Moringa oleifera; A Miracle Tree - Review on Bioactive Compounds, Its Therapeutic Properties, application of innovative technology and value addition

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Abstract

Moringa (M. oleifera Lam) native crop of north India grows in both semi-arid and arid zones of the planet. It is universally called horseradish, drumstick and other in different regions. Moringa oleifera evolved as an extremely admired crop due to its unique aroma and flavor. Moringa oleifera was used in cosmetics, pharmaceutical and nutraceuticals industrial applications. It is prevalently known as a miracle tree because it contains an enormous amount of Vit-C, Vit-A, calcium, protein, potassium and iron respectively. It is twice profitable to farmers compared to other agricultural commodities. Traditionally it is used as an analeptic, antispasmodic, diuretic and expectorant. Due to its esteemed medicinal value, it is replaced with coriander leaves for enhancing flavor. Due to its eminent nutritional contents, it acts as anti-cancer, anti-fertility, hepato-protective, anti-oxidant, cardiovascular activity, anti-epileptic, anti-asthmatic, anti-diabetic, anti-urolithiasis, diuretic, anti-helminthic, anti-ulcer, wound healing, analgesic, anti-pyretic, CNS activity. It has the additional application of advanced technologies like encapsulation, micro-encapsulation and nano-technology. Nowadays mostly used in value-added products such as bakery and confectionery, beverages, instant mixes and dairy products. People found moringa oleifera as a superfood for the individuals who endure malnourishment and poverty.

Keywords: *Bio-active components, Miracle tree, Moringa oleifera, Therapeutic value and Value-added products.*

Introduction:

Moringa oleifera is a quick-growing perennial angiosperm tree that belongs to the family of Moringaceae (Alegbeleye, 2018). Based on the region it is called by different names like drumstick, horseradish, kelor, Marengo, benzolive, maluoggay and other names (Fahey, 2005). It received attention as socioeconomic importance both in torrid regions

(Alegbeleye, 2018). *Moringa oleifera* consists of all edible parts such as leaf, stem, flowers and pods which are highly nutritious and considered nutraceuticals (Ganatra *et al.,* 2012). Because of its high protein value, there will be demand as a supplement in food application industries (Islam *et al.,* 2021). Oleifera is called a multifunctional plant (Adedapo *et al.,* 2009). In the herbal medicine field, it has established accelerated growth both in developed and developing countries due to its intimate source and lower side effects (Mishra *et al.,* 2011). Nearly 70% of people are still adopting it as a non-allopathic medicine (Paikra, 2017). The Moringa pods are well known in south Indian cuisine mainly for their noticeable flavor. On the pacific coast of Mexico, it was used for ornamental purposes (Milla *et al.,* 2021). From ancient times it is pre-owned as a health curing agent (Paikra, 2017; Islam *et al.,* 2021). People found *Moringa oleifera* as a superfood for individuals suffering from hunger and deprivation (Islam *et al.,* 2021).

Origin and cultivation:

Moringa oleifera is a popularly cultivated crop of the Monogeneric family of Moringaceae, a native to sub-Himalayan regions of India, Bangladesh, Pakistan and Afghanistan (Vergara *et al.,* 2017; Fahey, 2005; Paikra, 2017). *M. oleifera* is found on all continents but it's a native crop of north India. Withstanding droughts, Miracle trees were nurtured in both semi-arid regions and arid regions. As reported by researchers it can endure soil pH around 4.5 and 8 nevertheless more favorable to slightly acidic or neutral conditions. *Moringa oleifera* survives for 20 years and in short term, it grows to a height of around 5-10m (Amrutia *et al.,* 2011; Milla *et al.,* 2021). Moringa grows at elevation points from the earth's surface to 1400meters (Roloff *et al.,* 2009). There seem to be 13 species in aggregate. Moringa oleifera is a well-known species in the Moringa genus and family moringacea (Vergara *et al.,* 2017; Adedapo *et al.,* 2009). It is extensively cultivated across India due to its intrinsic pods, leaves and blossoms (Islam *et al.,* 2021). It is commonly called a graceful tree for its breakable branches and cork grey bark (Amrutia *et al.,* 2011).

Taxonomic classification

Kingdom	**Plantae**
Subkingdom	**Tracheobionta**
Superdivision	**Spermatophyta**
Division	**Magnoliophyta**
Class	**Magnoliopsida**
Subclass	**Dilleniidae**
Order	**Capparales**
Family	**Moringacea**
Genus	**Moringa**
Species	**Oleifera**

Sources: Mishra *et al.,* (2011)

Production and exports in Tamil Nadu

In Tamil Nadu moringa considered as main source crop which was cultivated around farm boundaries, cattle sheds, a group of trees in wastelands and isolated fences. In the early 1990s perennial type of moringa was grown by people of the southern part of Tamil Nadu. Moringa is cultivated as intercrop in some parts like Dharapuram taluk in between sorghum and vegetables. It shields farmers during summer from dry winds and provides an additional income source. Farmers considered moringa as foothold summer vegetables. Moringa became a very dominant crop because of its peculiar aroma and flavor. In the southern part of India, many people will consider the serving of food without moringa incomplete (Sekhar *et al.,* 2018; Milla *et al.,* 2021).

In the production of *moringa oleifera*, Tamil Nadu is one of the leading providers with an area of 1.3042ha and an average generation of around 6.71lakhs tones of tender fruits. The production of moringa surrounded areas of Tamil Nadu was Theni which has the highest production and land area (3424ha), Karur (2070ha), Dindigul (2645ha), Tiruppur (1191ha), Thoothukkudi (1465ha), Madurai (536ha) and Ariyalur (813ha) respectively. Because of good income and excellent soil characteristics, moringa cultivation is popular in some districts. The premier spot for the production of moringa was in the mulanur block of Tiruppur district next to santhankulam of Thoothukkudi district. In Tamil Nadu, the hub of moringa cultivation was santhankulam (Paikra, 2017; Sekhar *et al.,* 2018).

From India, approximately 33 tons of moringa seed-based products and seeds are exported especially from Tamil Nadu through Thoothukkudi port. In total exports moringa seed products, alone accounts for 84% and moringa seed kernels were around 15% respectively. The powder is exported abroad from Tamil Nadu to around 12 significant harbors. Big business states of drumstick leave exports in India were Tamil Nadu, Karnataka, Andhra Pradesh and Orissa. Foremost imported countries of oleifera leaves are the United States of America, Germany, South Korea, and the United Kingdom and European countries. There was over a 30% increase in the export of market rate of moringa. They are used in the cosmetics, pharmaceutical and nutraceuticals industries. (Sekhar *et al.,* 2018; Amrutia *et al.,* 2011; Gandji *et al.,* 2018).

Why it is a miracle tree?

Numbers of indispensable compounds are available in plants, leaves, pods and seeds. *Moringa oleifera* contains 7 times more vitamin-C than oranges, 7 times more vitamin-A compare to carrots, 17 times more calcium compare to milk, 9 times greater protein than yogurt, and 15 times more potassium compare to banana, and 25 times more iron compare to spinach. The leaf is a trove of micronutrients that contain more protein compared to eggs (Islam *et al.,* 2021). The seeds are highly nutritious (vitamins and minerals) (Ganatra *et al.,* 2012) and also contain sulphur containing essential amino acids (Paliwal *et al.,* 2011).

Morphological characteristics:

Moringa oleifera is a quick-growing, small and deciduous tree.

Leaves: leaves may be bipinnate or tripinnate long up to 45cm. the leaflets are around 1-2 centimeters long, green, and delicately hairy on the upper portion and bottom along with red-tinged midveins, entire margins, short pointed bases and round apex. The twigs are hairy,

green, and turn brown with time. (Gandji *et al.,* 2018; Ganatra *et al.,* 2012; Milla *et al.,* 2021).

Flowers: Hairy stalks disseminate axillary panicles of around 10-25cm long, bearing bisexual pleasant yellowish-white flowers. Individual blossoms are around 0.7-1cm long and 2cm wide, with five uneven yellowish thinly veined, white, spathulate petals, five stamens with five smaller sterile filaments, and a pistil consisting of a one-celled ovary and slender style (Ganatra *et al.,* 2012; Paikra, 2017).

Fruits: these are trilobed capsules which are commonly called pods. Pods are brown, triangular, and pendulous and split into three parts based on length. When dry, 30-120cm long and 1.8cm wide. In March and April, fruit production mainly occurs. During the development phase, each fruit contains 26 seeds. Pods are in green color when they are immature and turn brown upon maturity (Ganatra *et al.,* 2012; Islam *et al.,* 2021).

Seeds: They are 1cm in diameter and have brownish semi-permeable seed shells with three papery wings. Hulls of seed's color vary from brown to black although they can be white if the kernels are of low viability. The germination time of fertile seeds occurs within 2 weeks. The hull white wings run around 120 intervals from top to bottom. Each tree produces nearly 15000-25000 seeds per year. The average mass of the kernel is around 0.3g/kernel. The hull to kernel ratio is around 75:25 respectively (Sekhar *et al.,* 2018; Ganatra *et al.,* 2012; Islam *et al.,* 2021).

Roots: Saplings produce a tuberous, swollen, taproot since it has a pungent odor and few lateral roots. Trees which are comes out from seeds develop a deep stout taproot with a wide-spreading system (Ganatra *et al.,* 2012; Gandji *et al.,* 2018).

Bark and wood: It is thick, soft, whitish gray, fissured, corky and become rough. When injured, the bark exudes gum that seems to be initially white color but upon exposure, it acquires to reddish-brown or brownish-black color (Roloff *et al.,* 2009; Vergara *et al.,* 2017).

Chemical constituents:

Seeds: it is composed of several compounds like 4-hydroxy phenyl acetonitrile, 4 (alpha-L-Rhamnosyloxy) benzyl isothiocyanate, 4(-L-rhamnosyloxy) phenyl acetonitrile, 4 (alpha-L-Rhamnosyloxy)-benzyl glucosinolate Roridin E, 4-hydroxy phenyl acetamide, 9-Octadecenoic acid, veridiflorol, niazimicin, beta-sitosterol, niazirin, beta-sitosterol-3-O-beta-D-glucopyranoside, glycerol-1-(9-octadecanoic) (Vergara *et al.,* 2017; Ganatra *et al.,* 2012; Milla *et al.,* 2021).

Leaves: it contains components like 4-Hexadecen-6-yne, 4-[(4'-O-acetyl alpha- L-rhamnosyloxy) benzyl isothiocyanate, niazirin and niazirin nitrile glycoside, 4 (alpha-L-Rhamnosyloxy)-benzyl glucosinolate, kaempferide 3-O-(2”-O-galloylrutinoside)-7-alpha-rhamnoside, ethyl palmitate, niaziminin A and B-three mustard oil glycosides, ethyl ester, 7-octadiene-3-ol, kaempferide 3-O-(2”-O-galloylrutinoside), palmitic acid, quercetin-3-O-(6"-

malonyl-glucoside, 3-cyclohexyliden-4-ethyl-E2-dodecenylacetate, 2- hexanone, 2,6-dimethyl-1 and other (Ganatra *et al.,* 2012; Paikra, 2017).

Roots: it is composed of components like deoxy-niazimicine, 4-(alpha-l-rhamnopyranosyloxy)-benzyl glucosinolate, 1, 3-dibenzyl urea, benzyl glucosinolate, alpha-phellandrene, aurantiamide acetate 4 (Gandji *et al.,* 2018; Ganatra *et al.,* 2012; Sekhar *et al.,* 2018).

Socioeconomic importance:

The propagation of Moringa can be done through both clonal and non-clonal. The production and maintenance are easy, owing to the low demand for soil nutrients, pH, and water. The introduction of oleifera into the farm provides a diversified environment, beneficial for both the surrounding ecosystem and the owner of the farm. In western Nigeria viability of leaf-based Moringa, production indicates an increase in net income of around 59.81% / year/ hectare. In north liberia, sellers and retailers believe the sales of leaves are profitable at around 26.6% and are twice profitable compared to other green vegetables (Paikra, 2017). It has wide applications specifically in terms of commercial potential only 2 products are available Moringa leaf powder and oil for cosmetic products. The leaf powder could be sold by placing simply it in containers or plastic bags for preventing moisture absorption, and mixed chocolate and in tea form (Gandji *et al.,* 2018). It is an antiquity tree to the classical civilization but recently it has been rediscovered as a utilitarian tree with more potential uses (Ganatra *et al.,* 2012; Milla *et al.,* 2021).

Economic uses:

Moringa is a rapidly growing tree cultivated in India abundantly and a potential wood source for the paper industry. The pulp provided by wood is considered suitable for newspaper, wrapping material, cellophane and textiles. In Jamaica, an aqueous extract is often used as a blue dye (Sekhar *et al.,* 2018; Ganatra *et al.,* 2012; Amrutia *et al.,* 2011).

Traditional uses:

Among infinite natural vegetation, it is called a wonder vegetable since it has tremendous medicinal and functional properties. It has high curative and medicinal properties. So, consumption in a daily diet will possibly reduce the risk of different degenerative diseases (Ganatra *et al.,* 2012; Islam *et al.,* 2021). Traditionally it is used as an antidepressant, antispasmodic, diuretic and expectorant. The fresh root resembles vesicant and acrid. Gum is viscous and tasteless material. Seeds are stimulant and acrid. The bark is even antifungal, abortifacient and anti-bacterial. Flowers are tonic, diuretic and stimulants which are useful for enhancing the flow of bile. Root bark also acts as an anti-inflammatory, antiviral and analgesic (Mishra *et al.,* 2011; Gandji *et al.,* 2018).

Dosage:

Different edible parts have different dosage levels like leaf juice: 10-20ml, stem bark powder: 2-5g, root bark powder: 2-5g, seed powder: 5-10g, decoction: 50-100ml and root powder 1-3g respectively (Mishra *et al.,* 2011).

Culinary Uses:

In southern India, it is often used in the preparation of different sambars and also it is fried. It is made into several dishes by mixing with mustard seeds, coconut and poppy seeds. It is applied in sambar, dhal, kormas, and curries and is often used as flavoring to the food. In Maharashtra, pods are being used in the creation of sweets and stinging curries which are popularly called Amateur. Saragvakikadhi is a picante popular dish in Gujarat where they use pods for preparation (Ganatra *et al.,* 2012; Milla *et al.,* 2021). Owing to its great medicinal value it could be used in place of coriander leaves for enhancing flavor (Paliwal *et al.,* 2011; Gandji *et al.,* 2018).).

Bioactive components in *moringa oleifera*:

Vitamins:

The better form of vitamin-A is raw leaves of moringa. The important functions of vitamin - An are vision, fertility, embryo development, immunological competence and development in comparison with oranges vitamin - C content concentration is greater in oleifera around 200mg/100g. It protects the body from different effects like pollutants, toxins, antioxidants, and free radicals. Raw leaves of moringa are a good source of Tocopherol (Vit-E) similar to concentrations found in nuts. Tocopherol inhibits cell proliferation (Amrutia *et al.,* 2011; Vergara *et al.,* 2017).

Polyphenols:

Moringa dried leaves are significant in polyphenols such as flavonoids and phenolic acids. Flavonoids, which have a common structure like the benzo-r-pyrone ring, respond to microbial infection in plants. Consumption of flavonoids shows the prevention of chronic diseases like cardiovascular diseases and cancer caused by oxidative stress. The Flavonoid compounds in leaves and their concentrations are myricetin-5.8mg/g, quercetin-0.207mg/g, and kaempferol-7.5 mg/g respectively. Dried leaves contain quercetin of concentration 100mg/100g available in quercetin -3-o-β-d-glucoside form. It is a potent antioxidant with innumerable pharmacological properties. It shows antidiabetic, hypotensive and hypolipidemic properties, apart from that it also diminishes hyperlipidemia and atherosclerosis. Quercetin is used to protect insulin-producing pancreatic β cells from oxidative stress-induced by streptozotocin (Vergara *et al.,* 2017; Sekhar *et al.,* 2018).

Phenolic acids are part of phenolic compounds that naturally occur in plants derived from hydroxybenzoic acid and hydroxycinnamic acid. It shows antimutagenic, antioxidant, anti-cancer, and anti-inflammatory properties. Dried leaves are the most plentiful source of Gallic acid with a concentration of around 1.034mg/g dry weight. On a dry weight basis, the concentration of chlorogenic acid and caffeic acid ranges from 0.018 to 0.489mg/g and 0.409mg/g respectively (Gandji *et al.,* 2018; Vergara *et al.,* 2017; Milla *et al.,* 2021)

The foremost phenolic compound acquaints in moringa is chlorogenic acid which has a major role in glucose metabolisms which forbids the glucose 6-phosphate translocase, and reduces hepatic glycogenolysis and gluconeogenesis. It also lowers postprandial blood glucose concentration, reduces glycemic response, and reduces plasma cholesterol and triglycerides it shows antilipidemic properties (Vergara *et al.,* 2017; Gandji *et al.,* 2018).

Glucosinolates, Alkaloids, and isothiocyanates:

The racemic mixture of chemical compounds which mostly contain necessary nitrogen atoms are called alkaloids. Several compounds are isolated from leaves which include N, α-L-rhamnopyranosyl vincosamide, 4-hydroxy phenylethanamide- α-L-rhamnopyranoside, phenyl acetonitrile pyrrolemarumine and other derivatives. The secondary metabolites derivatives of plants are glucosinolates (Milla *et al.,* 2021; Paikra, 2017; Vergara *et al.,* 2017).

Tannins:

These are water solubilized phenolic components that precipitate gelatin, alkaloids and as well as other polypeptides. In dried leaves, tannin concentration ranges from 13.2g/Kg and 2.06g/kg, with a little higher concentration in freeze-dried leaves. It shows anti-inflammatory, anti-cancer, anti-atherosclerotic, and anti-hepatoxic properties (Vergara *et al.,* 2017; Sekhar *et al.,* 2018).

Saponins:

Oleifera leaves are a wealthy resource of saponins, innate components which are made up of isoprenoids derived aglycone, linked together with one or more glycosidic linkages. On a freeze-dried basis, leaves contain saponins in concentration ranges between 64 and 81g/kg (Vergara *et al.,* 2017).

Fats:

The seeds contain a high proportion of saturated/ monounsaturated fatty acids. M. oleifera seed oil has similar physicochemical and fatty acid content parameters as that of other vegetable oils. So it is considered the best alternative to Tran's fats in the formulation of food. The primary health fats present in the oil are stearic, linoleic, arachidic, behenic, palmitic, oleic, linolenic, eicosenoic, heptadecanoic acids (Vergara *et al.,* 2017; Amrutia *et al.,* 2011).

***Moringa oleifera* as a food additive:**

By inclusion of moringa oleifera into food and value-added products it improves the organoleptic and physicochemical properties and quality and safety of food products. Moringa oleifera plays a potential role in the pathogenesis of food-borne diseases. Moringa oleifera leaf and seed extracts exhibited antibiotic properties which inhibit bacterial growth. Moringa ethanol leaves extract showed some broad-range activity to unfavorable foodborne pathogens like pseudomonas aerugonisa and escheria. coli, staphylococcus aureus, enterobacter aerogenes. The seed chloroform extract exhibited some antimicrobial activity against microorganisms like escheria coli, salmonella Typhimurium, mucor, and rhizopus species. It not only inhibits food-borne pathogens but also inhibits the development of deteriorative microorganisms in food under laboratory conditions. Isothiocyanates in moringa showed antibiotic activity against the microorganism Helicobacter pylori. The existence of numerous antioxidant compounds like carotenoids, flavonoids, phenolics, and ascorbic acid, prolongs the storage period of lipid-containing food products. Incorporating moringa into animal nutrition prevents oxidative stress in in-vivo studies and lipoprotein oxidation in meat products. The oxidative strength of butter oil is improved by drum stick oil. Moringa oleifera

oil also improves butter oil's nutritional value by increasing oleic acid concentration. It improves the water holding capacity, pH, of meat and it also lowers cookery deficit and thiobarbituric acid value. It improves meat quality by enhancing juiciness, and tenderness; prevents discoloration and off-flavor formation. *Moringa oleifera* can be used to improve sensory characteristics of food such as meat and pastries. The incorporation of dehydrated moringa leaves in cookies raised the farinograph absorption of water, reduces dough strength and autograph pasting temperature, and peak viscosity. It increases the hardness, and cohesiveness of dough and reduces the cookie spread ratio (Alegbeleye, 2018; Islam *et al.,* 2021; Gandji *et al.,* 2018).

Adverse effects:

It is considered not safe entirely; studies found various compounds associated with liver, kidney, and other illness conditions. Partially fried seeds of moringa oleifera contain viable mutagens like 4(α-l-ramnopyranosyloxy)-benzyl glucosinolates which increase the volume of micronucleated polychromatophilic erythroblasts and indicate the degree of genotoxicity. Saponin concentration is high in leaves so it is harmful to the vegetarians, consumption decreases the systematic absorption of covalently bonded and tetravalent metals like zinc and magnesium (Milla *et al.,* 2021; Vergara *et al.,* 2017).

Therapeutic uses:

Anti-cancer activity: various ethanol extracts of seeds and leaves of moringa exhibit anti-tumor activity. Isothiocyanates and thiocarbamate are the compounds isolated and act as an inhibitor for tumor promoters like teleocodin B-4-induced Epstein Barr virus (EBV) (Sekhar *et al.,* 2018; Ganatra *et al.,* 2012).

Anti-fertility activity: aqueous extract of oleifera is very effective antifertility in the presence or absence of estradiol dipropionate and progesterone, showing raise in histoarchitecture of uterine (Gandji *et al.,* 2018; Ganatra *et al.,* 2012; Paikra, 2017).

Hepatoprotective activity: alcohol extract of seeds and ethanolic extracts of leaves shows Hepatoprotective effects in isoniazid, rifampicin which induce liver damage. Hepato toxicity is also induced by diclofenac (Vergara *et al.,* 2017; Ganatra *et al.,* 2012). Leaf extract helps in reducing fibrosis in the liver (Islam *et al.,* 2021).

Antioxidant activity: the different extracts of leaves like aqueous 70% methanol, and 80% ethanol extract shows strong radical scavenging activity. Leaves show antioxidant activity because of the presence of a compound called kaempferol (Ganatra *et al.,* 2012). Leaf extract of moringa prevents oxidative damage caused by a high-fat diet (Paikra, 2017).

Cardiovascular activity: ethanolic extract of leaves of oleifera shows hypotensive activity. Thiocarbamate and isothiocyanate glycosides may be responsible for the hypotensive activity. Alkaloids of the moringa tree act as a cardiac stimulants (Ganatra *et al.,* 2012; Milla *et al.,* 2021).

Antiepileptic activity: using pentylenetetrazole methyl group extract of oleifera exhibited anticonvulsant activity (Sekhar *et al.,* 2018; Ganatra *et al.,* 2012; Islam *et al.,* 2021).

Antiasthmatic activity: Seeds are useful for treating patients suffering from bronchial asthma. The dosage is 3g for 3 weeks. It showed good results like reduced erythrocyte sedimentation rate, increases heartbeat values symptoms score and severity of asthma attacks also reduced. After 3 weeks of treatment, there was progress in enforced expiratory volume, vital capacity, and expiratory flow rate values. Alcohol extract of moringa oleifera seeds exhibits spasmolytic in histamine, and acetylcholine-induced bronchospasm (Paikra, 2017).

Antidiabetic activity: Moringa leaves aqueous extract shows antidiabetic activity. It is not only antidiabetic control it acts as glycemic control also (Ganatra *et al.,* 2012). It is considered a vital component in diabetes control and immediately after consumption glucose concentration in the blood drops shortly (Islam *et al.,* 2021).

Antiurolithiatic activity: aqueous extract of bark reduce the load of stones produced using 1% ethylene glycol. Moringa oleifera bark has both therapeutic and precautionary properties (Ganatra *et al.,* 2012; Sekhar *et al.,* 2018).

Diuretic activity: the infusion of flowers, seeds, leaves, roots, and bark into hot water will increase the flow of urine output (Gandji *et al.,* 2018; Ganatra *et al.,* 2012; Paikra, 2017).

Antihelminthic activity: against Indian earthworms the ethanolic extracts of leaves exhibit more antihelminthic activity (Milla *et al.,* 2021; Ganatra *et al.,* 2012).

Antiulcer activity: is exhibited by aqueous extract of leaves (Vergara *et al.,* 2017; Ganatra *et al.,* 2012).

Wound healing activity: this activity was shown by aqueous extract of Moringa oleifera (Biswas *et al.,* 2012). It also raises wound closure rate, decreases scar area, skin breaking strength. Ethanolic and ethyl acetate extract of moringa oleifera shows both wounds healing properties and antipyretic properties (Ganatra *et al.,* 2012; Paikra, 2017).

Analgesic activity: is shown by methanolic bark extract of moringa (Sekhar *et al.,* 2018; Ganatra *et al.,* 2012).

Antipyretic activity: seed extract of ethanol and ethyl acetate shows antipyretic properties (Islam *et al.,* 2021).

CNS activity: leaf extract restores monoamine levels in the brain, which is useful for Alzheimer's disease patients (Paikra, 2017; Milla *et al.,* 2021).

Advanced technologies:

Encapsulation of Lactobacillus species:

Leaf concentration is employed to produce encapsulated lactobacillus food products. The researcher aimed to find out the best possible treatment combination between filler and extract of leaf in producing food supplements of lactobacillus species. Necessary nutrients are available in leaf extract of moringa which is required by the body. 18 various kinds of amino acids were found in an encapsulated food product, in which 9 are essential amino acids. Arginine is one of the important amino acids were humans can't synthesize, this amino acid has significant development in infants suffering from protein regarding their growth (Kumalaningsih *et al.,* 2011).

Due to leaf extract, the cells of lactobacillus start to grow after 3hrs of the initial lag phase. The cell count was rapidly increased after 10hours of time from 10^3 to 10^8 cells per ml respectively. The combination of 8% (w/v) oleifera leaf extract and filler as 15% maltodextrin was used during encapsulation of the product to obtain a great number of nutritive values like calcium 773.45 mg/ 100g, vitamin C50.95mg/100g &A 159.60mg/g, protein 27.37% respectively. The best concentration of 8% leaf extract and maltodextrin was fed to rats and they observed that there was a rapid increase in body weight from 150g-230g respectively (Kumalaningsih *et al.,* 2011).

Microencapsulation:

The anti-oxidants present in moringa oleifera decrease due to the presence of degradation of bioactive compounds. To overcome such a problem microencapsulation technique was used. The researchers studied the consequences of two vegetable polypeptides like soy and pea protein as core material for encapsulating leaf extract by a technique called spray drying. The encapsulation was performed using two different compositions of core: wall material like 1:4 and 1:9 w/w at different temperatures like 140^{o}C, 160^{o}C, and 180^{o}C respectively. The powder quality was high in pea protein encapsulated moringa oleifera extract compare to soya protein encapsulated *moringa oleifera* extract based on Physico-chemical analysis. The moringa oleifera leaf extract micro-encapsulated with soya protein serves as the best carrier of bioactive compounds like 2,2-diphenyl-1-picrylhydrazyl activity and whole flavanoids concentration at temperature ranges from 140-180^{o}C respectively. The encapsulation efficiency of microencapsulated moringa oleifera by both soya and pea protein was better at 4^{o}C compared to 25^{o}C respectively. Encapsulation yield of both proteins ranges from 65.46 to 85.22% and 63.63 to 88.64% respectively. Compare to pea protein isolate, soy protein isolate serve as the best core material for microencapsulation (Osamede *et al.,* 2019).

Nanotechnology:

Silver nanoparticle synthesis was studied from leaf extract of moringa using irradiation sunlight as the main energy source and antimicrobial properties. The production of silver nanoparticles was confirmed in both fresh and freeze-dried samples by using surface plasma resonance at 450nm and 440nm respectively. The diameters of both samples were found to be 9 and 11nm respectively. The synthesized silver nanoparticles showed antimicrobial

activity on fungal and bacterial strains. This may employ a broad range of anti-microbial agents (Moodley *et al.,* 2018).

Value-added products of moringa oleifera:

Biscuits prepared from moringa leaf powder exhibited several health benefits. It acts as anti-inflammation, anti-free radicals, and anti-premature anemia among infants. It protects cell structure and also improves iron, riboflavin content and others. Researchers Selected leaves by sorting process, dehydrated them in a tray drier at 45°C for 24h and dried leaves were blended and sieved (100-mesh size). The researchers have prepared biscuits by using different formulations with a ratio of flour and moringa oleifera powder like 1:1, 1:2, 1:3, 1:4,1:5 and other ingredients were also added based on the required composition. After the preparation of the dough, the biscuits were baked for 25min at a temperature of around 130°C, 135°C, 140°C, 145°C, and 150°C respectively. The result shows that biscuits made with a 1:5 ratio of flour and moringa, baked at 130°C were best. The nutritive value of biscuits were around carbohydrates-(70, 51g/100g), iron- (30.1mg/100g), proteins- (14, 7g/100g), fat- (12, 34 g/100g), riboflavin content- (17, 57mg/ 100g) and calcium – (1181mg/100g) respectively (Dwi *et al.,* 2017).

Scientists have prepared jelly by using moringa leaf purees at various concentrations like 20%, 30% and 40% respectively. Based on sensory evaluation the candy made by moringa leaves was characterized as brownish-green in color, slightly sweet, slightly chewy texture and slight weak aroma odor. Based on organoleptic formulation 20% formulated candy is best and nutritive value was around 0.84 and it is considered nourishment (Nurjanah *et al.,* 2021).

Moringa leaf powder incorporated instant idly mix was prepared at three various percentages like 5%, 10% and 15% respectively. The researchers have evaluated the physiochemical and sensory characteristics of the control and moringa incorporated samples and compared both samples. The instant idli mix in which 10% incorporated leaf powder was widely accepted by sensory evaluation and the score was around 8 respectively. High protein content was noticed in the moringa leaf powder incorporated product compared to the control sample. By increasing in supplementation of moringa leaf powder the proximate compositions like carotenoids, crude fiber and minerals increase respectively. The study showed that 8-10 servings of moringa leaf powder will full fill the daily requirement (35-40% calcium and 11-12% protein) of children and reduces their malnutrition (Reddy *et al.,* 2020).

The researchers studied the moringa leaf powder incorporated in cookies to reduce wastage and give an inexpensive healthy product. In the formulation of cookies, maida flour was blended with drum stick leaf powder with the percentage of 35%, 45% and 55% and baking at 130° for 30-35min respectively. Moringa leaf powder incorporated of ratios 55% and 45% showed the best results, the both percentages also highest sources of ascorbic acid, protein and beta-carotene respectively (Shaik *et al.,* 2018).

By knowing the nutritional importance of moringa leaf, the scientists have studied the effect of moringa leaf incorporated maida flour biscuits by its overall quality. The maida flour was blended with leaf powder with different percentages like 2%, 4%, 6%, 8% and 10% and baked at temperature 180^{o}C for 17min respectively. The results showed that moringa leaf powder incorporated biscuits has high crude fat, protein, crude fiber and ash content compared to wheat flour biscuits. In Farinograph the mixing tolerance and water absorption index of composite wheat and moringa flour was increased with an increase in the concentration of moringa leaf powder the dough stability decreased. With the increase in moringa leaf powder, there was an increase in thickness, decrease in spread ratio and width of biscuits. There was an increase in protein fiber and ash content in 10% moringa leaf powder incorporated biscuit supplements, based on sensory analysis the result showed that 10% incorporated biscuits were widely accepted (Riaz *et al.,* 2021).

Researchers understood the importance of bioactive compounds available in moringa oleifera leaves and aqueous extract contains 340.82mg/g of gallic acid of total phenol content. The researchers have taken IC 50 variety of moringa which gives an extract of around 75.82µg/ml, to enhance the nutritional value of yogurt when it is incorporated with moringa oleifera leaf extract. Researchers formulated moringa leaf incorporated yoghurt at various concentrations like 0.1%, 0.2%, 0.3% and 0.4% for 3hours at 43^{o}C respectively. The pH of yogurt enriched with moringa was slightly decreased. From the above ratio of 0.4% moringa oleifera leaf extract, incorporated yogurt showed the best results and is suitable for manufacture as functional yogurt (El-Gammal *et al.,* 2017).

The researchers have prepared bread by incorporating moring and stevia for diabetic people, formulated in 3 different batches control (100% wheat flour), 1% moringa (50% wheat flour), 2% moringa (100% wheat flour) and baked at temperature 45^{o}C for 30minutes. The result showed that 2% incorporated moringa oleifera bread has a high composition of minerals (10.52g/100g), fiber (37.3g/100g), proteins (13.14g/100g) and carbohydrates and fats when compared to other two samples (control and 1% moringa) respectively (Aurora *et al.,* 2019).
The researchers formulated the biscuits by employing moringa leaf powder with different ratios like 0,5,10 and 15g/ 100g of commercially available gluten-free flour. By incorporation of Moringa oleifera total dietary fiber and protein content was gradually increased the researchers stated that there will be an increase of resistant starch content ranging from 1.1 to 2.7g/100g of dry matter for all moringa oleifera leaf powder incorporated biscuits (0 to 15g/100g) respectively. By incorporating the moringa oleifera leaf powder the hardness, color, and spread ratio of biscuits were affected. The results showed that the highest hardness was recorded in 15g/100g incorporated moringa oleifera incorporated biscuits and the threshold value was high in 10/100g incorporated moringa oleifera incorporated biscuits with a similar spread ratio compared to control biscuits (Giuberti *et al.,* 2021).

Conclusions:

The studies on *M. oleifera* have great importance in India because it was one of the important nutrient-rich trees and make used for various purposes. It possesses anti-cancer, and anti-

diabetic properties Different studies on M. oleifera had proved ROS in cancer cells, which leads to necrosis. The protein present in moringa is responsible for anti-cancer, anti-diabetic activity had evolved into several new therapeutic compounds. The graceful trees have more demand for value addition due to their cost-effectiveness and their nutritious benefits. The demand for snacks is also very high. Several fortification methods are employed in snack development to demolish protein-energy malnutrition. Though it belongs to India different studies like encapsulation, nano-technology, and micro encapsulation procedures made this moringa oleifera completely eminent to the population.

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