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Review Article

PHYTOCHEMISTRY AND MEDICINAL USES OF *MORINGA OLEIFERA*: AN OVERVIEW

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ABSTRACT

This paper review the retrospective studies on the *Moringa oleifera* at molecular level. There are about thirteen species of *Moringa* trees in the family Moringaceae. *Moringa oleifera* Lam. (synonym: *Moringa pterygosperma* Gaertn.) is the most widely known species but other species deserve further research as to their uses. Medicinal value a choice of parts of this plant such as leaves, roots, seed, bark, fruit, flowers and immature pods act as cardiac and circulatory stimulants, have power over antitumor, antipyretic, anti-inflammatory, antiulcer, antispasmodic, diuretic, antihypertensive, cholesterol lowering, antioxidant, antidiabetic, hepatoprotective, antibacterial and antifungal activities, and are being in used for the treatment of different ailments in the indigenous system of medicine. This review focuses on the pharmacological action and pharmaceutical application along with other uses of different parts of this tree.

Keywords: *Moringa*, Cultivation, Pharmacological, Phytochemistry, hepatoprotective.

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INTRODUCTION

The *Moringa* tree is one of the most incredible plants I have ever encountered. This may sound sensationalist, but *Moringa*'s nutritional and medicinal properties have the potential to end malnutrition, starvation, as well as prevent and heal many diseases and maladies worldwide.¹ *Moringa* is truly a miracle plant, and a divine gift for the nourishing and healing of man. This plant has so many uses and special features; it is hard to know where to begin sharing what I have learned about this wonderful plant.

Moringa oleifera is commonly known as drumstick. It is found widely in the sub Himalayan range and commonly cultivated in all places of India. It is a very popular backyard tree that grows to over 9 m height². It has soft, white corky trunk and branches bearing a gummy bark. Each tripinnately compound leaf bears several small

leaflets. The flowers are white and the three winged seeds are scattered by the wind³. The flowers, tender leaves and pods are eaten as vegetable. The leaves are rich in iron and therefore highly recommended for expectant mothers. Since all essential amino acids are present *Moringa* may be rightly called a complete food for total nutrition.⁴

Moringa is the sole genus in the flowering plant family Moringaceae. The genus *moringa* in turn is made up of 13 species.⁵ The species most common, and which is the main subject of this book is the species called "*Moringa Oleifera*." *Moringa Oleifera* is found in many tropical and sub-tropical regions.⁶ *Moringa* can be grown in the even the harshest and driest of soils, where barely anything else will grow. In fact, one of the nicknames of *Moringa* is "never die" due to its incredible ability to survive harsh weather and even drought.⁷



CULTIVATION AND PRODUCTION

Cultivation and Production Moringa oleifera development is achieved in two main ways: sowing and cutting. Traditionally in Sudan the seeds are preferred while vegetative propagation is common in India, Indonesia and in some areas of West Africa⁸. Sowing requires selection of the seeds, when they are easily available and human labor is limited, while the possibility to transplant seedlings allows flexibility in field planting even if it requires extra labor and costs. Seeds germinate within two weeks, at a maximum 2 cm depth. When sowing is planned in nursery, the seedlings can be transplanted when they reach about 30 cm (3–6 weeks after germination)⁹. The number of seeds per kilogram ranges from 3000 to 9000, depending on the variety, with a germination rate of 80%–90% for ideal storage conditions (3 °C, 5%–8% moisture). However, the viability decreases if seeds remain at ambient temperature and high relative humidity, their germination rate dropping to 7.5% after three months¹⁰. Cutting is preferred when seeds availability is scarce and/or when labor is not a limiting factor. Ramachandran et al¹⁰. Reports that plants raised from seeds produce fruits of poorer quality, while Animashaun et al¹³. Suggest that trees grown from seeds develop longer roots (an advantage for stabilization and access to water) compare to that grown from cuttings that have much shorter roots.

When hard woodcuttings (1–2 m long 4–16 cm diameter) from adult trees are planted during the rainy season burying one third in the soil, they readily develop roots that in few months reach a considerable size¹³. Moringa oleifera is an exceptionally fast growing tree, in three months it can be 3 m high and in few years reaches 12 m if it is left to growth naturally. Since the tree vigorously re-sprouts after cutting, pruning or pollarding are usually practiced to enhance lateral branching and give the tree a bush shape in order to facilitate the harvest. Nevertheless, since literature reports about the good practice management of Moringa oleifera are scant, practical trials are needed¹⁴. Leaves and seeds are the parts of the plant of interest. Accordingly, the spatial

distribution in planting Moringa oleifera trees is designed to facilitate the relevant harvest and the management practices. For production of leaves, Moringa oleifera plantation can be designed as follows: (i) intensive production with spacing ranging from 10 cm × 10 cm to 20 cm × 20 cm, harvest interval between 35 to 45 days, irrigation and fertilization are needed; (ii) semintensive production with spacing about 50 cm × 100 cm, harvest interval between 50 to 60 days, irrigation and fertilization suggested; (iii) integrate in an agroforestry system with spacing distance of 2–4 m between rows, harvest interval around 60 days, fertilization and irrigation not strictly necessary. Production decreases from intensive production to less dense spacing (agroforestry system), although a tremendous variability can be observed for a given spatial distribution and the same cultivation management¹⁴. For example, the yield of an intensive plantation can range from 580 to 40 m/ha/year, being season dependent with the largest yield in wet or cold season. There is a need for further studies to assess optimum spacing and harvest intervals that comply with the different climates and production systems. Harvest can be mechanical or manual. Shoots are cut at a 0.5–1 m height above the ground; but leaves can be picked directly off the tree; this practice, however, albeit quicker, leads to a less vigorous re-growth. For the production of seed a low density plantation has a positive effect on yields: typically 2.5 × 2.5 m or 3 × 3 m triangular pattern¹⁵. Fruits (trilobite capsule), referred as pods (brown color and dry and split longitudinally), ripen about three months after flowering and must be harvested as soon as possible. Each pod usually contains about 26 1-cm diameter seeds lined by three whitish papery leaflets on the edge. Like for leaves, also the production of seed shows a tremendous variability. A single tree can produce from 15,000 to 25,000 seeds with an average weight of 0.3 gram per seed moreover early flowering varieties produce pods in six month, while other varieties require more than one year. After pruning, branches develop new pods within 6 months¹⁶.

Vitamin & Mineral Content of Moringa

All values are per 100 grams of edible portion

	Fresh leaves	Dry leaves
Carotene (Vit. A)*	6.78 mg	18.9 mg
Thiamin (B1)	0.06 mg	2.64 mg
Riboflavin (B2)	0.05 mg	20.5 mg
Niacin (B3)	0.8 mg	8.2 mg
Vitamin C	220 mg	17.3 mg
Calcium	440 mg	2,003 mg
Calories	92 cal	205 cal
Carbohydrates	12.5 g	38.2 g
Copper	0.07 mg	0.57 mg
Fat	1.70 g	2.3 g
Fiber	0.90 g	19.2 g
Iron	0.85 mg	28.2 mg
Magnesium	42 mg	368 mg
Phosphorus	70 mg	204 mg
Potassium	259 mg	1,324 mg
Protein	6.70 g	27.1g
Zinc	0.16 mg	3.29 mg

Amino Acid Content of Moringa

All values are per 100 grams of edible portion.

	Fresh Leaves	Dry Leaves
Arginine	406.6 mg	1,325 mg
Histidine	149.8 mg	613 mg
Isoleucine	299.6 mg	825 mg
Leucine	492.2 mg	1,950 mg
Lysine	342.4 mg	1,325 mg
Methionine	117.7 mg	350 mg
Phenylalanine	310.3 mg	1,388 mg
Threonine	117.7 mg	1,188 mg
Tryptophan	107 mg	425 mg
vaniline	374.5 mg	1,063 mg

Geographical sources

M. oleifera is a quick growing tree of 10 m tall, widely cultivated all over the plains of India and naturalized in tropical area. It is also cultivated in north-eastern Pakistan, north-eastern Bangladesh, Sri Lanka, West Asia, the Arabian Peninsula, East and West Africa, throughout the West Indies and southern Florida, in Central and South America from Mexico to Peru, as well as in Brazil and Paraguay. It is cultivated in hedges and homeyard. It grows in all types of soil and grows best in conditions provided in North India and South India⁸. Leaves are up to 60 cm long. The flowers are 1.5-2 cm long. Fertile filaments covered with long fire hair pods 15 to 30 cm long pendulous¹⁷.

Taxonomical classifications

Kingdom -	Plantae
Subkingdom -	Tracheobionta
Super division -	Spermatophyta
Division -	Magnoliophyta
Class -	Magnoliosida
Subclass -	Dilleniidae
Order -	Capparales
Family -	Moringaceae
Genus -	Moringa Adans
Species -	Moringa oleifera Lam
Synonyms -	Moringa pterygosperma

Botanical Description

Synonyms.

Latin -	Moringa oleifera
Sanskrit -	Subhanjana
Hindi -	Saguna, Sainjna
Gujarati -	Suragavo
Tamil -	Morigkai
Telugu -	Mulaga, Munaga

Malayalam –Murinna, Sigr

Punjabi - Sainjna, Soanjna

Unani - Sahajan

Ayurvedic - Akshiva, Haritashaaka, Raktaka, Tikshnagandhaa

Arabian - Rawag

French - Moringe à graine ailée, Morungue

Spanish - Ángela, Ben, Moringa

Portuguese - Moringa, Moringueiro

Chinese - La ken

English - Drumstick tree, Horseradish tree, Ben tree

Traditional uses

Each part of *M. oleifera* has unique medicinal properties; hence traditionally it is used for the treatment of various diseases. Some of them are listed below

a) **Leaves:-** It possess different properties such as Antibacterial, Infection, Urinary tract infection, Epstein –bar virus, Herpes simplex virus, Fever, Hepatic, Anti-tumor, Headache, Antioxidant, Lactation, Antiseptic, Scurvy, and tonic.

b) **Flowers:-** Throat infection, Common cold, Anthelmintic, Antitumor, Rheumatism, Diuretic, Tonic.

c) **Roots:-** Cardiotonic, Dental caries, Common cold, Diuretic, Antispasmodic, Epilepsy, Gout, Headache, Abortifacient, Carminative.

d) **Bark:-** Dental caries, Toothache, Common cold, Antitumor, Snakebite, Scorpion bite, Abortifacient, Birth control and Scurvy.

e) **Pods:-** Anthelmintic, Skin cancer, Anti-hypertensive, Diabetes, Joint pain.

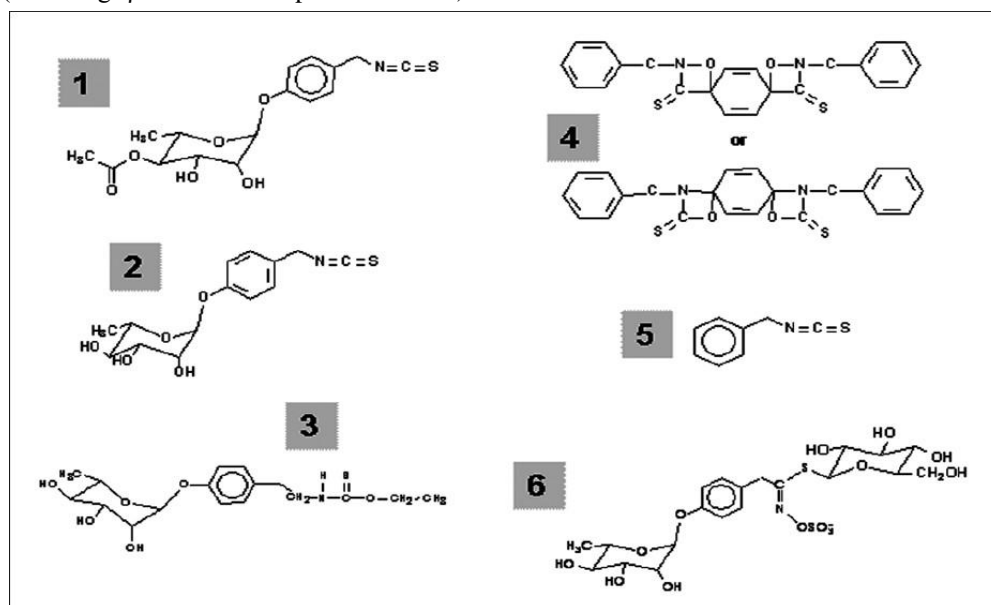
f) **Gum:-** Rheumatism, Astringent.^{18,19,20.}

PHYTOCHEMISTRY

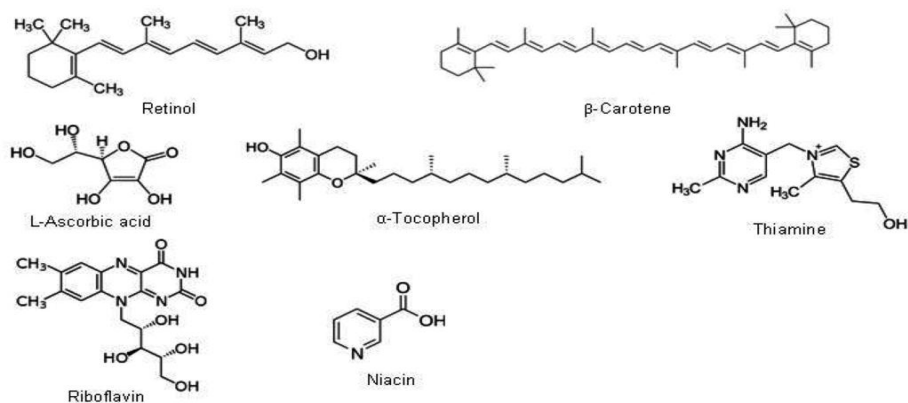
Phytochemicals are, in the strictest sense of the word, chemicals produced by plants. Commonly, though, the word refers to only those chemicals which may have an impact on health, or on flavor, texture, smell, or color of the plants, but are not required by humans as essential nutrients. An examination of the phytochemicals of Moringa species affords the opportunity to examine a range of fairly unique compounds²¹. In particular, this plant family is rich in compounds containing the simple sugar, rhamnose, and it is rich in a fairly unique group of compounds called glucosinolates and isothiocyanates. For example, specific components of Moringa preparations that have been reported to have hypotensive, anticancer, and antibacterial activity include 4-(4'-O-acetyl- α -L-rhamnopyranosyloxy)benzyl isothiocyanate [1], 4-(α -L-rhamnopyranosyloxy)benzyl isothiocyanate [2], niazimicin [3], Pterygospermin [4], Benzyl isothiocyanate [5], and 4-(α -L-rhamnopyranosyloxy)benzyl glucosinolate [6]. While these compounds are relatively unique to the Moringa family, it is also rich in

a number of vitamins and minerals as well as other more commonly recognized phytochemicals such as the carotenoids (including β -carotene or pro-vitamin A).

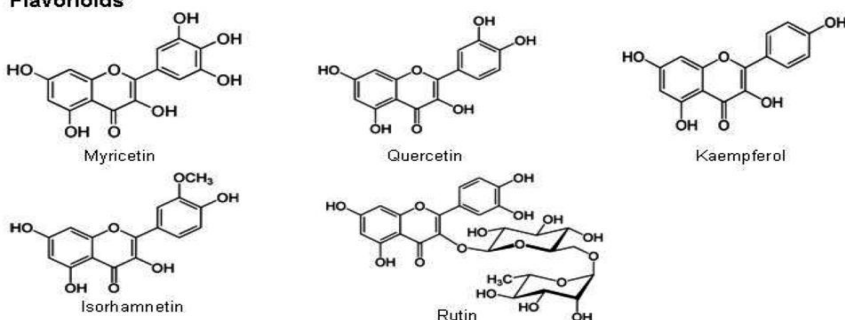
These attributes are all discussed extensively by Lowell Fuglie and others, and will be the subject of a future review in this series²².



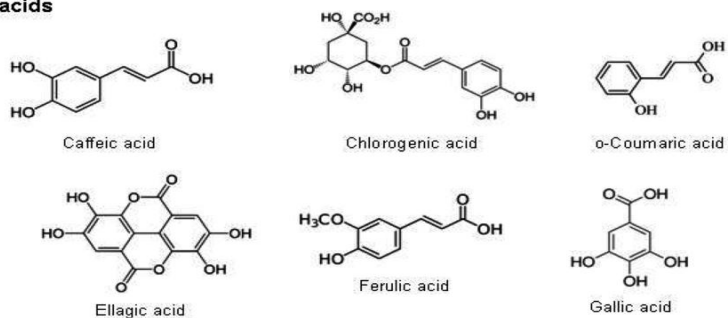
Vitamins



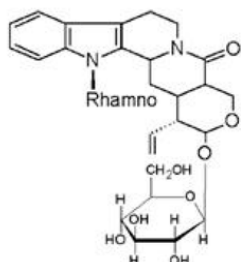
Flavonoids



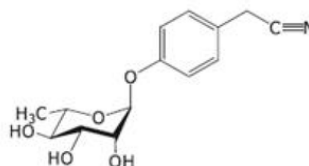
Phenolic acids



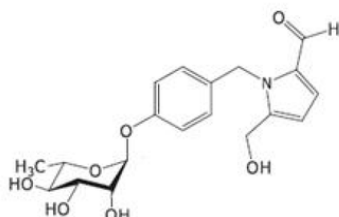
Alkaloids



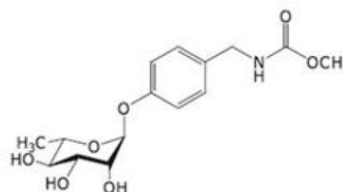
N,α-L-rhamnopyranosyl vincosamide



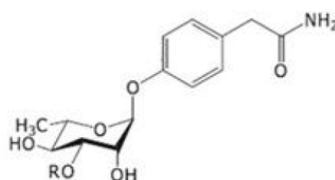
4-(α-L-rhamnopyranosyloxy)phenylacetonitrile (Niazirin)



Pyrrolemarumine 4''-O-α-L-rhamnopyranoside



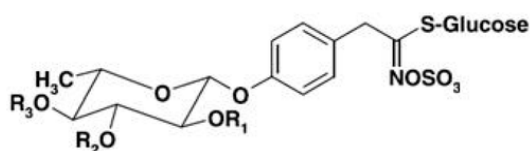
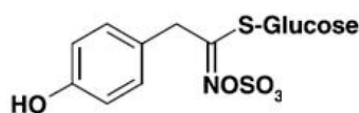
methyl 4-(α-L-rhamnopyranosyloxy)-benzylcarbamate



4'-hydroxyphenylethanamide-α-L-rhamnopyranoside (Marumoside A) (R = H)

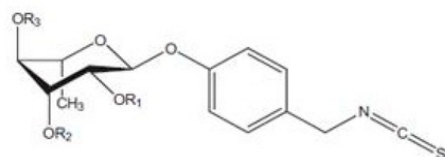
4'-hydroxyphenylethanamide-α-L-rhamnopyranoside (Marumoside B) (R = D-Glucose)

Glucosinolates

4-O-(α-L-rhamnopyranosyloxy)-benzyl glucosinolate (R₁, R₂, R₃ = H)4-O-(α-L-acetyl-rhamnopyranosyloxy)-benzyl glucosinolate Isomer 1 (R₁, R₂ = H; R₃ = Ac)4-O-(α-L-acetyl-rhamnopyranosyloxy)-benzyl glucosinolate Isomer 2 (R₁, R₃ = H; R₂ = Ac)4-O-(α-L-acetyl-rhamnopyranosyloxy)-benzyl glucosinolate Isomer 3 (R₂, R₃ = H; R₁ = Ac)

4-hydroxybenzyl glucosinolate (sinalbin)

Isothiocyanates

4-(α-L-rhamnosyloxy)benzyl isothiocyanate (R₁, R₂, R₃ = H)4-(4'-O-acetyl-α-L-rhamnosyloxy)benzyl isothiocyanate (R₁, R₂ = H; R₃ = Ac)4-(3'-O-acetyl-α-L-rhamnosyloxy)benzyl isothiocyanate (R₁, R₃ = H; R₂ = Ac)4-(2'-O-acetyl-α-L-rhamnosyloxy)benzyl isothiocyanate (R₂, R₃ = H; R₁ = Ac)

Vitamins

Fresh leaves of *Moringa oleifera* are reported to contain 11,300–23,000 IU of vitamin A. Vitamin A plays key roles in many physiological processes such as vision, reproduction, embryonic growth and development, immune competence, cell differentiation, cell proliferation and apoptosis, maintenance of epithelial tissue, and brain function. Its deficiency is still prevalent in many developing countries, and considered responsible for child and maternal mortality. Fresh leaves of *Moringa oleifera* are also a good source of carotenoids with pro-vitamin A action.

They contain 6.6–6.8 mg/100 g of β -carotene, greater than carrots, pumpkin and apricots (6.9, 3.6 and 2.2 mg/100 g, respectively). β -carotene is more concentrated in the dried leaves, with amounts ranging from 17.6 to 39.6 mg/100 g of dry weight (DW). This wide range may be explained by the different environmental conditions existing among different origin countries, genetic of the plant, drying method and the different extraction and analysis methods employed as well. Freeze-drying seems to be the most conservative dehydration method. In freeze-drying leaves the β -carotene content is approximately 66 mg/100 g. B-carotene is more concentrated in the dried leaves, with amounts ranging from 17.6 to 39.6 mg/100 g of dry weight (DW). This wide range may be explained by the different environmental conditions existing among different origin countries, genetic of the plant, drying method and the different extraction and analysis methods employed as well. Freeze-drying seems to be the most conservative dehydration method. In freeze-drying leaves the β -carotene content is approximately 66 mg/100 g.

Moringa oleifera is an interesting source of vitamin C. Fresh leaves contain approximately 200 mg/100 g, greater than orange. These amounts are of particular interest, as the vitamin C intervenes in the synthesis and metabolism of many compounds, like tyrosine, folic acid and tryptophan, hydroxylation of glycine, proline, lysine carnitine and catecholamine. It facilitates the conversion of cholesterol into bile acids and hence lowers blood cholesterol levels and increases the absorption of iron in the gut by reducing ferric to ferrous state. Finally, it acts as antioxidant, protecting the body from various deleterious effects of free radicals, pollutants and toxins²³. However, being vitamin C sensitive to heat and oxygen, it is rapidly oxidized, so much so that its concentration in the *Moringa oleifera* dried leaves is lower than in the fresh leaves, dropping to 18.7 to 140 mg/100 g of DW.

Moringa oleifera fresh leaves are a good source of vitamin E (in particular α -tocopherol) and contain approximately 9.0 mg/100 g of this compound, similarly to nuts. Vitamin E acts mainly as liposoluble antioxidants, but it is also involved in the modulation of gene expression, inhibition of cell proliferation, platelet aggregation, monocyte adhesion and regulation of bone mass. Drying procedure determines a concentration of vitamin E up to values of 74.45–122.16 mg/100 g of DW. Among vitamins of group B, only thiamine;

riboflavin and niacin seem present in *Moringa oleifera* leaves. These vitamins mainly act as cofactors of many enzymes involved in the metabolism of nutrients and energy production, and their concentration in fresh leaves ranges 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, similarly to fruits and vegetable. Only one study reported the contribution of vitamin B1, B2 and B3 of dried leaves of *Moringa oleifera*. Their concentrations were 2.85, 22.16 and 8.86 mg/100g of DW, respectively. However, the amount of riboflavin in dried leaves seems very high compared to that of fresh leaves. Further studies are needed to confirm these values. Finally, Girija *et al.* showed an appreciable physiological availability of these three vitamins in leaves of *Moringa oleifera* (61.6%, 51.5% and 39.9%, respectively). We did not find studies about other vitamin of group B or vitamin D and K in *Moringa oleifera* leave; therefore further studies on this topic are needed²⁴.

Polyphenols

Moringa oleifera dried leaves are a great source of polyphenols. Their concentrations range from 2090 to 12,200 mgGAE/100 g of DW (or 1600 to 3400 mgTAE/100g of DW). These amounts are greater than those found in fruits and vegetable. The different environmental conditions in the various origin countries, the harvesting season, the genetic of the plant, the drying method, the leaf maturity stage and the extractive method used may explain such wide range of reported values. Principal polyphenol compounds in *Moringa oleifera* leaves are flavonoids and phenolic acids²⁵.

Phenolic Acids

Phenolic acids are a sub-group of phenolic compounds derived from hydroxybenzoic acid and

hydroxycinnamic acid, naturally present in plants. Thanks to their documented effects on human

Health, the contribution of food-supplied phenolic acids is a subject of increasing interest. In particular, these compounds are mainly studied for their documented antioxidant, anti-inflammatory, antimutagenic and anticancer properties. Particularly abundant in fruit and vegetables, phenolic acids were found in great amounts in *Moringa oleifera* leaves too. In dried leaves, gallic acid seems to be the most abundant, with a concentration of approximately 1.034 mg/g of DW, although Bajpai *et al.* only found poorly detectable amounts. The concentration of chlorogenic and caffeic acids ranges from 0.018 to 0.489 mg/g of DW and ND to 0.409 mg/g of DW, respectively. Lower, but appreciable, concentrations were found for ellagic and ferulic acids.

Their concentrations range from ND to 0.189 mg/g and 0.078 to 0.128 mg/g of DW, respectively. Some of these compounds were found more concentrated in freeze-dried leaves. Specifically, Zhang *et al.*, in leaves harvested in Florida and subsequently freeze-dried, found approximately 6.457 mg/g of DW of o-coumaric acid and 0.536 mg/g of DW of caffeic acid, while p-

coumaric, synaptic, gentistic and syringic acids were found in poorly detectable amounts. Like for the flavonoids, the different environmental conditions, harvesting season, genetic of the plant, drying method, leaf maturity stage, extraction method used and the different sensitivity of the analytical methods may have contributed to the high inter-study variation in the concentrations of phenolic acids in *Moringa oleifera* leaves²⁶.

Alkaloids

Alkaloids are a group of naturally occurring chemical compounds that contain mostly basic nitrogen atoms. This nitrogen may occur in the form of a primary amine (RNH₂), a secondary amine (R₂NH) or a tertiary amine (R₃N). In addition to carbon, hydrogen and nitrogen, most alkaloids contain oxygen. Alkaloids are of particular interest thanks to their pharmacological properties. The presence of these compounds has been confirmed in *Moringa oleifera* leaves. Several of these compounds, such as *N*, α -L-rhamnopyranosyl vicosamide, 4-(α -L-rhamnopyranosyloxy) phenyl acetonitrile (niazirin), pyrrolemarumine 4''-*O*- α -L-rhamnopyranoside, 4'-hydroxy phenylethanamide- α -L-rhamnopyranoside (marumosi A) and its 3-*O*- β -D-glucopyranosyl-derivative (marumosi B) and methyl 4-(α -L-rhamnopyranosyloxy)-benzylcarbamate, have been isolated in *Moringa oleifera* leaves²⁷.

Glucosinolates and Isothiocyanates

Glucosinolates are a group of secondary metabolites in plants. Structurally they are β -D-glucosides of thiooxime-*O*-sulfates and synthesized from amino acids. Appreciable amounts of these compounds were found in *Moringa oleifera* leaves. In particular, around 116 and 63 mg/g of DW in young and older leaves, respectively, are reported. These amounts are close to, and in some case larger than, those found in many cruciferous vegetables (e.g., broccoli, cabbage, radish), mainly sources of these compounds. 4-*O*-(α -L-rhamnopyranosyloxy)-benzyl glucosinolate has been identified as the dominant leaf glucosinolate of *Moringa oleifera* and is accompanied by lower levels of three isomeric 4-*O*-(α -L-acetyl-rhamnopyranosyloxy)-benzyl glucosinolates, which reflect the three position of the acetyl group at the rhamnose moiety of the molecule. The concentrations of these compounds seem affected by the physiological stage of the plant and by the maturity stage of the leaves.

The concentration of 4-*O*-(α -L-rhamnopyranosyloxy)-benzyl glucosinolate ranges from 21.84 to 59.4 mg/g of DW, while the concentrations of the three isomer of 4-*O*-(α -L-acetyl-rhamnopyranosyloxy)-benzyl glucosinolates range from 2.16 to 5.0 mg/g of DW, 1.2 to 1.8 mg/g of DW and 12.76 to 50.2 mg/g of DW for isomer 1, 2 and 3, respectively. Amaglo *et al.* Report the presence of 4-hydroxybenzyl (sinabin), with a concentration ranging between ND and 2.36 mg/g of DW. Glucosinolates can be hydrolyzed by myrosinase to produce D-glucose and various other degradation products like isothiocyanates²⁸.

Tannins

Tannins are water-soluble phenolic compounds that bind to and precipitate alkaloids, gelatin and other proteins. They exhibit various biological properties: anti-cancer, antiatherosclerotic, anti-inflammatory, anti-hepatotoxic, antibacterial and anti-HIV replication activity. *Moringa oleifera* leaves are an appreciable source of tannins. Their concentrations range between 13.2 and 20.6 gTAE/kg in dried leaves and between 5.0 and 12.0 gTAE/kg in freeze-dried leaves. These amounts are greater than concentrations found in nuts, similar to those found in some plants and berries, but much lower compared to the concentrations found in other medicinal plants²⁹.

Saponins

Saponins are a group of natural compounds that consist of an isoprenoidal-derived aglycone, designated genin or sapogenin, covalently linked to one or more sugar moieties. Even though some saponins have hemolytic side effects, they are studied for their anti-cancer properties. *Moringa oleifera* leaves are a good source of saponins. Their concentration in dried leaves is approximately 50 gDE/kg of DW, while in freeze-dried leaves it ranges between 64 and 81 gDE/kg of DW. These amounts are greater than the concentrations found in other plants, but slightly lower than ginseng root, one of the mainly source of these compounds³⁰.

Oxalates and Phytates

Oxalates and phytates are anti-nutritional compounds as they bind minerals inhibiting the intestinal absorption. *Moringa oleifera* leaves present high contents of these compounds. Oxalates content of dried leaves range from 430 to 1050 mg/100 g of DW, similar to other plants rich in these compounds, while phytates concentration range from 25 to 31 g/kg of DW in dried leaves and from 21 and 23 g/kg of DW in freeze-dried leaves. These amounts are greater than those found in legumes and cereals, but lower than brans³¹.

PHARMACOLOGICAL ACTIVITY:

Antimicrobial Activity

Antimicrobial Activity A. Cáceres *et al.* (1991) reported antimicrobial activities of *Moringa oleifera* leaves, roots, bark and seeds in vitro against bacteria, yeast, dermatophytes and helminths by a disk-diffusion method²³. The fresh leaf juice and aqueous extracts from the seeds inhibit the growth of *Pseudomonas aeruginosa* and *Staphylococcus aureus*³². No activity was demonstrated against other pathogenic Gram-positive and Gram-negative bacteria and *Candida albicans*. Doughari, J. H. *et al.* were demonstrated the aqueous and organic leaves extracts of M.O. for the treatment of infectious disease were tested for their activity against *Salmonella typhi* isolated from blood clot culture using the disc diffusion method³³.

Moringa roots have antibacterial activity and are reported to be rich in antimicrobial agents. These are reported to contain an active antibiotic principle, pterygospermin, which has powerful antibacterial and fungicidal effects. A similar compound is found to be responsible for the antibacterial and fungicidal effects of

its flowers. The root extract also possesses antimicrobial activity attributed to the presence of 4- α -L-rhamnosyloxy benzyl isothiocyanate³⁴,

The aglycone of deoxy-niazimicine (N-benzyl, Sethyl thioformate) 7 isolated from the chloroform fraction of an ethanol extract of the root bark was found to be responsible for the antibacterial and antifungal activities. The bark extract has been shown to possess antifungal activity, while the juice from the stem bark showed antibacterial effect against *Staphylococcus aureus*. The fresh leaf juice was found to inhibit the growth of microorganisms (*Pseudomonas aeruginosa* and *Staphylococcus aureus*), pathogenic to man³⁵.

Antitumor, anticancer and antiinflammatory activities

Moringa leaves to be a potential source for antitumor activity. O-Ethyl- 4-(α -L-rhamnosyloxy)benzyl carbamate 11 together with 4(α -L-rhamnosyloxy)-benzyl isothiocyanate 3, niazimicin 4 and 3-O-(6'-O-oleoyl- β -D glucopyranosyl)- β -sitosterol 15 have been tested for their potential antitumor promoting activity using an in vitro assay which showed significant inhibitory effects on Epstein–Barr virus-early antigen³⁶. Niazimicin has been proposed to be a potent chemo preventive agent in chemical carcinogenesis. The seed extracts have also been found to be effective on hepatic carcinogen metabolizing enzymes, antioxidant parameters and skin papillomagenesis in mice. A seed ointment had a similar effect to neomycin against *Staphylococcus aureus* pyoderma in mice. It has been found that niaziminin 9 10, a thiocarbamate from the leaves of *M. oleifera*, exhibits inhibition of tumor-promoter-induced Epstein–Barr virus activation³⁷. On the other hand, among the isothiocyanates, naturally occurring 4-[(4'-O-acetyl- α -i-rhamnosyloxy) benzyl] 2, significantly inhibited tumor-promoter induced Epstein–Barr virus activation, suggesting that the isothiocyano group is a critical structural factor for activity 26. The crude ethanol extract of dried seeds inhibited the carrageenan-induced inflammation in the hind paw of mice³⁸. The hexane fractions of the crude ethanol extract of the dried seeds also inhibited inflammation, and both butanol and water fractions inhibited inflammation. On the other hand, the ethyl acetate fraction caused an increase in inflammation and exhibited toxicity. The mice died after oral administration of the fraction. The crude ethanol extract also inhibited the formation of Epstein-Barr virus-early antigen (EBV-EA) induced by 12-O-tetradecanoylphorbol-13-acetate (TPA) suggesting its antitumor-promoting activity³⁹.

A Cáceres et al. (1992) reported anti-inflammatory activity from the hot water infusions of flowers, leaves, roots, seeds and stalks or bark of *Moringa oleifera* using carrageenan-induced hind paw edema in rats. B. Medhi et al. (1996) evaluated anti-inflammatory activity of methanol extract of *Moringa oleifera* root bark using carrageenin induced paw edema in mice as animal model⁴⁰. M. Ndiaye et al. (2002) tested anti-inflammatory action of an aqueous extract of root of *Moringa oleifera* in rats using indomethacin (10 mg/kg) as standard drug and oedema was induced in the rat-paw

by subcutaneous injection of carrageenin. At a dose of 750 mg/kg the *Moringa oleifera* treatment significantly inhibited the development of oedema at 1, 3 and 5 hours (reduction by 53.5, 44.6 and 51.1% respectively). S.G. Mahajan et al. (2007) investigated anti – inflammatory activity from the ethanolic extract of seeds of *Moringa oleifera*^{41,42}. The extract was pharmacologically evaluated against immunemediated inflammatory responses in toluene diisocyanate (TDI as antigen)-induced asthma in Wistar rats. S.G. Mahajan et al. (2007) reported anti-arthritis activity of ethanolic extract of seeds of *Moringa oleifera* Lam. in adjuvant-induced arthritis in adult female Wistar rats. K.V. Sashidhara et al. (2009) from the roots of *Moringa oleifera* isolated and characterized aurantiamide acetate 4 and 1,3-dibenzyl urea 5. Isolated compounds inhibited the production of TNF-alpha and IL-2. S.G. Mahajan et al. (2009) evaluated anti-inflammatory activity from the n-butanol extract of the seeds of *Moringa oleifera* against ovalbumin-induced airway inflammation in guinea pigs. The crude methanol extract of root by oral administration inhibits carrageenan-induced rat paw oedema in a dose dependent manner^{43,44}.

Hepatoprotective Activity

Alaaeldin A. Hamza et al investigated that the administration of M.O seed extract decreased the CCl₄-induced elevation of serum aminotransferase activities and globulin level⁴⁵. The elevations of hepatic hydroxyproline content and myeloperoxidase activity were also reduced by M.O treatment. Liver fibrosis was induced by the oral administration of 20% carbon tetrachloride (CCl₄), twice weekly and for 8 weeks⁴⁶. The biochemical and histological results showed that M.O. reduced liver damage as well as symptoms of liver fibrosis. S. Fakurazi et al showed that initiation of acetaminophen toxicities is believed to be promoted by oxidative stress during the event of overdose. MO showed that the hepatoprotective activity gives significant histopathological analysis and reduction of level of alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ASP) in the group treat with MO compared to those treated with acetaminophen alone. The level of glutathione (GSH) was found to be restored in MO treated animal^{47,48}.

U.K. Mazumder et al. (1999) investigated hematological along with hepatorenal functions of methanolic extract of *Moringa oleifera* roots. Doses of the crude extract (CE) on liver and kidney functions and hematological parameters in mice were studied. No alteration in hematological and biochemical parameters at low and moderate dose level of daily and low dose level of weekly treatment of the extract was observed. However, the extract at moderate dose level in weekly treatment changed serum aminotransferase and plasma cholesterol levels significantly. High dose in addition to the above parameters changed total bilirubin, non protein nitrogen, blood urea and plasma protein. High dose of daily treatment and moderate and high dose of weekly treatment of CE increased WBC count and decreased clotting time significantly⁴⁹. L. Pari & N.A. Kumar

(2002) evaluated hepatoprotective effect of ethanolic extract leaves of *Moringa oleifera* on liver damage induced by antitubercular drugs such as isoniazid (INH), rifampicin (RMP), and pyrazinamide (PZA) in rats. Oral administration of the extract showed a significant protective action made evident by its effect on the levels of glutamic oxaloacetic transaminase (aspartate aminotransferase), glutamic pyruvic transaminase (alanine aminotransferase), alkaline phosphatase, and bilirubin in the serum; lipids, and lipid peroxidation levels in liver. This observation was supplemented by histopathological examination of liver sections. A.A. Hamza (2007) reported hepatoprotective action of *Moringa oleifera* seeds against Diclofenac (DIC)-induced hepatic toxicity in male albino rats. Administration of DIC at 150 mg/kg developed acute hepatic damage, as demonstrated by increased serum alanine aminotransferase (ALT) activity and histopathological changes⁵⁰.

In addition, DIC treatment resulted in an increase in the hepatic malonaldehyde level and depletion in total antioxidant capacity, reduced glutathione content, catalase, and superoxide dismutase activities. Treatment with herbal extracts for 30 days before DIC treatment significantly ameliorated the indices of hepatotoxicity induced by DIC. S. Fakurazi et al. (2008) reported hepatoprotective action of *Moringa oleifera* against acetaminophen induced liver injury in Sprague-Dawley rats using silymarin as standard drug⁵¹. The hepatoprotective activity of *Moringa* extract was observed following significant histopathological analysis and reduction of the level of alanine aminotransferase (ALT), aspartate aminotransferase (AST) and alkaline phosphatase (ALP) in groups pretreated with *Moringa* compared to those treated with Acetaminophen alone. Meanwhile, the level of glutathione (GSH) was found to be restored in *Moringa* treated animals compared to the groups treated with Acetaminophen alone. A.A. Hamza (2010) evaluated the effect of *Moringa oleifera* seed extract on liver fibrosis. Liver fibrosis was induced by the oral administration of 20% carbon tetrachloride (CCl₄). Simultaneously, *M.oleifera* seed extract (1g/kg) was orally administered daily. The administration of *Moringa* seed extract decreased the CCl₄-induced elevation of serum aminotransferase activities and globulin level. The elevations of hepatic hydroxyproline content and myeloperoxidase activity were also reduced by *Moringa* treatment. Furthermore, the immunohistochemical study showed that *Moringa* markedly reduced the numbers of smooth muscle alpha-actin-positive cells and the accumulation of collagens I and III in liver.

Anti-ulcer study were conducted to test the methanolic extract of MO has ulcer protective effects as dose dependently against pylorus-ligation, ethanol, cold resistant stress and aspirine induced gastric ulcer in rats (Vinay kumar verma et al, 2012). The aqueous extract of MO also has been studied for its protecting action against ulcer formation by modulating 5-HT secretion through EC cell count and mucosal thickness (Siddhartha debnath et al, 2011). Devraj et al conducted a study which showed that the extract of leaves and

fruits of MO has ability to heal acetic acid induced chronic gastric ulcers. The leaf extracts showed a significant reduction of stress induced gastric ulcers and cysteamine induced duodenal ulcers. Ankur Patel et al examined that the ethanol extract of roots of MO has protective effect against ethanol induced gastric mucosal injury in rats which showed that the MO has ability to act against gastric ulcer⁵³.

M. oleifera roots have been reported to possess antispasmodic activity. *Moringa* leaves have been extensively studied pharmacologically and it has been found that the ethanol extract and its constituents exhibit antispasmodic effects possibly through calcium channel blockade. The antispasmodic activity of the ethanol extract of *M. oleifera* leaves has been attributed to the presence of 4-[α -[L-rhamnosyloxy] benzyl]-o-methyl thiocarbamate [trans], which forms the basis for its traditional use in diarrhea. Moreover, spasmolytic activity exhibited by different constituents provides pharmacological basis for the traditional uses of this plant in gastrointestinal motility disorder. The methanol fraction of *M. oleifera* leaf extract showed antiulcerogenic and hepatoprotective effects in rats. Aqueous leaf extracts also showed antiulcer effect indicating that the antiulcer component is widely distributed in this plant. *Moringa* roots have also been reported to possess hepatoprotective activity. The aqueous and alcohol extracts from *Moringa* flowers were also found to have a significant hepatoprotective effect which may be due to the presence of quercetin, a well known flavonoid with hepatoprotective activity^{54,55}.

Antihypertensive, diuretic and cholesterol lowering activities

The widespread combination of diuretic along with lipid and blood pressure lowering constituents make this plant highly useful in cardiovascular disorders⁵⁶. *Moringa* leaf juice is known to have a stabilizing effect on blood pressure. The Wealth of India, 1962; Nitrile, mustard oil glycosides and thiocarbamate glycosides have been isolated from *Moringa* leaves, which were found to be responsible for the blood pressure lowering effect. Most of these compounds, bearing thiocarbamate, carbamate or nitrile groups, are fully acetylated glycosides, which are very rare in nature⁵⁷.

Bioassay guided fractionation of the active ethanol extract of *Moringa* leaves led to the isolation of four pure compounds, niazinin A, niazinin B, niazimicin and niazininA + B which showed a blood pressure lowering effect in rats mediated possibly through a calcium antagonist effect. Activity-directed fractionation of the ethanol extract of pods of *M.oleifera* has led to the isolation of thiocarbamate and isothiocyanate glycosides which are known to be the hypotensive principles^{58,59}. Methyl phydroxybenzoate and β -sitosterol investigated in the pods of *M. oleifera* have also shown promising hypotensive activity, *Moringa* roots, leaves, flowers, gum and the aqueous infusion of seeds have been found to possess diuretic activity and such diuretic components are likely to play a complementary role in the overall blood pressure lowering effect of this plant. The crude

extract of Moringa leaves has a significant cholesterol lowering action in the serum of high fat diet fed rats which might be attributed to the presence of a bioactive phytoconstituent, i.e. β -sitosterol. Moringa fruit has been found to lower the serum cholesterol, phospholipids, triglycerides, low density lipoprotein [LDL], very low density lipoprotein [VLDL] cholesterol to phospholipid ratio, atherogenic index lipid and reduced the lipid profile of liver, heart and aorta in hypercholesteremic rabbits and increased the excretion of fecal cholesterol^{60,61 62}.

Antiurolithiatic Activity

The effect of oral administration of aqueous and alcoholic extract of *M. oleifera* root-wood on calcium oxalate urolithiasis has been studied in male Wistar albino rats. Ethylene glycol feeding resulted in hyperoxaluria as well as increased renal excretion of calcium and phosphate. Supplementation with 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 in the kidneys of calculogenic rats was also significantly lowered by curative and preventive treatment using aqueous and alcoholic extracts. Thus the results indicate that the root-wood of *M. oleifera* is endowed with antiurolithiatic activity⁶³.

Antifertility Activity

The aqueous extract of root and bark at a dose of 200mg/kg and 400mg/kg, respectively showed post-coital antifertility. Effect in rat and also induced foetal resorption at late pregnancy. An aqueous extract of *Moringa oleifera* roots was investigated for its estrogenic, antiestrogenic, progestational and anti-progestational activities. Doses up to 600 mg/kg of the extract orally failed to induce a decidual response in the traumatized uterus of ovariectomized rats. The antifertility effect of the extract appears to be due to multiple attributes⁶⁴.

A.O. Prakash et al. (1987) investigated antifertility activity from the aqueous extract of *Moringa oleifera* roots. The effect of aqueous extract has been studied on histoarchitecture of the uterus during pre and post-implantation stages in rats. S. Shukla et al. (1988) reported anti-implantation activity from the aqueous extract of *Moringa oleifera* in female reproductive organs of cyclic rats and also antifertility activity from the aqueous extract of the roots of the plant. Oral administration of extract progressively increased the uterine wet weight of bilaterally ovariectomized rats. This estrogenic activity was supported by stimulation of uterine histo-architecture. When the extract was given conjointly with estradiol dipropionate (EDP), there was a successive reduction in the uterine wet weight when compared to the gain with EDP alone and uterine histological structures were also inhibited. S. Shukla et al. (1989) investigated antifertility effect of aqueous extract of *Moringa oleifera* roots was studied histologically on the genital tract of ovariectomized rats in the presence and absence of estradiol dipropionate

and progesterone. Administration of the extract itself stimulated the uterine histoarchitecture as revealed by increases in the height of luminal epithelium, well developed glands, loose stroma and rich vascularity. The cervix showed metaplastic changes in the epithelium with marked keratinization. In the vagina, cornification was very prominent, rugae increased and stroma was loose. Conjoint administration of the extract with estradiol showed a synergistic action, and an inhibition was observed when administered conjointly with progesterone. D. Nath et al. (1992) investigated antifertility property from the aqueous and 90% ethanol extracts of the plant in rats orally dosed for 10 days after insemination with special reference to effects on foetal development. Leaf extracts of *Moringa oleifera* were 100% abortive at doses equivalent to 175 mg/kg of starting dry material⁶⁵.

Antidiabetic Activity

An extract from the moringa leaf has been shown to be effective in lowering blood sugar levels within 3hrs ingestion, though less effectively than the standard hypoglycemic drug, glibenclamide⁶⁶.

Wound Healing Properties

Three wound models viz excision wound, incision wound and dead space wound were selected for assessing wound healing activity of ethanolic and ethyl acetate extracts of leaves. Ethyl acetate extracts (10% extract in the form of ointment) showed significant wound healing activity that is comparable with the standard vicco turmeric cream. Phytosterols and phenolic compounds present in these extracts promote the wound healing activity⁶⁷.

Antipyretic Activity

The antipyretic activity of ethanolic, petroleum ether, solvent ether and ethyl acetate extracts of seeds was screened using yeast induced hyperpyrexia method. Paracetamol I.P (200mg/ kg) was used as standard for comparison. The ethanolic and ethyl acetate extracts of seeds showed significant antipyretic activity in rats⁶⁸.

Antioxidant Activity

Antioxidant activity reported in oil from the dried seeds is higher than BHT and alpha-Tocopheryl. Aqueous methanol (80%) and ethanol (70%) extracts of freeze dried leaves showed radical scavenging and antioxidant activities. The drumstick leaves are found to be a potential source of natural antioxidants⁶⁹.

Anti-Oxidant Effect: The antioxidant property of *Moringa* may be due to the presence of phenolic compounds that was confirmed by phytochemical screening of the hydro-ethanolic extract. In this respect, *Moringa* pods contain important bioactive compounds including glucosinolates, isothiocyanates, thiocarbamates, and flavonoids. These compounds quench ROS, chelate metal ions and regenerate membrane-bound antioxidants. B-carotene, the major component reported from the drumsticks of the plant 16 and vitamin A and C present in *M. oleifera* serve as an explanation for their mode of action in the induction of

antioxidant profiles in the present investigation. The biochemical basis of the chemopreventive potency of *M. oleifera* extract may be attributed to the synergistic action of the constituents of the extract and the induction of Phase II enzymes (GSTs) and antioxidant enzymes, which might be implicated in the anticarcinogenic activity. The aqueous extract of *Moringa oleifera* exhibited strong scavenging effect on 2, 2-diphenyl-2-picryl hydrazyl (DPPH) free radical, superoxide, nitric oxide radical and inhibition of lipid per oxidation. The free radical scavenging effect of *Moringa oleifera* leaf extract was comparable with that of the reference antioxidants. The extracts of *Moringa oleifera* both mature and tender leaves have potent antioxidant activity against free radicals, prevent oxidative damage to major biomolecules and afford significant protection against oxidative damage⁷⁰.

The *Moringa oleifera* hydro- alcoholic leaf extracts (1000 mg/kg) and *Moringa oleifera* aqueous pod (fruit) extract (750 mg/kg) contain high amount of tannin, phenolic compounds and flavonoids. The poly phenolic constituents of this plant could be contributory to their ethano-medical use. Thus, it can be concluded that extracts of *Moringa oleifera* produce significant antioxidant activity and the presence of kaempferol in leaves of *Moringa oleifera* showed the antioxidant activity which was also reported⁷¹.

As Gelling agent

A study was carried out to find the gelling potential of gum exudate from the stem of *Moringa oleifera*. Diclofenac sodium gels were formulated with concentration of mucilage ranging from 5.5 to 8.5% w/w. Better gel characteristics were observed at the concentration of 8%. It is also reported that because the p H of the gum is below 5.77 and the viscosity of the formulation with 8.5w/w gum is 4.6x10⁶cps, it is ideal for topical application⁷². Suspending agent: A comparative study of gums of *Moringa oleifera* and *tracaganth* were reported. Zinc oxide suspensions were prepared with gum of *Moringa oleifera* and *tracaganth*. Their sedimentation profile, redispersibility, degree of flocculation and rheologic behaviour were compared. The results revealed that the suspending properties of *Moringa oleifera* gum are comparable with that of gum *tracaganth*. Detoxification/water purification: Studies have shown *Moringa*'s ability to remove hazardous materials from water. After oil extraction of *Moringa* seeds the left press cake contains water soluble proteins that are as effective coagulants for water purification⁷³. The charged protein molecules can serve as nontoxic natural polypeptides to settle mineral particles and organics in the purification of drinking water, vegetable oil, depositing juice and beer. As been reported, *Moringa* seeds show similar coagulation effects to alum.

It is also reported that a recombinant protein in the seed is able to flocculate gram positive and gram negative bacterial cells. *Moringa* seeds could be used as a biosorbent for the removal of cadmium from aqueous media. Thus water purifying attributes of *Moringa* seeds are as coagulant, microbial elimination and as a biosorbant. Surfactant behavior: A study on interfacial properties and fluorescence of a coagulating protein extracted from *Moringa* seeds and its interaction with sodium dodecyl sulphate (SDS) was carried out. The study reported that 1) the protein extracted from *Moringa* seeds has significant surfactant behavior; 2) the coagulant protein interacts strongly with SDS and the protein might have specific binding sites for SDS; 3) there is formation of protein-SDS complex. Film forming property: Studies reported that gum has enormous potential for use in the preparation of polymeric films as drug delivery systems. The films prepared using gum of *Moringa oleifera* (5 parts of 10% w/w of mucilage of gum of M.O. with different proportion of plasticizers) were evaluated for parameters like water uptake, tensile strength, folding endurance and water vapour transmission rate. The results obtained are comparable with films made from other polymers and concluded that the gum can be used for preparing polymeric drug delivery systems and as a film coating agent in tablets as it has low vapour transmission rate and satisfactory tensile strength. As stabilizer: Plant phenolics have gained considerable interest in recent years for their potential effects against food related microorganisms. Phenolic extract obtained from the leaves of *Moringa oleifera* & *Morus indica* showed stabilizing activity. In the present study effect of addition of phenolic extract from leaves of *M. oleifera* and *M. indica* on the shelf life of pineapple juice stored at 4 degree °C^{74, 75, 76}.

Cosmetic Use

Various parts of *Moringa oleifera* have cosmetic value. Cognis Laboratoires Serobiologiques team developed Puricare™ and Purisoft™, two active ingredients based on botanical peptides.

From the seeds of *Moringa oleifera* tree that purify hair and skin and offer protection against the effects of pollution^{77, 78}. *Moringa* seed oil, known as Behen oil is widely used as a carrier oil in cosmetic preparations. The healing properties of *moringa* oil were documented by ancient cultures. *Moringa* oil possesses exceptional oxidative stability which may explain why the Egyptians placed vases of *Moringa* oil in their tombs. It is high in oleic acid and similar in composition to olive oil. *Moringa* oil is light and spreads easily on the skin. It is good oil for use in massage and aromatherapy applications^{79, 80}.

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