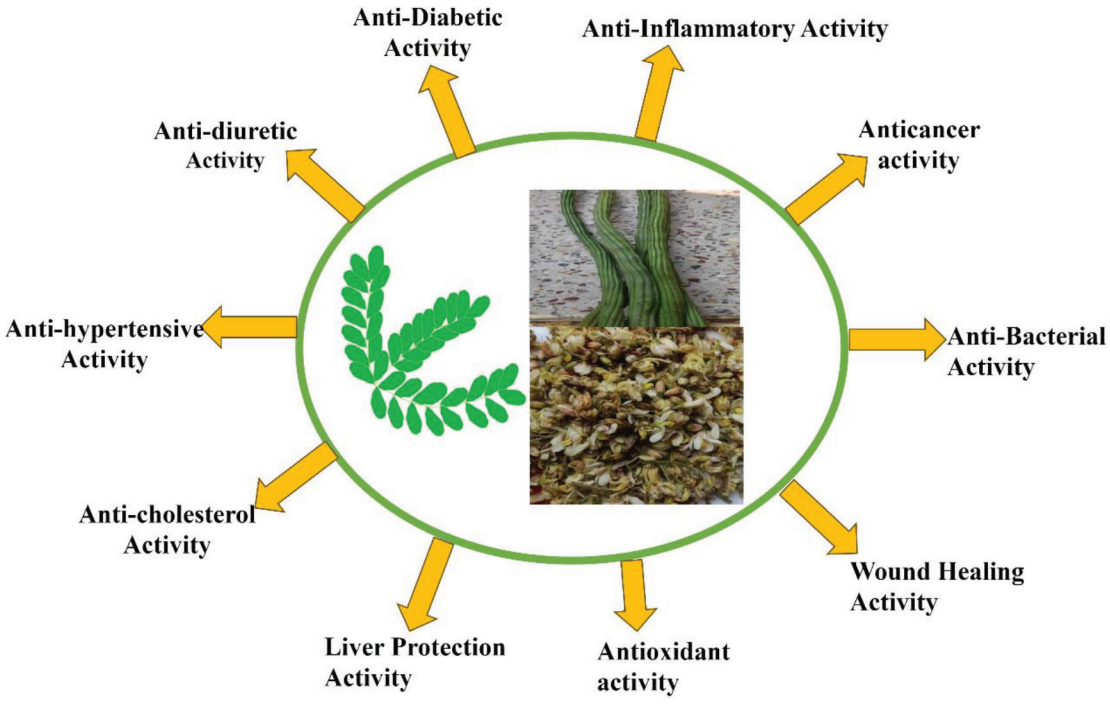

Figure 1. Ethnopharmacological activity of *Moringa oleifera*.

seed flour has a large amount of phytoconstituents[9]. This could be caused by biochemical and microbiological activity during germination and fermentation. Surprisingly, boiling was the most effective method, significantly reducing the amounts of phytate, oxalate, and cyanide in comparison to the other two[10].

1.5 Preservation Methods

Moringa retains its nutritious worth even after being preserved for a long time. The best way to conserve the leaves is by freezing or drying them. According to research by Yang *et al.*, freeze-drying loses more nutrients than dehydrating leaves in a low-temperature oven, with the exception of vitamin C. Iron overload might occur if *Moringa* intake is too high. High iron levels might result in hemochromatosis and digestive problems[11].

1.6 Phytochemicals

In *Moringa oleifera*, a variety of substances are present, including the simple sugar rhamnose and the particularly shaped glycosylates and isothiocyanates. Purified *M. oleifera* gum includes L-arabinose, galactose, glucuronic acid, L-rhamnose, mannose, and xylose[12]. Alkaloids, kaempferitrin, isoquercitrin, kaempherol and flavonoids may be present in *Moringa*[13]. The chemical structures of major phytochemicals present in the different parts of this plant are given in Figure 2.

2. General Treatment by *M. oleifera* in Medical Field

Moringa can be used to treat bacterial, fungal, viral, and parasite infections as well as conditions including thyroid disorders, headache, intestinal spasms, diarrhoea, anaemia, and arthritis[14]. In addition to promoting breast milk production, strengthening the immune system, and acting as an aphrodisiac, *Moringa* can help decrease oedema. Additionally, it can be utilised as a tonic or dietary supplement. *Moringa* is used in animal feeding systems to fight malnutrition in India and Africa. Following oil extraction, the residual seed cake is used as fertiliser, to filter well water, and to remove salt from saltwater.

2.1 Anti-hypertensive, Anti-diuretic and Anti-cholesterol Actions

M. oliefera is frequently used in the treatment of cardiovascular diseases. Juice made from *Moringa* leaves is thought to reduce blood pressure[15]. The bulk of these substances are quite rare in nature acetylated glycosides with thiocarbamate, carbamate, or nitrile groups[16]. Fractionation of the ethanol extract of *M. oleifera* pods, thiocarbamate and isothiocyanate glycosides with hypotensive effects may be isolated.

2.2 Anti-diabetic Properties

Both Type 1 and Type 2 diabetes can be reversed with *Moringa*. Diabetes has an element of insulin resistance[17]. The β cells of hyperglycaemic patients

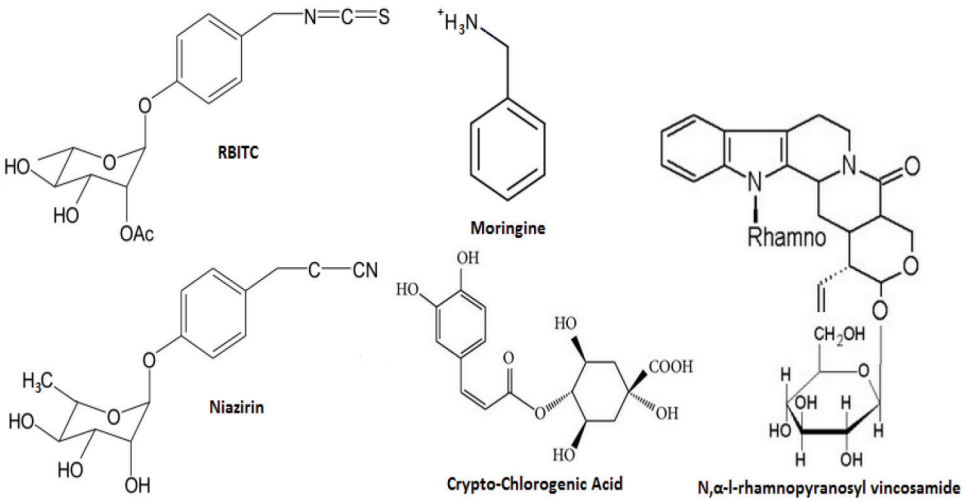

Figure 2. Shows chemical structures of a few important constituents of *Moringa*.

are destroyed. Reactive Oxygen Species (ROS) are discharged as a result of too much glucose entering the mitochondria[18]. Cells go through apoptosis because they lack antioxidants. Reduced insulin secretion causes hyperglycaemia and diabetes.

2.3 Anticancer Activity

M. oleifera can prevent cancer in specified doses since it is normal, efficient, and secure. This is facilitated by the overexpression of caspases 3 and 9, which are both components of the apoptotic cascade. *Moringa* is a perfect anticancer medication since its ROS creation is unique and targets cancer cells only[19].

2.4 Activities that Fight Against Germs and Fungus

It has been established that a comparable substance is in charge of giving its flowers their antibacterial and fungicidal characteristics[20]. The presence of 4-L-rhamnosyloxybenzyl isothiocyanate is responsible for showing the antibacterial activity of root[21].

2.5 Using *Moringa* Seeds as a Binding Agent

Crushed seeds are used as coagulants rather than artificial ones. High turbidity water benefits greatly from the coagulation properties of *Moringa* seeds, which are equivalent to those of alum[22]. In addition to being used to reduce alkalinity and soften surfaces, *Moringa* seeds may also be utilised to change pH levels. Additionally, it features a built-in buffering system that enables it to handle both surface and ground waters that range from slightly to strongly alkaline. Additionally, *Moringa* seeds can be utilised to disinfect drinking water[23].

High molecular weight polyelectrolytes are more likely to flocculate. A bridging effect is unlikely to reflect the coagulation process since the coagulant protein of *M. oleifera* is so small (6.5-13 kDa)[24].

2.6 Microbial Elimination with *Moringa* Seeds

Excellent antibacterial properties are offered by *Moringa* seeds. An in-seed recombinant protein, according to Broin *et al.*, can flocculate both Gram-positive and Gram-negative bacteria cells[25]. In this situation, microorganisms may be eliminated by settling like how colloids are recovered from water that has been adequately coagulated and flocculated. On the other side, the seeds may directly affect bacteria, which would restrict its growth. Antimicrobial peptides are intended to work by rupturing cell membranes or inhibiting vital enzymes. According to Sutherland *et al.*, *Moringa* seeds have been shown to inhibit the reproduction of bacteriophages[26].

2.7 Wound Healing Capability

Excision, incision, and dead space wound models were the three used to evaluate the effects of ethanolic and ethyl acetate leaf extracts on wound healing. These extracts include phytosterols and phenolic compounds that promote wound healing[27].

2.8 Liver Protection Action

It has been demonstrated that *Moringa* roots contain hepatoprotective qualities. Quercetin, a well-known hepatoprotective flavonoid, has been shown to have a considerable hepatoprotective effect[28]. Ethno pharmacological action of different parts of *M. oleifera* is listed in detail in Table 1.

2.9 Agriculture Uses

During the process of extracting oil from the seeds, a non-consumable seed cake containing toxic ingredients is produced. Other plants' saponins have an adverse effect on animal development, however, the saponins in *Moringa* have no haemolytic action[29].

2.10 Human Consumption

The tropical crop *Moringa* is one of the least utilised and undeveloped in the world. A special emphasis is given to leaves[30].

3. Potential Food Application of *Moringa oleifera* Leaves

Nutritionists and food experts advise growing, incorporating, and consuming *Moringa oleifera*[31]. Its use in the preparation of straightforward, delectable, and nutrient-dense foods might help the global effort to combat nutritional shortages. The creation of such items will also increase the diet's variety. The extended shelf life of leaves makes them simple to handle and store, especially when they have been dried. Additionally, the nutrients become more concentrated after drying, increasing their richness and virtue[32].

Table 1. Ethnopharmacological action of different parts of *M. oleifera*

Different Portion	Extracts/detailed compound	Disease	Animal model/ cell culture	Dose	References
Moringa leaf	Flavonoid and alkaloids group, vincristine and vinblastine present	Anticancer activity	Human Multiple Myeloma Cell Lines	relatively less viability at the lowest dose (2%) and least viability at the maximum dose (12%)	[33]
	The most effective extract for cytotoxicity and chemoprevention is dichloromethane. Quercetin, Kaempferol, Glycosylate, and Sulforaphane are the active ingredients.	Anticancer activity	HeLa cells	10-100 µg mL^{-1}.	[34]
	The active compound is Vitamin C.	Bone marrow chromosomes' radiation resistance	Swiss albino mice were used in an *in vivo* experiment to investigate the radioprotective effects.	150 mg/kg	[35]

3.1 Various Parts are Utilised in Food Applications

- After extensive research, it was shown that *Moringa* paneer and paneer infused with *M. oleifera* leaf extract at various concentrations had more nutrients than conventional paneer.
- The nutritional value of a mixture of chocolate and *Halawa Tahinia* and *Moringa* leaf powder was determined.
- It has been demonstrated that adding 5% *M. oleifera* leaf powder to herbal cookies increases their protein content by 14%.
- The amount of protein and dietary fibre in bread that was enhanced with 5% *M. oleifera* increased by 17 and 88 %, respectively[36].
- Wheat flour, butter, eggs, and milk are used to make the Nigerian snack known as chin chin. It has a crisp texture because it is a deep-fried food[37].
- *Moringa* Muffin: Additionally, *Moringa oleifera* dry powder was utilised to make muffins, where it was added in concentrations of up to 12% (per 55g of wheat used). It was found that the *Moringa* muffin has a lot of protein, beta carotene, lipids, and ascorbic acid. For the *Moringa* muffin, the mineral content was similarly high[38].

4. Risks

4.1 Treatment for Thyroid Issues using Levothyroxine

Although the thyroid-supporting components in *Moringa* leaves may be useful, they shouldn't be used in addition to other thyroid treatments[39].

4.2 Any Medication that the Liver Might be able to Break Down

This process may be accelerated by *Moringa* extract, which may have a number of undesirable consequences or problems.

4.3 Diabetes Medications

Moringa also lowers blood sugar levels, much like drugs for diabetes are used to do[40].

4.4 High Blood Pressure Management

Blood pressure can be lowered with *Moringa* leaves taken. Different Isolation methods and medicinal use of various constituents present and marketed formulations of *Moringa olifera* are highlighted in Table 2.

5. Potency and Toxicity

It is evaluated for its effectiveness on rats and humans, among other animals. It is a safe, affordable, and effective pharmacological and dietary option. The type

Table 2. Isolation methods and medicinal use of various constituents present in *Moringa oleifera*

Constituents	Isolation Method	Solvent Used	Specification of Isolation	% of Yield	Medicinal Use	References
Pods	saponin isolated from benzene extract	chloroform: methanol: H2	HPLC, TLC, NMR	IS1-1.3% IS2-0.98%	anticholesterolemic, anti-inflammation, anti-parasite, antibacterial	[41]
Leaf	Isolated Total phenolic, flavonoid Ascorbic acid contents Aqueous -methanol extract method	methanol-water co-solvent	UV-VIS spectrophotometer	Aqueous-28.46% Methanol-35.02%	Antioxidant property	[42]
Leaf, Seed	Petroleum ether fraction, ethyl acetate fraction and the residual aqueous-methanol fraction	Methanol, water	Ascorbic acid Crude Methanol extract (leaf) Crude Methanol extract (seed) Petroleum ether fraction (leaf) Ethyl acetate fraction (leaf) by UV-VIS spectrophotometer	crude methanol extract (leaf)-58.00 ± 1.00 Crude methanol extract (seed)-17.67 ± 2.02 Petroleum ether fraction (leaf)-26.67 ± 3.88 Ethyl acetate fraction (leaf)-78.67 ± 3.40	Antioxidant activities	[43]
Leaf	Subcritical ethanol extraction method	Ethanol–water solvent	Isolation of flavonoids by UV–vis spectrophotometry analysis, HPLC–MS	flavonoids yield 26.7%	Antioxidant property	[44]

Table 3. Patents available on *Moringa oleifera*

Sl. No.	Title	Description	Design no./Author name	References
1.	Nutraceutical *Moringa* composition	Seeds are rich in important omega-3 fatty acids, vital amino acids such arginine, cysteine, and phenylalanine, and vitamin B1 (thiamin)	US20060222682A1	[45]
2.	*Moringa*: The nutritionally superior plant	*Moringa* tree as a nutrient. Malnutrition may be successfully and reasonably treated with *Moringa* trees. More than half of all child fatalities globally are attributed to malnutrition, which results in significant human suffering.	Dhakar *et al*., 2011	[46]
3.	A liquid dermatological product made from *Moringa oleifera* leaf and its processing process	The liquid used to create the skin care product, which is created by adding ionised water to fresh *Moringa oleifera* leaves before juicing, freezing, and separating it, has advantageous effects on anti-aging, moisturising, tenderising skin, reducing inflammation, resisting UV rays, and promoting blood circulation. Additionally, it raises the value of *Moringa oleifera* leaves for use.	CN104586707A	[47]
4.	Preparation method of *M. oleifera* and its composition	The following raw components, in percentages by weight, are used to create the composition: 20 to 80% *Moringa oleifera* leaves, 1% to 5% *Moringa oleifera* seeds, 1% to 20% milk powder, 1% to 20% brown sugar, 1% to 20% active dry yeasts, 1% to 5% daucus carrots, 1% to 5% siraitiagrosvenorii, and 1% to 20% fructo-oligosaccharide.	CN105077246A	[48]

Table 4. Marketed formulations of *Moringa oleifera*

Marketed product	Company	Function of product	References
Tablets	Herbal Hills, Geo Fresh	Strengthens joints, and help in digestion.	[49]
Capsule	Sun food, Green Opia, Mahaved, Nutra Vigour, PAX, Vigora Life, and Green Virgin.	High energy, optimal nutrition, and immunity booster	[50]
Powder	The following companies: Micro Ingredients, Vitamin haat	cholesterol reduction and immune system booster, nourishing, detoxifying, and energising boost general nutrition, control blood pressure, and promote digestion	[51]
Tea	Authentic Remedies	Enhances digestion, promotes weight loss, immunity booster	[52]
Syrup	Auric, Kapiva	energy increase, bone and muscular growth	[53]

of formulation to be used, the dose and the plant portion utilised all affect how safe it is to consume *Moringa*. In clinical or human studies, lower doses of *Moringa* were not associated with any negative effects or toxicities. As a superfood supplement and immune booster, *Moringa* is used. The bioactive elements of *Moringa* do not cause liver damage or cancer. *Moringa* may now be used by industry to manufacture drugs. A detail of Patents and marketed formulations available on *Moringa oleifera* are listed in Tables 3 and 4.

6. Future Prospects

M. oleifera is a fantastic food crop with clear economical, medicinal, and nutritional advantages. Numerous studies have shown that it can control physiological processes, as well as both prevent and treat illnesses. Studies to support these claims must be done because the alleged antispasmodic characteristics are in conflict with the medication's designated medical use as a stimulator of gastrointestinal motility[54].

The *M. oleifera* plant has to be widely cultivated in most regions where the climatic conditions favour its best development because of its many applications. Most goods of various kinds for human wellbeing may be generated by maximising the production of its many beneficial components[55-58].

7. Conclusion

M. oleifera has a lot of potential to improve nutrition in low-income families and improve human well-being internationally, according to information acquired from the reviewed research. It appears to be a very important plant with a wide range of untapped potential applications in food science. However, there is increasing global interest in it. It possesses a range of medicinal advantages including antibacterial, anti-inflammatory, antioxidant, antidiabetic, analgesic, antipyretic, cardio protecting, anti-asthmatic, and water filtration properties. Because it serves many purposes for humanity and is therefore referred to as a gift from nature at a very low cost, *Moringa oleifera* is known as a ″Miracle tree″.

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