

MORINGA OLEIFERA: MEDICINAL VALUES, ANTIMICROBIAL PROPERTIES AND APPLICATION AS FOOD INGREDIENTS-A REVIEW

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Abstract

Moringa oleifera Lamarck is a native plant to the southern foothills of the Himalayan areas of Asian countries and currently grown in many tropical and subtropical countries. The plant parts are used in the preparation of herbal medicine for the treatment of diver's pains and diseases in South Asia. It is an important food source in some parts of the world such as India and Africa where it is used to combat malnutrition. The immature green pods, seeds, dried leaves and seed oil are used in food preparation. The interest in utilization of moringa seed as antimicrobial agents, medicinal uses, food additives and application in food preservation has been amplified in the past few decades by an increasingly negative consumer perception of most synthetic food preservatives and drugs. In addition, food-borne diseases are overwhelmingly increasing public health problem which calls for more effective preservation strategies. The nutritional composition, medicinal uses and antibacterial properties of the various parts of *Moringa oleifera* have been documented extensively. However, there is dearth's of information and limited knowledge about the mode of action of the plant extracts. This review encourages researchers to focus on methods of processing the parts into a more useful and acceptable food products, the mode of action of the individual chemical component or synergistic interactions of the chemical compounds of the plant on different microbial species, and on their reactions with food chemical matrix that will enhance its extracts to be used as food preservative.

Key words: *Moringa oleifera*, medicinal value, antimicrobial properties, food ingredients

Introduction

The plant *Moringa oleifera* Lamarck (*M. ptreygosperma* Gaertn.) is a naturalized species of a monogeneric family Moringaceae (Anwar *et al.*, 2007). The tree ranges in height from 5 to 10 m and distributed in many parts of Asia (Morton, 1991). According to Anwar *et al.* (2007), it grows in wild, cultivated in hedge, garden and back yards of the house. The plant grows well in tropical climate in the humid tropics or hot dry land and on loamy or sandy loam soil. *Moringa* grows and flower in less than a year. It survives low fertile soils and less affected by drought (Morton, 1991). The plant tolerates wide range of rainfall with minimum annual rainfall requirements estimated at 250 mm and maximum at over 3000 mm and pH of 5.0-9.0 (Palada & Chang, 2003). *Moringa oleifera* is native to the western and sub-Himalayan tracts, India, Pakistan, Asia Minor, Africa and Arabia (Anwar *et al.*, 2007). In some parts of the world, *M. oleifera* is referred to as 'drumstick' or 'horse radish' tree (Anwar *et al.*, 2007). In Pakistan, *M. oleifera* is known as '*Sohanjna*' (Anwar *et al.*, 2005; Anwar *et al.*, 2007). *Moringa oleifera* is an

important food substance with great attention as 'natural nutrition of the tropics and subtropics'. Every part of the plant such as leaves, fruit, flowers and immature pods are used as vegetable in many parts of the world, particularly in Asian countries and Africa (Anwar & Bhangar, 2003; Anwar *et al.*, 2005; Anwar *et al.*, 2007). Moringa leaf has been reported to be a rich source of nutrients like β -carotene, protein, ascorbic acid, calcium (4times more than milk), potassium; it acts as good source of natural antioxidants such as ascorbic acid, flavonoid, phenolic and carotenoid; thus enhances the shelf-life of food containing high quantity of fats (Dillard & German, 2000). Morimitsu *et al.* (2000) and Anwar *et al.* (2007) reiterated the facts that the parts such as root, bark, gum, leaf, fruit (pods), flowers, seed and seed oil have been used for treatment of various ailments in South Asia. Some of the parts have also be implicated in the treatment of inflammation and infectious diseases along with cardiovascular, gastrointestinal, haematological and hepatorenal disorders (Morimitsu *et al.*, 2000; Anwar *et al.*, 2007). Moringa seed has antipyretic properties, very bitter and show antimicrobial activity (Anwar *et al.*, 2007). Its seeds may be eaten raw or roasted and pound followed by pressing into high quality oil such as 'Ben oil. The unique property is the ability of its dry, crushable seed which may be pressed into cake. The cake contains polypeptide that serves as natural coagulants for water treatment (Ndabigengesere & Narasiah, 1998). Pioneering reviewers have elucidated some uses of the plant part in the treatment of some diseases as indicated in Table 1. Although, detailed knowledge about the mode of action of the plant constituent compounds is lacking, from literature search, there has not been a comprehensive review on the versatile utility of the antimicrobial activities of *Moringa oleifera* plant and its uses as food additives. This has persuaded us to create a viaduct for information flow among researchers and to give a comprehensive review of areas where researches has been conducted on *Moringa oleifera* plant.

Table 1: Overview of the medicinal uses of various parts of *Moringa oleifera* plant

Plant parts	Application	References
Leave	Treatment of fevers, sores and sore throat, bronchitis, ear and eye infections, scurvy and catarrh, pile and headaches.	Morton, 1991; Makonnen <i>et al.</i> , 1997; Anwar <i>et al.</i> , 2007
Seed	Used as laxative, anti-stress, anti-menstrual pain, anti-diabetic antihypertensive, brain booster, improved vision, alleviates constipation and aids in sleeplessness or insomnia.	Faizi <i>et al.</i> , 1998; Lalas and Tsaknis, 2002; Anwar <i>et al.</i> , 2007.
Flower	Used as stimulant, aphrodisiac, anti-inflammations and abortifacient. Treatment of tumour and prevention of enlargement of the spleen. Decreases lipid profiles such as cholesterol, phospholipids, and triglycerides. Increased discharge of faecal cholesterol in rat.	Bhattacharya <i>et al.</i> , 1982; Dahot, 1988; Mehta <i>et al.</i> , 2003; Anwar <i>et al.</i> , 2007.
Stem bark	Used for the treatment of diseases of the eye; prevention of spleen enlargement and formation of tubercles glands on the neck. Has effect on tumour cells and used for the treatment of ulcer. The juice from the root bark has anti-tubercular activity and has been used as pain killer for the treatment of ears and teeth.	Bhatnagar <i>et al.</i> , 1961; Anwar <i>et al.</i> , 2007.

Pod	Antihypertensive	Faizi <i>et al.</i> , 1998; Anwar <i>et al.</i> , 2007
Gum	Treatment of dental carries. The Gum could be mixed with sesame seed oil before used for the treatment of headache, fevers, intestinal pains, dysentery, asthma and rheumatism.	Anwar <i>et al.</i> , 2007
Root	Used for the following: anti-inflammatory, anti-constipation, anaesthetic, vesicant, carminative, anti-fertility, laxative, stimulant especially in paralytic conditions and possesses spasmodic activity.	Caceres <i>et al.</i> , 1992; Padmarao <i>et al.</i> , 1996; Ezeamuzle <i>et al.</i> , 1996; Anwar <i>et al.</i> , 2007.

Processing and extraction of *Moringa oleifera* plant parts

Different methods and solvents have been employed for processing and extraction of various parts of *Moringa oleifera* plant used in research studies. Moringa leaves have been dried-milled (Karim *et al.*, 2013), aqueous extracts of the leaves has been freeze dried (Chuang *et al.*, 2007), the seed oil has been extracted using 2% bacterial nutrase enzymes (Novozyme, Denmark) obtained from the bacteria '*Bacillus amyloliquefaciens*' (Abdulkarim *et al.*, 2005). Among the solvents that have been used for the extraction of moringa leaves and seeds are cold or hot water (Chuang *et al.*, 2007), methanol, hexane, ethanol and supercritical extraction with CO₂ (Ortiz-Palafox *et al.*, 2010), chloroform and petroleum ether (Abdulkarim *et al.*, 2005), hexane, butanol and ethyl acetate (Chuang *et al.*, 2007; Ortiz-Palafox *et al.*, 2010) or combination of two or more of the solvents at different ratio. Steam distillation has been used for the extraction of essential oil from the leaves (Chuang *et al.*, 2007). The seed was extracted consecutively three times with combinations of *n*-hexane, ethyl acetate and *n*-butanol followed by complete dryness under reduced pressure or freeze drying to obtain sub-fractions of seed extracts (Chuang *et al.*, 2007). In addition, Mani *et al.* (2007) had also extracted the oil of moringa seeds using *n*-hexane, petroleum spirit and acetone.

Chemical properties and medicinal value of *Moringa oleifera* extracts

Gilani *et al.* (1992) reported on the antispasmodic activity of the ethanol extract of *M. oleifera* leaves and attributed the presence of 4-[α -(L-rhamnosyloxy) benzyl]-*o*-methyl thiocarbamate, which forms the basis for its traditional use in treating diarrhoea. The leaf extracts in rats were found to regulate thyroid status and cholesterol levels (Tahiliani & Kar, 2000; Ghasi *et al.*, 2000). Many reports described *M. oleifera* as a highly potent anti-inflammatory (Ezeamuzle *et al.*, 1996), hepatoprotective (Pari & Kumar, 2002), anti-hypertensive (Faizi *et al.*, 1995) and anti-tumor (Murakami *et al.*, 1998).

The methanol fraction of *M. oleifera* leaf extract showed anti-ulcerogenic and hepatoprotective effects in rats (Pal *et al.*, 1995). Makonnen *et al.* (1997) considered moringa leaf as potential ingredients to be used as antitumor and anticancer. The authors affirmed that the compounds *O*-Ethyl-4-(α -L-rhamnosyloxy) benzyl carbamate, α -L-rhamnosyloxy-benzyl isothiocyanate, niazimicin and 3-*O*-(6'-*O*-oleoyl- β -D-glucopyranosyl)- β -sitosterol are implicated as potential antitumor promoting agents using an *in vitro* assay which showed significant inhibitory effects on Epstein-Barr virus-early antigen. Niazimicin has been proposed to be a potent chemopreventive agent in chemical carcinogenesis (Guevara *et al.*, 1999). Aqueous leaf extracts also

showed antiulcer effect (Pal *et al.*, 1995) indicating that the antiulcer component is widely distributed in this plant.

Chuang *et al.* (2007) reported a total of 44 compounds present in the essential oil of *Moringa oleifera* leaf and gave the major constituents as: pentacosane (17.41%), hexacosane (11.20%), E-phytol (7.66%) and 1-[2,3,6-trimethyl-phenyl]-2-butanone (3.44%).

Moringa oleifera flower contains nine amino acids, sucrose, D-glucose, alkaloids, wax, quercetin and kampferat (Ruckmani *et al.*, 1998). Both the aqueous and alcohol extracts from moringa flowers were also found to have a significant hepatoprotective effect (Ruckmani *et al.*, 1998), which may be due to the presence of quercetin, a well-known flavonoid with hepato-protective activity (Gilani *et al.*, 1997). The seed oil has physical and chemical properties equivalent to that of olive oil and contains a large quantity of tocopherols (Tsaknis *et al.*, 1999). In recent years, many people in Taiwan or China have been using the seed of moringa as herbal medicine to treat tinea and athlete's foot diseases and found that it is effective. The seed extracts are also found to be effective on hepatic carcinogen metabolizing enzymes, antioxidant parameters and skin papillomagenesis in mice (Bharali *et al.*, 2003). The seeds of *Moringa oleifera* contain the compounds rhamnose, glucosinolates and isothiocyanates (Fahey *et al.*, 2001; Bennett *et al.*, 2003). The compound O-ethyl-4-(α -L-rhamnosyloxy) benzyl carbamate (Guevara *et al.*, 1999) and seven other bioactive compounds namely 4(α -L-rhamnosyloxy)-benzyl isothiocyanate, niazimicin, 3-O-(6'-O-oleoyl- β -D-glucopyranosyl)- β -sitosterol, β -sitosterol-3-O- β -D-glucopyranoside, niazirin, β -sitosterol and glycerol-1-(9-octadecanoate) have been isolated from the ethanol extract of the Moringa seed (Anwar *et al.*, 2007). Moringa roots have also been reported to possess hepatoprotective activity (Ruckmani *et al.*, 1998). The bark was reported to contain the alkaloids moringine and moringinine (Anwar *et al.*, 2007). The stem was also reported to contain the compounds vanillin, β -sitosterol, β -sitostenone, 4-hydroxymellin and octacosanoic acid (Faizi *et al.*, 1994; Anwar *et al.*, 2007). The purified gum exudate of *moringa* was found to contain L-arabinose, L-galactose, L-glucuronic acid and L-rhamnose, L-mannose and L-xylose, while the acid hydrolysed gum exudate consists of L-galactose, glucuronic acid and L-mannose (Bhattacharya *et al.*, 1982). The ethanol extract of moringa pods yielded an antihypertensive compounds namely thiocarbamate and isothiocyanate glycosides (Faizi *et al.*, 1998).

Antimicrobial activity of *Moringa oleifera* extracts

Das *et al.* (1957) and Rao *et al.* (2001) reported the presence of an active antibiotic principle called pterygospermin in the leaf and flower respectively. This active component of *Moringa oleifera* has powerful antibacterial and fungicidal effects (Ruckmani *et al.*, 1998). The aglycone of deoxy-niazimicine (N-benzyl, S-ethyl thioformate) isolated from the chloroform fraction of an ethanol extract of the root bark was found to be responsible for the antibacterial and antifungal activities (Nikkon *et al.*, 2003). The bark extract has been shown to possess antifungal activity (Bhatnagar *et al.*, 1961), while the juice from the stem bark showed antibacterial effect against *Staphylococcus aureus* (Mehta *et al.*, 2003). The fresh leaf juice was found to inhibit the growth of pathogenic microorganisms such as *Pseudomonas aeruginosa* and *Staphylococcus aureus* (Caceres *et al.*, 1991). The root extract possesses antimicrobial activity attributed to the presence of 4- α -L-rhamnosyloxybenzyl isothiocyanate (Eilert *et al.*, 1981). Caceres and Lopez (1991) reported the efficacy of the seed ointment of moringa when compared with neomycin; a synthetic antibacterial agent against *Staphylococcus aureus* in mice with pyoderma. Ethanol extracts showed anti-fungal activities in vitro against dermatophytes such as *Trichophyton*

rubrum, *Trichophyton mentagrophytes*, *Epidermophyton floccosum*, and *Microsporum canis* (Chuang *et al.*, 2007). The authors showed that both crude and sub-fraction of the essential oil of the leaf and sub fractions of the seed extracts using different organic solvent such as ethanol, ethyl acetate, hexane and butanol have anti-fungal effect on *T. rubrum*, *T. mentagrophytes*, *E. floccosum* and *M. canis*. From their findings, the minimum inhibitory concentration (0.156 mg/ml) of the seed extract of ethyl acetate fraction showed the strongest anti-fungal activity against *M. canis*. However, both leaf crude extract and sub-fractions had little effect on dermatophytes (Chuang *et al.*, 2007).

Application of *Moringa oleifera* food ingredients for man

The consumption of *Moringa oleifera* leaves is critical to the alleviation of worldwide nutritional deficiencies. In addition foods that are rich in antioxidant substances and micronutrients are strongly recommended for consumption by victims of AIDS or HIV. Yang *et al.* (2006) surveyed over 120 species of both tropical and subtropical edible vegetables for anti-nutrients, antioxidants and crop traits and concluded that *Moringa oleifera* is a promising crop that could contribute to the increased intake of micronutrients and antioxidants. Presently, *Moringa oleifera* plant has been included as part of the world Vegetable Centre (WVC) nutritional seed kit, which is distributed by the regional centres to farmers and extension workers (Yang *et al.*, 2006). Yang *et al.* (2006) evaluated four species of moringa namely: *Moringa oleifera*, *Moringa stenopetala*, *Moringa peregrina* and *Moringa drouhardii* and comparatively reported highest nutritional composition in *Moringa oleifera*. The authors stressed the importance of harvest period and stage of development when leaves are harvested to have significantly influenced nutritional composition of moringa; for instance higher protein, vitamin A, glucosinates and antioxidant contents were obtained in hot-wet season, whereas, higher iron, vitamin C and phenolic were found in cool-dry season (Yang *et al.*, 2006). Mature leaves were found to be more nutritious than young shoots, it also dries earlier with minimum loss in nutrients; however young shoots exhibited better eating quality and are better accepted for fresh market (Yang *et al.*, 2006)

The nutritional quality of four different species of moringa were reported on wet matter basis by Yang *et al.* (2006) and among the four species; *Moringa oleifera* contained the highest amounts of protein (5.8), β -carotene (15mg/100g) and iron (9.2mg/100g). The antioxidant content of moringa is high compared with common vegetables and fruits. On dry matter basis, the antioxidant compositions of moringa varieties were given as follow: phenolic (74-210 μ mol/g), ascorbate (70-100 μ mol/g), β -carotene (1.1-2.8 μ mol/g) and tocopherol (0.7-1.1 μ mol/g).

The seed of *Moringa oleifera* has been used to fortified yam flour for production of 'amala' a stable diet in the Western parts of Nigeria (Karim *et al.*, 2013). There was no significant ($p < 0.05$) difference among the samples for the sensory qualities of colour, mouldability and mouth feel at up to 8.0% inclusion level (Karim *et al.*, 2013). The sample prepared from yam flour fortified with 2.5% *Moringa oleifera* leaf powder compared favourably well with the control sample (yam flour only) in all sensory attributes, proximate and mineral composition without affecting the overall acceptability (Karim *et al.*, 2013). Moringa seeds contain between 30-42% oil consisting of saturated fats (13%) and unsaturated fatty acids (82%) which are important in human diets. Moringa oil known as Ben oil in Mexico has about 70 % oleic acid and possesses good oxidative stability. It is very good for frying when used alone or when mixed with other oils and also more stable than common oils extracted from canola, soybean, and palm trees. Blending Ben oil with sunflower oil and soybean oil enhance the oxidative stability of the

mixture (Abdulkarim *et al.*, 2005). Mani *et al.* (2007) affirmed the edibility and high quality attributes of moringa oils when compared with edible olive oil.

Moringa seeds also contain phytochemicals with known powerful antioxidant ability such as kampferol, quercetin, caffeolyquinic acids, β -sitosterol, rutin, and zeatin. Oliveira *et al.* (1999) reported the nutritional composition of mature seeds of *Moringa oleifera* on dry matter basis as crude protein (33.25%), crude fat (41.20%), carbohydrate (21.12 %) and ash (4.43 %). The essential amino acid profiles compared favorably with the FAO/WHO/UNU scoring pattern requirements for human. However, the authors showed that the seed is deficient in some essential amino acids such as lysine, threonine and valine (Oliveira *et al.*, 1999). They reiterated that the content of methionine + cysteine (43.6 g kg^{-1} protein) was exceptionally higher and close to that of milk (human and cow) and egg (chicken) (Oliveira *et al.*, 1999). Feeding rats with a diet containing the seed meal showed loss of appetite, retarded growth and increased weight of some parts such as the stomach, intestine, liver, pancreas, kidney, heart and lung when compared with rats fed on an egg-white diet. The authors suggested suitable processing methods as a means of abolishing the yet unknown adverse factors in matured *Moringa oleifera* seeds if it must be used as food ingredients in human diet (Oliveira *et al.*, 1999).

Conclusion

Many scientists have conducted different studies on different parts of *Moringa oleifera* plant. Food plants are considered very safe for human consumption especially if properly processed and well preserved; as it is believed to have synergistic effects and combinations of neutralizing activities in humans. It is worthwhile, to conduct research on the positive impacts and neutralizing side-effects of the different parts of *Moringa oleifera* plant in human, animal and diversity of microbial species.

From various studies over a decade, *Moringa oleifera* leaves have been reported to contain high quantity protein source which has been recommended to combat protein shortage in the world especially in Africa. However, it is imperative to assess the quality of protein in various parts of moringa, especially the seeds and leaves to determine whether it could compete favourably in bioavailability with more common animal proteins.

Many studies have been carried out on performance using animal models. Broilers, piglets and other animal species have been fed *Moringa oleifera* leaves or seeds at different inclusion levels. Many studies have reported the antimicrobial activities of *Moringa oleifera* extract on different microbial species. However, reports on antimicrobial effects of essential oils, purified lipid and protein from *Moringa oleifera* leaves and seeds are rarely found; as such researchers should focus on the isolation and purification of moringa's important components which may in turns be used as antimicrobial agents or basis to formulate substances potent enough to combat some epidemics and diseases. It is imperative to conduct researches that would monitor the mode of action of the extracts obtained from different parts of moringa on different microbial species. Since these plant species naturally grow in different habitats, there may not be great differences in qualitative and quantitative chemical compositions of *Moringa oleifera* tree planted in various regions of the world. However, the extent to which the chemical composition varies in region where the tree are grown is yet unknown and should be investigated. Since the seeds and leaves are been used as food ingredients studies should also be conducted on the extracts reaction with food chemical matrix.

Finally, considering the multi-purpose applications of this important plant species, it could be suggested that government, private and individuals should be engaged in massive cultivation of the plant in countries where climatic conditions would favour its growth. In this process, there could be maximum production of the plant that could be processed into different food products and medicinal substances that can be used for the benefits of mankind.

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