IJCSPUB.ORG ISSN : 2250-1770

INTERNATIONAL JOURNAL OF CURRENT SCIENCE (IJCSPUB)

IJCS PUBLICATION (IJCSPUB.ORG) An International Open Access, Peer-reviewed, Refereed Journal

MORINGA OLEIFERA LAM. (SAHIJAN)

: An updated comprehensive review of the medicinal, phytochemical Traditional uses, phytochemistry, and pharmacological properties of Moringa oleifera plant.

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Abstract: *Moringa oleifera* Lam. syn *M. pterygosperma* Gaertn (Family-Moringaceae) is exemplified as a panacea for various ailments in traditional medicine. Scientific studies over a few decades have reconfirmed the folklore claims, establishing its potential as an analgesic, anti-inflammatory, diuretic, antihypertensive, antioxidant, and antitumor agent. The purpose of this paper is to review the nutritional and phytochemical value of Moringa

oleifera L., along with its health benefits. Moringa oleifera, a highly valued plant grown throughout the world and all parts of trees used in different food formulations, possess industrial and therapeutic uses. This plant is gaining popularity because of its nutrient-rich root, leaves, flowers, and fruits, having immense traditional medicinal uses and proven pharmacological properties.

Keywords: Moringa; natural preservatives; bakery products; functional food; Phytochemical profile; Pharmacological attributes; *Moringa oleifera*; Toxicity studies.

I. INTRODUCTION

Moringa oleifera, Lam syn. *M. pterygosperma*, Gaertn (Family –Moringaceae), is a small or medium-sized tree, attractive enough to be a focal point in the tropics and sub-tropics owing to its creamy–-white, sweetly scented flowers and light–green, tripinnately compound foliage [1]. Described as

"one of the most amazing trees god has created", almost every part of drumstick viz. bark, root, fruit, flowers, leaves, seed, and gum is a rich repository of proteins, iron, folic acid as well as β carotene. Leaves can be eaten fresh, cooked, or stored as dry powder for many months without refrigeration, without loss of nutritional value.

Almost all the parts of this plant have been used for various ailments in the indigenous medicine of south Asia [2]. Consumer awareness of food's nutritional and health promoting effects is constantly increasing, particularly in potential antioxidant compounds in addition to classical basic nutrients.

Research into antioxidant sources is justifiable because there is increasing scientific evidence that various diseases are linked to oxidative stress [3].To recover bioactive compounds with high efficiency, conventional extraction methods are used, among which maceration and used percolation are the most popular. Still, large solvent amounts and long extraction times are required[4]. Many herbal medicines and foodstuffs are believed to have preventive effects on chronic diseases due to their radical scavenging or antioxidant properties [5]. In herbal products, phenolic compounds are effective antioxidants constituents. Many polyphenolics exert a more powerful antioxidant effect than vitamin E *in vitro* and inhibit lipid peroxidation by chain-breaking peroxyl-radical scavenging. They can also directly scavenging reactive oxygen species (ROS), such as hydroxyl, superoxide, and peroxy-nitrite radicals[6]. *Moringa oleifera* is widely grown in many tropical and subtropical countries. It is a highly valued plant because almost every part is useful for food or other uses . The seeds ,leaves, flowers, and pods are used in cooking as spices, while the oil is valuable for cosmetic and health- related applications[7].The high nutritional value and the array of health benefits have prompted several research works on moringa[8]. Some of the moringa tree include antiulcer, antipyretic, anti-inflammatory, antihypertensive, antiepileptic, antidiabetic, hepatoprotective bacterial, anti-fungal and cholesterol-lowering ability[9]. The common names of *Moringa oleifera are* horseradish tree, drumstick, miracle tree and mother's best friend. The fruits of moringa are pendulous, linear, three-sided pods and generally 250-450mm long having approximately 20 globular seeds. Seeds can be consumed raw, can be roasted, powdered for curries, and steeped for tea or other beverages. The flowers are white and can be consumed in the form of vegetables along with the pods. *Moringa oleifera* is native to the India subcontinent, grows wild in Asia, Africa and the Middle East and is most extensively cultivated in tropical and subtropical regions of the world. The plant preferably grows in sandy or loamy soil with pH 6.5-7.5, a temperature of 25°C-35°C and rainfall of 250-300 cm. It is often recommended as famine food

because of its high imperviousness to dry conditions according for their tuberous root[10].In addition, many studies have revealed its therapeutic value including anti-diabetes, anti-rheumatoid arthritis, pain relief, anti-depression, and diuretic and thyroid regulation. Due to these reported functions, the bioactivity of *Moringa oleifera* has gained tremendous attention over the last decade, thereby leading to the increasing exploration and understanding of its pharmacological functions and underlying mechanisms current research progress related to its nutraceutical or pharmacological functions, corresponding mechanism of action potential benefits for human health[11].Itis an edible plant with a high nutritional value, as it is rich in proteins, vitamins, oils, fatty acids, micro/macro elements, and phenolics. This plant also has important medicinal properties and is considered to be a promising healer due to its richness in anti-inflammatory, anti-microbial, anti-oxidant, anti-cancer, and anti-ulcer compounds. Extensive research on this wild plant might lead to the recovery of novel agents to be used commercially to lower human blood sugar and cholesterol levels, and in the treatment of human cancer and cardiovascular diseases, in addition to many other medical applications[12].Therefore, *Moringa oleifera* provides nutrients that benefit health, making it a key food for food security in areas with fewer economic resources[13].This review summarises recent knowledge on bioactive compounds from *Moringa oleifera* plants and their potential use in the formulation of food products, especially bakery products. The objective of this review is to know the uses and applications of *Moringa oleifera* in bakery products, to know what the quality or concentration of *moringa oleifera* is that allows maintain the sensory characteristics of the product.

TAXONOMIC CLASSIFICATION
BOTANICAL DESCRIPTION

Kingdom -Plantae
Sub-kingdom -Tracheobionta
Super Division -Spermatophyta
Division – Magnoliophyta
Class – Magnoliopsida
Subclass -D illeniidae
Order -C apparales
Family -M. oringaceae
Genus -M. oringa
Species -oleifera

Synonyms
Latin – *Moringa oleifera*
Sanskrit - Subhanjana
Hindi -Saguna,Sainjna
Gujarati -Suragavo
Tamil -Morigkai
Telugu -Mulaga, Munaga
Malayalam -Murinna, Sigru
Ayurvedic -Akshiva, Raktaka
Arabian -Rawag[13]

GEOGRAPHICAL SOURCE

The tree is wild in the sub-Himalayan tracts from Chenab to Oudh. It grows at elevations from sea level to 1400 m. It is very commonly cultivated near houses in Assam, Bengal and peninsular India. It is a prolific coppice[28].It is also cultivated in north-eastern Pakistan, north-eastern Bangladesh, Sri Lanka, West Asia, the Arabian peninsula, East and West Indies and southern Florida, in central and South America from Mexico to Peru, as well as in Brazil and Paraguay[29].

MORPHOLOGY

Moringa oleifera is a small, fast-growing evergreen or deciduous tree that usually grows as high as 9 m, with a soft and white wood and corky and gummy bark. Roots have the taste of horseradish. Leaves are longitudinally cracked leaves, 30-75 cm long main axis and its branch jointed ,glandular at joints, leaflets are glabrous and entire. The leaflets are finely hairy, green and almost hairless on the upper surface, paler and hairless beneath, with red-tinged mid-veins, with entire(not toothed) margins, and are rounded or blunt-pointed at the apex and short-pointed at the base. The twigs are finely hairy and green. Flowers are white, scented in large axillary down panicles, pods are pendulous, ribbed, seeds are 3-angled [30].

TRADITIONAL USE

Traditionally, the plant is used as antispasmodic, stimulant, expectorant and diuretic. Fresh root is acrid and vesicant (has the taste of horse-radish). Internally it is used as stimulant, diuretic and antilithic. Gum is bland and mucilaginous. Seeds are acrid and stimulant. Bark is emmenagogue and even abortifacient, antifungal, antibacterial. Flower are cholagogue, stimulant, tonic and diuretic and useful to increase the flow of bile. The plant is also a cardiac circulatory tonic and antiseptic[31]. Pods are antipyretic, anthelmintic; fried pods are used in diabetes. Root juice is employed in cardiac tonic, antiepileptic. Used for nervous debility, asthma, enlarged liver and spleen, deep-seated inflammation and as diuretic in calculus affection. Decoction is used as a gargle in hoarseness and sore throat. Root and fruit are anti-paralytic. Leaf juice is used in hiccough (emetic in high doses); cooked leaves are given in influenza and catarrhal affections. Root-bark is used as antiviral, anti-inflammatory, analgesic. Stem-bark and flowers are hypo-glyceamic. Infusion of seed is anti-inflammatory, antispasmodic and diuretic, also given in venereal diseases. Along with other therapeutic applications, *The Ayurvedic Pharmacopoeia of India* indicated the use of the dried root bark in goitre , glycosuria and lipid disorders (also dried seeds), and leaf, seed, root bark and stem bark in internal abscess, piles[32].

DOSAGE

Leaf :-10–20ml. juice;

root bark :- 2–5 g powder;

stem bark :- 2–5g powder;

seed :- 5–10 g powder.

Leaf, flower, fruit, seed, bark, root:-1–3 g powder; 50–100 ml decoction. [8, 9].

PHARMACOLOGICAL ATTRIBUTES

ANTIPYRETIC

A dose-dependent reduction in normal body temperature and yeast-provoked pyrexia was observed after administration of ethanol extract of seeds to albino rats[14].

- ANTI-HYPERTENSIVE

Muñoz et al.(2020)have studied the effect of MOLE on epinephrine-induced hypertension in test animals. Epinephrine hormone can raise blood pressure by sympathetic nervous activation to induce hypertension in rats. Then, three different treatments were applied: 1mL of saline solution, 1.25mg/kg BW of nifedipine,

462.5mg/kg ethanolic extracts of MOLE. The results showed that MOLE successfully reduced blood pressure from 162mmHg to 118mmHg and hemoglobin content from 15.1 g/L to 14.08g/L after one hour of epinephrine administration in rats. The blood pressure-lowering effect of MOLE was comparable with nifedipine administration. Therefore, MOLE exhibits promise as a potential treatment for hypertension. The presence of glycosides in MOLE, is responsible for its hypotensive effects, which involve vasodilation, similar to the actions of nifedipine, a calcium-blocking agent used in the treatment of high blood pressure[15].

- ANTI-ARTHRITIC

Rheumatoid arthritis is an inflammatory disease with joint inflammation, synovial growth, and articular cartilage degradation. This disease is mainly caused by the increased attack of free radicals in the body, which causes joint inflammation and associated pain and damage. In this context, MOLE, with its high antioxidant content, can be used to prevent this disease and reduce inflammation. The high antioxidants in MOLE help to reduce the detrimental effects of free radicals and reactive oxygen, protecting joint tissues and preventing bone degeneration. In addition , massaging MOLE in to the skin can help in reducing skin inflammation (Kapil et al.,2021) [16]. MOLE has been employed as a remedy to alleviate arthritis and joint pain. Its application has shown the potential in providing relief from the symptoms associated with these conditions. Mahdi et al.(2018) studied paw edema, body weight, arthritic index, X-ray radiography, hematological parameters, and walk track and locomotion analysis in complete Freund's adjuvant (CFA)-induced arthritis in rat models. MOLE(250mg/kg) showed the strongest inhibition activity in the chronic phase at 70.8%, compared to the positive control, indomethacin(70.48%). This proves that MOLE helps in preventing the development or improving arthritis disease severity. The presence of phytochemicals in MOLE can inhibit the absorption of free radicals [17] .

- ANTI-ASTHMATIC

The ethanolic seed extract of *Moringa oleifera* has potential to prevent immune mediated inflammatory responses in toluene diisocynate-induced asthma in wistar rats. Levels of TNF-alpha, IL-4 and IL-6 were found to reduce significantly in the serum and bronch-alveolar fluid[18].The n-butanol extract of the seeds of the plant possess inhibitory effect on airway inflammation[19].

- ANTI-INFLAMMATORY AND ANALGESIC

Extract of roots of M. *oleifera* reduces the carrageenin- induced paw oedema to similar extent as the potential anti-inflammatory drug indomethacin[20]. Aurantiamide acetate and 1,3 dibenzyl urea isolated from roots showed significant anti-inflammatory /antiarthritic and analgesic activity mediated via inhibition of TNF-alpha, IL-2 and other cytokines [21]. The serum level of rheumatoid factor (RF) was also reported to decrease [22]. The alcoholic extract of seeds was found to be a potent analgesic when study was carried out in wistar male albino rats using hot plate and tail immersion method . It was found that methanolic extract of the root not only produced analgesia in mice but also potentiated the analgesic action morphine and pethidine [23].

- HYPOCHOLESTEROLEMIC

A dose of 1 mg/g of crude leaf extract was co-administered with high fat diet to male Wister rats for 30 days .The high-fat diet- induced increase in cholesterol was reduced in serum (14.35 %), liver (6.40 %) and kidney (11.09 %), compared to the high fat exclusive group, when their levels were determined by the method of Zlatis[24]. *M. oleifera* treated hyper-cholesterolaemic rabbits also showed a decrease in lipid profile of liver, heart and aorta with an increase in excretion of faecal cholesterol [25]. The incidence of formation of atherosclerotic plaque reduced to about 86% after 12 weeks of treatment [26].

- WOUND HEALING

The aqueous extract of *M. oleifera* leaves and ethyl acetate extract of dried leaves was found to possess significant wound healing potential. For study, 10 % extract were applied on excision, incision and dead space (granuloma) wound models in rats, in the form of ointment[27].

- ANTI-MICROBIAL ACTIVITY

A series of investigations have been conducted to evaluate the antimicrobial activity of Moringa species with the reports that the extracts from different parts of the M. oleifera plant—including seeds, stem bark, leaves, and root bark—can exert antimicrobial potential [33]. For example, the water-soluble lectin isolated from the extract of M. oleifera seeds has inhibitory effects on the growth, survival, and cell permeability of multiple species of pathological bacteria[34]. In addition, the extract of M. oleifera roots are reported to contain an active antibiotic pterygospermin that has powerful antibacterial and fungicidal effects [35]. The aglycone of deoxy-niazimicine isolated from the chloroform fraction of an ethanol extract of M. oleifera root bark is found to be responsible for antibacterial and antifungal activities[36], while the juice from the stem bark exhibits an antibacterial effect against Staphylococcus aureus[37]. The aqueous and ethanoli extracts from the leaves of M. oleifera have promising anti-bacterial properties, with strong inhibitory effects on Gram-positive species (Staphylococcus aureus and Enterococcus faecalis) over Gram-negative species (Escherichia coli, Salmonella, Pseudomonas aeruginosa, Vibrio parahaemolyticus, and Aeromonas caviae) [38]. In addition, the ethanol extract from leaves of M. oleifera has demonstrated the highest mean inhibitory zone against the growth of both S. aureus and Streptococcus mutants during the comparison between experimental toothpaste containing the extract from different parts of the M. oleifera plant versus mouthwash solutions [39].

- ANTI-OXIDANT AND HEPATOPROTECTIVE EFFECTS

Usually, natural compounds rich in polyphenols have strong anti-oxidant properties and can decrease oxidative damage in tissues by scavenging free radical[40].The methanol extract of *M. oleifera* leaves contains chlorogenic acid, rutin, quercetin glucoside, and kaempferol rhamnoglucoside, whereas in the root and stem barks, several procyanidin peaks are detected [41]. Similarly, the *Moringa* genus has high antioxidant activity mainly due to its high content of bioactive polyphenols[42]. Fortunately, as a medicinal plant, M. oleifera extracts from both mature and tender leaves exhibit strong antioxidant activity against free radicals and prevent oxidative damage due to the enrichment of polyphenols tissue[43].

- ANTI-THYROID

Tahilyani and Kar studied the role of *Moringa oleifera* leaf extract in the regulation of thyroid hormone status in adult Swiss rats and found that it plays an inhibitory role in the peripheral conversion of tetraiodothyronine (T4) to triiodothyronine (T3). Lower concentration of this extract can be used to check hyperthyroidism[44].

- ANAPHYLACTIC

Ethanolic extract of seeds *Moringa oleifera* was reported to possess profound anti-anaphylactic potential[45].

- HEPATOPROTECTIVE

Various studies reported the ethanolic extract of Moringa oleifera seeds and leaves to possess hepatoprotective reaction. The root and flower extracts also showed anti-hepatotoxic activity[46].

Remarkable protective effect has been observed against CCl4-induced liver fibrosis in rats[47].

- RADIOPROTECTIVE

Radioprotective effect was observed in the methanolic leaf extract pretreated, irradiated Swiss albino mice[48].

- ANTI-ULCER

Methanolic flower bud extract showed a decrease in ulcer index in aspirin-induced gastric ulcers in rats[49]. The leaf extracts also produced a significant reduction of stress-induced gastric ulcer and cysteamine-induced duodenal ulcers. The possible mechanism behind the ulcer protective effect may be an increase in EC cell count and 5-HT levels[50].

- ANTI-SPASMODIC

The roots as well as ethanol extract of the leaves showed antispasmodic action, possibly through calcium channel blockade. Spasmolytic activity exhibited by the constituents of the plant provides a scientific basis for the traditional uses of the plant in gastrointestinal motility disorders[51].

- DIURETIC AND ANTIUROLITHIATIC

In vitro studies depicted antiprotozoal effect of *M. oleifera* [56]. The soluble lectin from the seed extract showed larvicidal activity by delaying larval development and promoting mortality in *Aedes aegypti*, possibly on account of its hemagglutinating activity [57].

- ANTIFERTILITY AND ABORTIFACIENT

M. oleifera root is shown to have unique anti-progestational Activities[58]. It is reported to induce alterations in the normal uterine histoarchitecture (metaplastic changes in cervical epithelia and cornification of vaginal epithelium) which might be the reason for anti- implantational characteristics [59].

- ANTIOXIDANT AND ANTIPEROXIDATIVE

Exploration of *M oleifera* as a potential source of antioxidants has yielded affirmative results [60]. The phenolic content present in the leaves imparts free-radical scavenging property while the ethanolic fraction showed considerable metal chelation properties with potential to protect against DNA nicking [61]. Pari and Kumar suggested that the protective effect may be attributed to decrease in liver lipid peroxides and enhanced antioxidants level [62].The seed powder showed reduction in tissue arsenic concentration, thus protecting from oxidative stress [63] .According to a traditional claim, powdered gum of *M. oleifera* mixed leavescan alter the brain monoamines (norepinephrine, dopamine and serotonin) in distinct areas of brain in rat model of Alzheimer's disease caused by intra-cerebroverticle (ICV) infusion of colchicine and hence can protect against monoaminergic deficits associated

- ANTI-HYPERGLYCMIC

The aqueous extract exhibited hypoglycemic and anti-diabetic effect in normal and streptozotocin-induced sub, mild and severely diabetic rats[52]. Studies have also approved that Moringa oleifera has an ameliorating effect for glucose intolerance which might be mediated by quercetin-3-glucoside and fiber contents in the leaf powder[53].

- ANTITUMOR

Epstein-Barr virus-early antigen (EBV-EA) activation in Raji cells was found to be inhibited by various bioactive compounds isolated from the ethanolic extract of *M. oleifera* [54]. Niazimicin, niaziminin and beta-sitosterol-3-o- beta-D-glucopyranoside showed antitumor action. Studies have explored possible chemo-preventive & antiproliferative potential of *M. oleifera* against chemical carcinogenesis, along with its

with curd taken daily for a week cures painful and burning urination [64]. The leaves, flowers, gum, roots and the aqueous infusion of seeds exhibited diuretic activity[65]. Administration of aqueous and alcoholic extract of *M. oleifera* root-wood significantly reduced the elevated urinary oxalate, showing a regulatory action on endogenous oxalate synthesis. The increased deposition of stone forming constituents was also significantly lowered in the kidneys of calculogenic rats [66].

- CARDIO PROTECTIVE

Moringa leaf juice exerts a stabilizing effect on blood pressure [67].A variety of glycosides viz. Nitrile, mustard oil glycosides, thiocarbamate and isothiocyanate, isolated through bioassay – directed fractionation of ethanolic extract of leaves and pods showed blood pressure lowering effect[68]. Presence of methyl phydroxybenzoate and beta sitosterol confer hypotensive potency to the pods[69].Lyophilized hydroalcoholic extract of *M. oleifera* showed myocardial preservative effect in isoproterenol (ISP)-induced model of myocardial infarction[70]. Recent investigations have explored platelet aggregation inhibitory potential in the leaf extract [71].

- CNS ACTIVITIES OF MORINGA OLEIFERA LAM

Chronic oral treatment of ethanolic extract of *M. oleifer*

with Alzheimer. The electrical activity was also altered [72]. Pretreatment with aqueous extract inhibited penicillin- induced seizure and markedly reduced locomotor activity. Chronic treatment significantly increased the 5-hydroxytryptamine and decreased the

dopamine level in cerebral cortex, midbrain, caudate nucleus and cerebellum. Norepinephrine level was significantly decreased in cerebral cortex. The aqueous extracts induce the potentiation of sleeping time induced by pentobarbitone, meprobamate and diazepam. Protection against strychnine- and leptazol-induced convulsions was observed on pretreatment with methanolic root extract including a dose dependent CNS depressant effect [73].

- NON-PHARMACOLOGICAL USES

Moringa oleifera possesses a multitude of non – pharmacological uses as well. The defatted seed meal is an excellent additive in sheep diet as it is reported to improve rumen fermentation [74]. Milk production in cows was found to increase on administration of Moringa as a protein supplementwith low quality diets [75].Biodiesel derived from M. oleifera oil by alkali-catalyzed transesterification with methanol is reported to bean acceptable substitute for petrodiesel. Its cetane number was found to be [76], the highest reported for a biodiesel fuel with much better oxidative stability[77].

The seeds serve as one of the best natural coagulants for water treatment and a cheap and feasible alternate to the synthetic ones. The seed extract is an effective natural phosphate monobasic anhydrous, thiobarbituric acid, trichloroacetic acid, gallic acid, and sodium carbonate were purchased from Sigma Louis, MO, USA). Absolute ethanol, copper sulfate pentahydrate, disodium hydrogen phosphate, methanol, potassium sodium tartrate tetrahydrate, sodium carbonate, sodium chloride, sodium dihydrogen phosphate anhydrous, and sodium hydroxide were purchased from Merck (Darmstadt, Germany). Ketamine (Calyosol®) was purchased from Gedeon-Richter (Hungary). Pentobarbital (Nembutal®) was purchased from Abbott (North Chicago, IL.USA). Other unstated chemicals and reagents were of analytical grade.

clarification agent for highly turbid and untreated pathogenic surface water [78]. Ben oil, a non-drying oil obtained from the seeds is employed in the manufacture of perfumes, hairdressings etc and as a lubricant for fine machinery. As it is resistant to rancidity, it is extensively used in the 'enfleurage' process whereby delicate fragrances are extracted from flower petals . The chemical properties of protein fraction of *M.oleifera* permit their use in a wide variety of skin care, hair care and cosmetic formulations such as purisoft, puricare etc. [79].

Shelled moringa seeds possess potential to eliminate toxic metals such as cadmium from water resources. The sorption was found to occur due to amino acid-Cd interactions, as revealed by Fourier transform infrared spectrometry[80].

MATERIALS AND METHODS :-

1) CHEMICALS

1,1-Diphenyl-2-picrylhydrazyl (DPPH) radicals, 6-hydroxy- 2,5,7,8-tetramethylchroman-2- carboxylic acid (Trolox®),1,1,3,3-tetraethoxy-propane (TEP), (+)-_-tocopherol (vitamin E), albumin (bovine), butylated hydroxytoluene (BHT), Folin- Ciocalteu's phenol reagent, potassium bromide, sodium

seeds are directly sown in sandy/ loamy soil with slightly alkaline pH at 2cm depth and are allowed to germinate for 5- 12 days [83]. Moringa can also be propagated from saplings and placed inside a plastic bag. Saplings are allowed to grow to about 30 cm in height and are then transplanted into the soil [84]. But transplantation should be done with extreme care without damaging the taproots. Moringa trees can also be cultivated[85].

Tree cuttings with 4-5cm diameter and 1m length

2) GROWTH CHARACTERISTICS

M. oleifera can grow and survive in harsh climatic conditions. It is cultivated all across the world as it can grow under severe drought and mild frost conditions[81]. The optimum growth requirements of *Moringa oleifera* [82] are depicted in Table 1 Moringa

can be cultivated. But this method has a drawback; plants grown with this method have a much weaker root system. Such plants are also affected by drought and winds. The nutritional composition of Moringa also varies according to the geographical area in which it grows. For example, Indian Moringa is slightly

different in nutritional composition as compared to Moringa grown in Nigeria. In the hot-humid season, Vitamin A was predominant, but in the cold-dry season, Vitamin C and iron were the predominant phytochemicals present . Soil is also one of the major factors that affect the nutritional composition of Moringa.

For example, studies revealed that the plants grown under poultry manure are found to possess high phosphorus, potassium, sodium, and manganese compared to those grown using fertilizer alone. Plants grown using fertilizers alone have a different nutritional composition compared to the one to which fertilizers are applied in combination[86] .

3) ESSENTIAL PHYTOCHEMICAL

The essential phytochemicals of *Moringa oleifera* are described in Table

Parts Used	**Active Constituents**	**Nutritional Value**
Dried Leaves	Vitamin A	10 times more than in carrots
Dried Leaves	Calcium	17 times more than in milk
Dried Leaves	Protein	9 times more than in yogurt
Dried Leaves	Potassium	15 times more than in bananas
Dried Leaves	Iron	25 times more than in spinach
Dried Leaves	Vitamin C	7 times more than in oranges

Table. **Essential phytochemicals possessed by Moringa species.**

4) NUTRITIONAL CHARACTERISTICS

a. LEAVES

The leaves of this tree are loaded with minerals and vitamins

and can be used to treat malnutrition and promote lactation in mothers. Moringa leaves are rich in vitamins, minerals,

PUFA, saturated fatty acids, and antioxidants[87].Moringa leaves consist of minerals (calcium, potassium, zinc, magnesium, iron, and copper), vitamins (beta-carotene of vitamin A, vitamin B, such as folic acid, pyridoxine, and nicotinic acid, vitamin C, D, and E), PUFA (omega-3 and omega-6), tannins, sterols, terpenoids, flavonoids (quercetin, glucosides, rutinosides, and malonyl glucosides), saponins, anthraquinones, alkaloids, reducing sugar and glucosinolates[88] .Moringa leaves are loaded with

Inhibitors of ROS (reactive oxygen species) intermediates and thus help in preventing cancer. These constituents further reduce the plasma cholesterol level and enhance the fecal excretion of the same. Moringa pods can be used in the treatment of colon cancer and digestive problems[95] .

c. SEEDS

Moringa seed oil consists of linoleic acid, oleic acid, and 76 % PUFA (Polyunsaturated fatty acids). Moringa seed oil is a good substitute for olive oil and is used for the control of cholesterol in the body. Moringa seed oil can be extractedby cold pressing technique. The oil comprises mainly behenic acid, which makes this oil more resistant to rancidity. Moringa seeds also possess anti- diabetic activity. 50-100mg/kg dose of Moringa seed powder in rats act by reducing the blood glucose level .Moringa seeds also show antiarthritic activity due to their anti-inflammatory property. The seeds also can purify water through the precipitation of heavy metals. Seeds also show antimicrobial activity due to the presence of constituents like pterygospermin and benzyl isothiocyanate[96].

d. FLOWERS

Moringa flowers can be used commercially to produce honey as these are a good source of nectar. The flowers also possess anti- cancer properties that act by inhibiting the growth of PC3 cells[97]. Therapeutic activities exerted by Moringa flowers are antimicrobial (active against bacterial, parasitic, and viral infection), antiulcer (due to the presence of alkaloids, saponins, and tannins), antipyretic, anti-psychiatric (nervous disorders such as hysteria and dementia), anticancer, diuretic, and hepatoprotective[98].

e. BARK

calcium [8 ounces of milk (300-400mg Calcium) < Moringa leaves (1000 mg Calcium)][89]. Moringa leaf powder can be used for the treatment of anemia, an effective substitute for iron tablets [Beef (2 mg Iron) < Moringa leaf powder (28 mg Iron)][90]. Moringa leaves can provide 25.5 to 31.03 mg of zinc per kg[91].It can fulfill the daily requirement of zinc, which is essential for the production of sperm and the synthesis of DNA and RNA. Moringa leaves also have a low calorific value and can be used in the diet of obese patients[92] .Leaves of Moringa are generally used in many countries as vegetables. The addition of Moringa leaves to cow feed increases milk production by about 43%- 65%[93] .The presence of phytosterols in leaves can promote the activity of mammary glands[94] .

b. PODS

Moringa pods consist of 46.78% fiber, 20.66% protein, 30% amino acids, palmitic acid, linoleic acid, and oleic acid. B-carotene and sterols in the plant pods are potent

Moringa bark extract shows antibacterial (Staphylococcus aureus, Citrobacter freundii, *Bacillus megaterium*) and antifungal activity (against *Neurospora crassa* and *Aspergillusniger*).Moringa bark can also be used to treat UTIs[99] .

METHODOLOGY

1) MATERIALS

Dry *Moringa oleifera* seeds used in this study were collected from gardeners in Serdang area, Selangor Darul Ehsan, Malaysia (Figure 1, 2, shows the tree and pods with seeds). The extraction of oil carried out by electro thermal Soxhlet using hexane. The bioactive constituents were extracted from *Moringa oleifera* using phosphate buffer (0.1M), jar test for measuring coagulation activity, turbidimeter for turbidity measurements, and the river water samples (low, medium, and high turbidity from Sungai Pusu, International Islamic University Malaysia) were collected to apply jar Test[100].

2) OIL EXTRACTION

The extraction of oil carried out by electro thermal Soxhlet using hexane. The oil percentage was 35% w/w. The dried cake was used in this study while the oil kept for other research work[101].

Figure . ***Moringa oleifera*** **Tree**

3) EXTRACTION OF BIOACTIVE CONSTITUENTS

Weighing of 10gm of *Moringa oleifera* cake, adding of 100ml of phosphate buffer (0.1M) with pH 7.5, mix with gentle stirring at 4ºC for 2hours to extract the bioactive constituents, then centrifuge the contents at 6000 rpm for 30 min, the supernatant was injected to the Ion Exchange column to separate the bioactive constituents (Gassenschmidt, U., et al, 1995)[102].

4) JAR TEST

Jar test for measuring coagulation activity, turbidimeter for turbidity measurements, and the river water samples (low, medium, and high turbidity from Sungai Pusu, IIUM) were used to apply jar test. The turbidity for river water samples were 43.9, 91, and 333 for low, medium and high turbidity, respectively[103].

Figure . Jar test for high turbidity river water

5) PLANT MATERIALS

The mature leaves of M. oleifera were collected from Baan Klang Sub-District, Muang District, Pathum Thani Province, Thailand in October 2010. The samples were identified by Dr. W. Gritsanapan and the voucher specimens (BVMO011010) were deposited at Department of Pharmacognosy, Faculty of Pharmacy, Mahidol University, Bangkok, Thailand. The leaves were cleaned by tab water and a portion was dried in a hot oven at 60 ◦C for 24 h. The dried samples were ground and passed through a sieve (20 mesh).

The powdered drugs were kept in sealed containers and protected from light until used. Another portion of fresh sample was used for squeezing, decoction, and maceration[104].

6) INVESTIGATION OF SUITABLE METHOD FOR EXTRACTING OF *MORINGA OLEIFERA*

Several extraction methods were performed using 50 and 70% (v/v) ethanol as solvents, except for squeezing and decoction in which distilled water was used. Each extraction was repeated many times until exhaustion. Each method was done in triplicate[105].

-[a]Squeezing (SZ)

The fresh leaves of M. oleifera were extracted by mincing with distilled water (1:10, w/v) and the mixture was squeezed and filtered through muslin cloth and Whatman No. 1 filter paper. The filtrate was lyophilized to yield a freeze-dried squeezing leaf extract (SZ).

-[b]Decoction of fresh leaves (DF) The fresh leaves were minced into small pieces, boiled with distilled water (1:10, w/v) at 100 ◦C for 30 min and filtered through a Whatman No. 1 filter paper. The marc was repeatedly extracted until exhaustion.

-[c]Decoction of dried leaves (DD) The dried powdered leaves was boiled with distilled water (1:10, w/v) at 100 ◦C for 30 min and then filtered. The marc was re-extracted until exhaustion.

-[d]Maceration of fresh leaves (MF70)

The fresh leaves were minced into small pieces and macerated

with 70% ethanol (1:20, w/v) for 72 h at room temperature (28 ± 2 ◦C) with occasional shaking. The extract was filtered and the marc was re-macerated with the same solvent until the extraction was exhausted.

-[e]Maceration of dried leaves (MD50 and MD70)

The dried powdered leaves were separately macerated with 50 and 70% ethanol (1:40, w/v) for 72 h at room temperature (28 ± 2 ◦C) with occasional shaking. The extract was filtered and the marc was re- extracted by the same process and solvent until the extraction was exhausted.

-[f]Percolation of dried leaves (PD50 and PD70)

The dried powdered leaves were separately mixed with 50 and 70% ethanol (1:5, w/v) and the mixture was allowed to stand for 1 h.

Then the mixture was transferred to a percolator, and 50 and 70% ethanol was added (final proportion of 1:10, w/v). The extraction was done at room temperature with a flow rate of 1 mL/min until the percolation was exhausted.

-[g]Soxhlet extraction of dried leaves (SD50 and SD70)

The dried powdered leaves were separately placed into a thimble and were extracted with 50 and 70% ethanol (1:50, w/v) in a soxhlet apparatus. Extraction was carried out at five cycles/huntil exhaustion (20 h). The combined extractfrom each extraction method (except squeezing) was separately filtered through a Whatman No. 1 filter paper. The filtrate was dried under reduced pressured at 50 ◦C using a rotary vacuum evaporator. The crude extract was weighed and kept in a tight container protected from light.

Body Part	Active Constituent	Therapeutic Application	References
Leaves	Behenic acid	Acne treatment	[79]
	Vitamin A, C and E	Anti-wrinkle	[80]
	Isothiocyanates (reduces insulin resistance) Terpenoids (reduces intestinal glucose uptake) Phenolic compounds (increases glucose tolerance)	Anti-diabetic	[81, 82]
	Vitamin C and E (prevent hair fall) Zinc (recovers damaged hair follicles) Arginine, Cysteine and Methionine (pro- mote hair growth) Omega-3 fatty acids (strengthens the hair)	Nourishment of Hair	[83, 84]
	Iron and Vitamin C (boosts immunity)	Boosts energy and stamina	[85]
	Isothiocyanate and Niazimicin (prevent thickening of arteries)	Anti-hypertensive	[86]
	Isothiocyanates	Anti-inflammatory	[87]
	Vitamin A, C, and E	Anti-ageing	[79, 80]
	Vitamin C and E	Anti-Alzheimer	[88]
Seeds	Behenic acid	Anti-hyperlipidemia	[89]
	rygospermin, Morngine and Benzyl isothiocyanate	Anti-microbial	[90]
	Glucosinolates	Anti-cancer	[78]
	dants (prevent oxidative damage of sperm)	Improves fertility	[91]
	Isothiocyanates	Anti-inflammatory	[87]
	Tryptophan	Sedative	[92]
	Zinc	Blood sugar regulation	[89]
	Calcium and Magnesium	Cures joint pain	[93]
Flowers	Tannins and Phenols	Antibacterial	[90, 91]
	Alkaloids, Saponins and Tannins	Antiulcer	[39]
	Vitamin A, C, and E	Anti-oxidant	[94]
	Isothiocyanates and Thiocarbamates	Hepato-protective	[95]
Bark	Flavonoids	Antimicrobial	[90, 91]
	Tannins, Phenols, and Alkaloid	Anti-inflammatory	[87]
	Peptides	Anti-fungal	[96]
	Terpenoids and Glycosides	Anti-pyretic	[97]

	Terpenoids and Glycosides	Anti-malaria	[98]
	Vitamin B	Cures Stomach pain	[99]
	Saponins	Cures tooth decay	[82]
Roots	Spirochin and Anthonine	Anti-bacterial	[90, 91]
	mpesterol, stigmasterol, itosterol andavenasterol	Diuretic	[100]
	Steroids	Sexual weakness	[58]

Composition of Moringa oleifera

The composition of Moringa oleifera varies depending on climatic variations, crop management, whether it is cultivated or wild, the state of maturity of the plant at the time of harvesting, the type of post-harvest processing and depends on the growing area, i.e., the land where it is grown [105].

1) Primary Metabolites

Moringa oleifera leaf is a rich source of minerals, such as calcium, potassium, zinc, magnesium, iron, phosphorus and copper [106],where it is represented in Table 1. One of the characteristics of the leaf is its high protein content, due to the essential amino acids, which constitute about 30% of its weight, being comparable to milk powder which contains 35%,and is available all year round, as the protein and essential amino acid content is present in the leaves, unlike other plants which contain them in the seeds [107], reporting a protein content of 29.4 g protein/100 g dry weight in the leaves. Thus, Moringa oleifera can be considered a new source of protein to be included in food, like chia seed, with a protein content of 24 g protein/100 g dry weight[108]. Regarding carbohydrates, its level is lower (8.1%) [109] compared to the other parts of the plant, as can be seen in Table 2. In addition, fibres were also found, witha value ranging between 18.1 and 21.1 g/100 g dry weight of the leaves [110].The leaves are noted for high levels of -carotene and provide more vitamin A than carrots and pumpkin [111], however it is not clear whether this vitamin is retained even after drying and grinding the plant. Even so, studies have shown that their consumption is sufficient to counteract the effects of this vitamin deficiency [112]. They are also a good source of B vitamins (quoted from the book tree miracle), among which thiamine, riboflavin and niacin have been found, with a concentration between 0.06 and 0.6 mg/100 g, 0.05 and 0.17 mg/100 g and 0.8 and 0.82 mg/100 g for thiamine, riboflavin and niacin, respectively. In the dried leaf, their concentrations were 2.85, 22.16 and 8.86 mg/100 g DW, respectively[113]. On the other hand, supplementation with 100 mg/dL of Moringa oleifera leaf per day has a similar effect to treatment with vitamin E at 50 mg/dL per day[111], contains more vitamin C than an orange and more calcium than dairy products, however a significant part of this calcium is present in the form of calcium oxalate crystals, which cannot be used by the body and is eliminated directly without being absorbed [112]. In addition, Moringa oleifera is high in potassium and iron; even more than bananas and spinach respectively [114]. Moringa oleifera seed has a high proportion of monounsaturated/saturated fatty acids (MUFA/SFA), sterols and tocopherols, as well as proteins rich in sulphur amino acids [115].

As reported in previous studies, Moringa oleifera seed oils (also called Behen oil, which is the commercial name given to Moringa oleifera oil) have similar fatty acid content and physicochemical parameters to those reported for other vegetable oils and can be considered as a healthy alternative to hydrogenated oils in food

formulations. The main fatty acids present in Moringa oleifera oil are behenic, linoleic, stearic, palmitic, oleic, arachidic, linolenic, eicosenoic and heptadecanoic acids [116], with oleic acid being the main unsaturated fatty acid, with 73.5% in the seed oil[117]; carbohydrate content is 27.5% [118]. The seeds are a rich source of Ca and Mg, respectively[119]. Of the other edible parts of Moringa oleifera, concerning carbohydrates, the pods contain 10.4%, stem 18.5%, bark 26.9% and stem with bark 31.1% [116]. Karuna et al. [120] found that the part with the highest level of fibre is the root (45.43%), compared to the stem (41.60%) and bark (25.73%). Immature pods and flowers are characterized by a higher content of total monounsaturated fatty acids (MUFA, 16–30%) and are low in PUFA(34–47%), compared to leaves[121] .The highest K content is found in vegetative parts and immature pods [119] .

2) Secondary Metabolites

The different parts of Moringa oleifera are good sources of glucosinolates, flavonoids and phenolic acids [122], carotenoids [123],tocopherols[124]. Alkaloids, saponins, tannins, steroids, phenolic acids, alkaloids, carotenoids, polyphenols, isothiocyanates, phytates, glucosinolates, flavonoids and terpenes can be found in the Moringa oleifera leaf [125]. Among the glucosinolates, benzyl 4-O-(_-L-rhamnopyranosyloxy) glucosinolate is the most predominant (glucomoringin)[126]. Its leaves include 11 phenolic acids (gallic acid, caffeic acid, chlorogenic acid, ocoumaric acid, p-coumaric acid, ellagic acid, gentisic acid, sinapic acid, syringic acid)[127] and their derivatives (coumaroylquinic acids and their isomers, feruloylquinic and caffeoylquinic), 26 flavonoids (present mainly as flavonol and glycoside: quercetin, rhamnetin, campferol, apigenin and myricetin[125]. Flavonoids include flavonol glycosides (glycosides, rutinosides and malonylglycosides) of quercetin "kaempferol" 0.05–0.67%) isorhamnetin and lignans (isolariciresinol, medioresinol, epipinoresinol glycosides and secoisolariciresinol)[128]. Furthermore, there is a difference according to geographical area, showing a higher phenolic content in Pakistan than in India, Thailand, Nicaragua and even in the United States[129].The flavonoid composition is higher in the leaves than in the seeds, ranging from 2000 to 12,200 mg per dl of Moringa oleifera leaf. Moringa oleifera seed contains phytosterols, the most abundant of which are _- sitosterol, stigmasterol and campesterol[130]. Alkaloids, saponins, phytates, tannin[131] and phenolic compounds (quercetin and p-hydroxybenzoic acid)[132] can also be found.

Conclusions

This review aimed to highlight the bioactive compounds of Moringa oleifera plants and recent approaches to functional applications and the influence of these biocompounds on the functional characteristics of bakery products. The main food products based on Moringa oleifera plants were found to be high in dietary fibre and low in fat, suggesting that this plant can be used in the formulation of low-calorie food products. Theincorporation of Moringa oleifera will increase the nutritional value, improving the contribution of macro and micronutrients, of which proteins, fibres, vitamins and minerals are the most important, however, there is a difference when using the leaves versus the seed of Moringa oleifera, as the latter will increase the value of lipids, which is not a characteristic of the leaves. The essence of the entire retrospection depicts that *M. oleifera* possesses diverse utility inviting further investigations in future. The multiple array of pharmacological activities need to be studied more exhaustively to establish exact molecular- mechanism responsible for the activity of individual components. Since the available data is somewhat illusive, standardization of the plant extract and structure elucidation of the phytochemicals reported is essential to develop coherence between its Phytochemistry and pharmacology. Bioavailability studies should be performed to optimize the active dose. In addition, clinical trials should be made to unfold its adverse effects or toxicity, to establish safe use of *M. oleifera* in human beings. Moreover, there is a great need to formulate the best alternative herbal preparation of *M. oleifera* that can either be used individually or as an adjuvant therapy to complement the synthetic drugs used presently. The valuable *Moringa oleifera* plant has diverse applications for its different parts, such as leaf extract, seed oil, and seed extract. Different Moringa derivatives offer pharmaceutical and nutraceutical benefits associated with their unique phytochemicals. MOLE, rich in phenolics and flavonoids, possesses antioxidant, antimicrobial, anti-obesity, anti- hypertensive, anti-cancer and anti-diabetic properties, thus making it suitable to act as a pharmacological agent. On the other hand, the high monounsaturated fatty acids (MUFA) with its content in MOSO, especially oleic acid, is a suitable functional edible oil that promotes health. MOSE, with its abundance of phytochemicals, is appropriate for developing functional products and water treatment processes. The plant can be widely utilized for its nutritionally important phytochemicals in pharmaceutical, cosmetic, nutraceutical, food and other industries. However, further research, including clinical trials and validation research is necessary to support the development of natural and functional drugs derived from Moringa. This study demonstrated that when *M.oleifera* seeds and leaves are prepared using very crude methods they can provide, to varying abilities, antimicrobial capabilities comparable to some contemporary remedies against common pathogens that cause human morbidity.

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