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Moringa oleifera Lam.: A Biofunctional Edible Plant from India, Phytochemistry and Medicinal Properties

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Abstract

Moringa oleifera is a versatile horticulture tree with important medicinal, nutritional and industrial applications, widely distributed and used in India. The *Moringa* tree originated in India and was introduced to Africa from India and other countries as a health supplement. Almost all parts of the plant have shown nutritional value and are used in India for a variety of food preparations. In India, *M. oleifera* leaves are available in powder to treat mild malnourishment in children. About all parts like leaves, seeds and pods are used as vegetables. Phytochemicals such as flavonoids, tannins, triterpenoids, saponins, flavonoids, anthraquinones, alkaloids and others, are responsible for the medicinal value of this plant. This species is rich in protein, fatty acids, vitamins and minerals that form part of its quality as superfood. It has been reported to have strong antimicrobial, antioxidant, anti-inflammatory, hepatoprotective, diuretic, anthelminthic and antiurolithiatic properties, among others. People in India use this species to treat common illnesses because of its availability and easy preparation. This review provides information on the significant potential of *Moringa* and its nutritional, medicinal, pharmaceutical and industrial values.

Keywords: *Moringa oleifera*, medicinal value, phytochemicals, underutilized nutritional plant

1. Introduction

The genus *Moringa* belongs to the monogeneric family Moringaceae and comprises thirteen species distributed from semi-arid Africa to Asia. Of these, *M. oleifera* Lam. (Figure 1) is the most commonly known species distributed in the northwest India (Mabberley, 2017; Nadkarni, 1976; Ramachandran *et al*., 1980; Jahn 1988; Somali *et al*., 1984; Mughal *et al*., 1999,). The tree ranges in height from 5 to 10m (Morton, 1991). This tree grows rapidly, with recording growth of 6-7 m in areas with rainfall of less than 400 mm per year (Odee, 1998). Although it is wild in NW India, it can be cultivated in different areas, growing at elevations of up to 1,000 m above sea level on pasturelands, river basins or hillsides.

Moringa oleifera is also known with different names including, horseradish tree, ben oil tree, drumstick tree, miracle tree, and "Mother's Best Friend", Kelor tree (Anwar and Bhanger, 2003, Prabhu *et al*., 2011). This species was introduced to Africa at the beginning of the twentieth century as a health supplement (Muluvi *et al*., 1999). The ben oil seems to show promise for the manufacture of soap with high washing efficiency. This makes it suitable for poor areas where people cannot afford buying these products but they have the plant available for use.

This nutritional plant is little known in the western world despite of being considered one of the world's most beneficial trees due to the potential use of each part of plant (Table 1) either as fodder, vegetable or medicine in South Asia (Odebiyi and Sofowora, 1999). The leaves, fruit, flower and immature pods (Figure 1) of this tree are commonly used as a nutritious vegetable in several countries, making it a great potential food source in dry season areas where food could be scarce. Countries such as India, Pakistan and Philippines (Gopalakrishnan et al., 2016; Anwar *et al*., 2005; Anwar and Bhanger, 2003; D'souza and Kulkarni.1993) use this species widely. *Moringa* is being used in diverse culinary ways and as a health supplement (McBurney *et al*., 2004; Fahey, 2005; DanMalam *et al*., 2001; Iqbal *et al*., 2006). A leaf powder from the plant can be used for children with malnutrition, pregnant and lactating woman (Price, 1985). For example, In the Philippines, this plant is commonly used to increase the production of milk in lactating women, hence its name of "mother's best friend"; and it has also been prescribed to patients with anemia (Siddhuraju and Becker, 2003; Estrella *et al*., 2000).

Interestingly, this species is reported to have natural and organic sunscreens with an SPF value of 2 at low concentrations (2-4%), giving a 50% sun protection (Baldisserotto et al., 2018), a potential alternative for use in children in tropical countries.

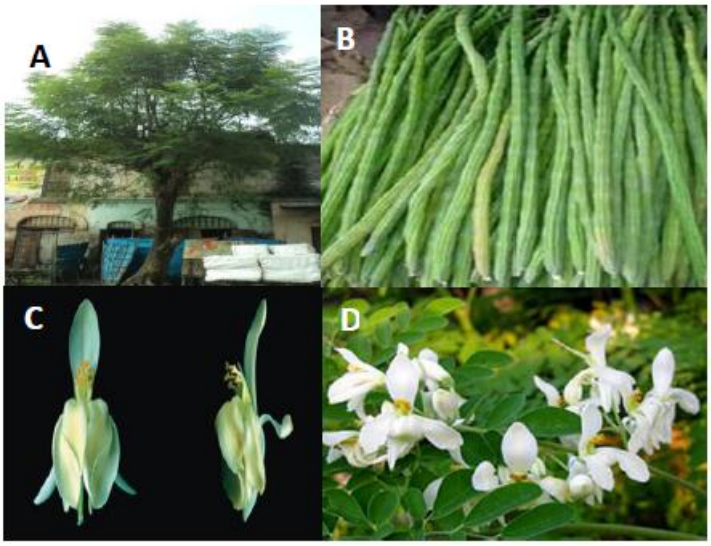


Figure 1. A *Moringa oleifera* tree planted along a street in Buxipur, Gorakhpur (A), green pods (B); frontal and side view of the flowers (C) and flowering branch (D)

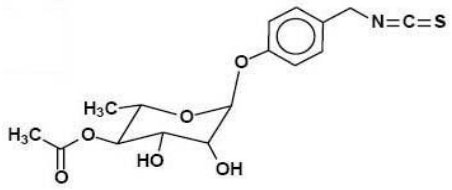
Table 1. Common uses of different parts of *Moringa oleifera* Lam

plant parts	Uses / applications	
	food	**medicine**
Leaves	Salads, vegetables curries	Powder for treating tumors; poultice for sores, piles, reduce glandular swelling, headaches, or body cleanser, to promote digestion; hypocholesterolemic, juice lowering glucose levels, eye and ear infection
Flower	extracts used for honey preparations	remedy for tumors, infections, muscle diseases, spleen enlargement and to lower cholesterol level
Pods / fruits	Salad, vegetable	treat malnutrition
Seeds	as a snack, oil for salads, cooking, cosmetics, lubricant; water purifying	To treat abdominal tumors and to remove harmful bacteria
Bark	For tanning	Promote digestion
Root	Used as a substitute for horseradish	To treat tumors, promote digestion, antilithic, antifertility and anti-inflammatory. Beneficial against rheumatism, constipation, kidney pain or back pain.

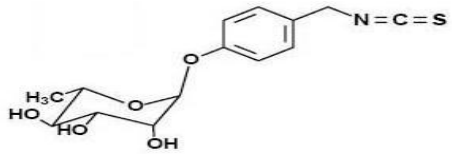
2. Phytochemistry and Chemical Constituents

The Phytochemicals (chemical compounds) responsible for the properties of this species have not been thoroughly studied (Liu, 2004, Brow and Arthur, 2001). Three structural types of phytochemicals of medicinal interest in this species includes, flavonoids, glucosinolates and phenolic compounds (Saleem, 1995; Manguro and Lemmen, 2007; Kasolo *et al*., 2010; Amaglo *et al*., 2010). The phytochemical of leaves of *Moringa* (Figure 2) can vary depending on the growing climate conditions where the plant grows, the method of collection and processing (Coppin, 2008; Mukunzi *et al*., 2011). These include tannins, saponins, alkaloids, flavonoids, anthraquinones, glycosides and steroids (Idris and Adamu, 2018). In addition, other compounds have been isolated from leaves, including different types of glycosides (Faizi *et al*., 1998, 1995, 1994, 1992; Murakami *et al*., 1998; Miean *et al*., 2001; Bennett *et al*., 2003; Wu *et al*., 2003). Leaves also contain carotenoids, tocopherols and vitamin C that can prevent free-radical damage linked to many diseases (Smolin

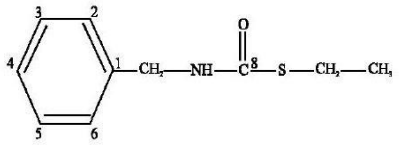
and Grosvenor, 2007). The root bark is rich in two alkaloids: moringine and moringinine.



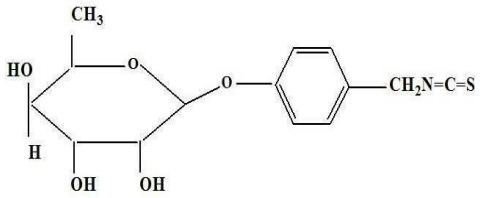
Benzyl isothiocyanate 4-(4'-O-acetyl-Lrhamnopyranosyloxy)



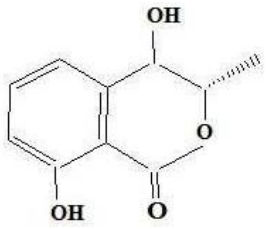
Benzyl isothiocyanate 4-(-L-rhamnopyranosyloxy)



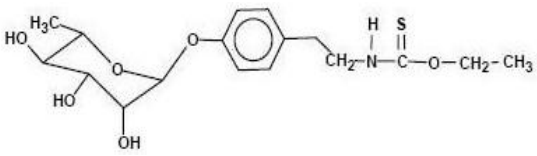
Aglycone of Deoxy- Niaziicine (N-benzyl, S- ethyl thioformate)



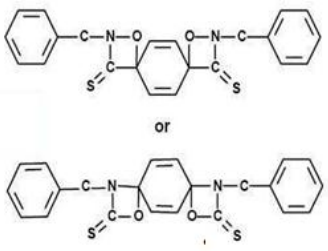
4- (α-L-rhamno Pyroanosyloxy) benzyl isothiacyanate



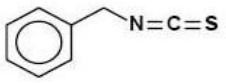
4-hydroxy mullein



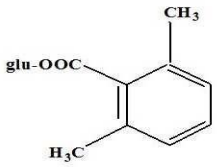
Niazimicin



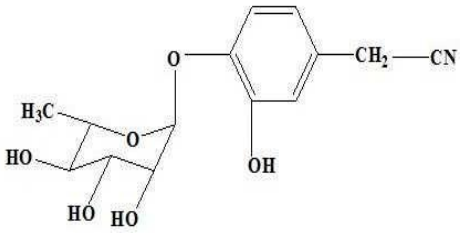
Pterygospermin



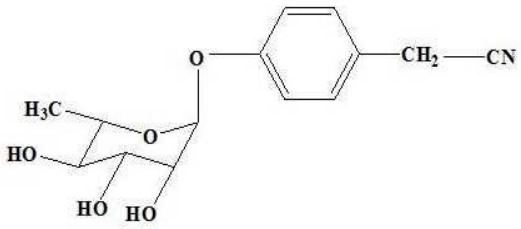
Benzyl isothiocyanate



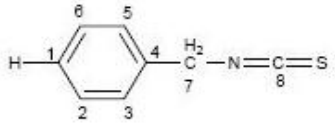
Moringyne



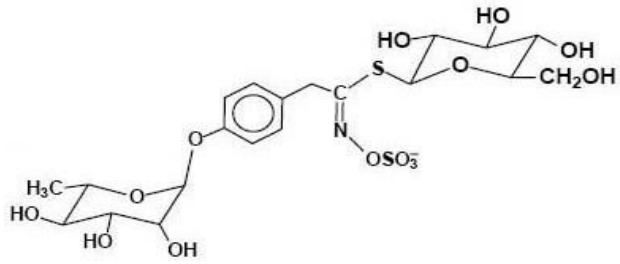
Niaziridin



Niazirin



Isothiocyanato methyl benzene



Benzyl glucosinolate

4(-α -L-rhamnopyranosyloxy)

Figure 2. Structures of some phytochemicals from *Moringa oleifera*

Moringa contains a substantial amount of palmiti, di-oleic, and stearic acids, proteins, saponins, proteins and a variety of vitamins, including Vitamin A, B1, B2, B3, C, nicotinic acid, pyridoxine, ascorbic acid and folic acid (Dahot and Memon 1985). In addition, it is rich in minerals such as iron, calcium, magnesium and phosphorus (Gopalakrishnan et al., 2016). A substantial amount of essential amino acids are found in the pods (Lako *et al*.,

2007) along with tocopherols (Gomez-Coronado *et al*., 2004; Sánchez-Machado *et al*., 2006). All these phytochemicals make *Moringa* a plant of great value.

3. Medicinal Value

Moringa is known in folk medicine in India (Fuglie, 1999.) because of its versatile medicinal properties and it has been used since ancient times by people. It is recognized for its anti-inflammatory, diuretic, abortifacient, antispasmodic, emmenagogue and ecbolic properties and it has been reported to be useful in the treatment of tumors, leukoderma and biliousness etc. (Das et al., 1957, Shaw and Jana, 1982). Interestingly, ethanolic extracts of Moringa leaves seem to have a radioprotection effect against damaged induced by high doses of ionizing radiation (Elwan et al., 2018) showing the versatility and potential uses of this plant.

3.1 Antimicrobial Properties

Virtually all parts of this species have shown antimicrobial properties (Caceres *et al*., 1991; Ali *et al*., 1999; Senthil Kumar and Reetha 2009); this includes leaves, bark, fruit, root and flowers (Khalil 1996; Tsaknis *et al*., 1999). This is important because there is a great need for antimicrobial compound in the medical community due to the development of antibiotic resistance. More studies need to be done to evaluate the use of this species and to isolate the proper compounds that can be use in allopathic medicine.

3.2 Antioxidant Properties

The antioxidant properties of this species is important to prevent of damage to important macromolecules such as DNA, proteins and lipids so cells can function properly (Ryter *et al*., 2007; Limon-Pacheco and Gonsebatt, 2009). The seeds and leaves of *Moringa* are a good source of antioxidants (Chumark *et al*., 2008) with 65.1 % in methanolic extracts and 66.8% in ethanolic extracts (Lalas and Tsaknis, 2002; Siddhuraju and Becker, 2003). Some studies have shown that quercetin and kaempferol seem to be responsible for this antioxidant activity (Bajpai *et al*., 2005; Siddhuraju and Becker, 2003). The qualitative properties of antioxidant in *Moringa* have been highlighted. Sreelatha and Padma (2009) indicated that the antioxidants in both mature and young leaves have a great potential to scavenge free radicals, along with nutritional antioxidants such as Vitamins A, C, and E (Limon-Pacheco and Gonsebatt, 2009). The highest therapeutic value of *M. oleifera* is further substantiated in terms of its high antioxidant level present in leaves, seeds, flowers and pods (Chumark *et al*., 2008; Verma *et al*., 2009; Atawodi *et al*., 2010). Kumar *et al*. (2007) demonstrated these antioxidant properties could be responsible for reduction of the chance of cancer development and other damage to the cell.

3.3 Anti-inflammatory Properties

The pathophysiology of many diseases, such as diabetes, obesity, hypertension and others can involve immunological responses (Rana *et al*., 2007). Leaf extracts from *Moringa* leaf extracts seem to modulate cellular immunity in rats and mice (Sudha *et al*., 2010; Gupta *et al*., 2010). Leaf preparations have shown anti-inflammatory properties in rodent models (Sulaiman *et al*., 2008; Mahajan and Mehta, 2009). Studies suggest that the anti- inflammatory properties are stronger in fruit and seed extracts (Mahajan and Mehta, 2010; Cheenpracha *et al*., 2010; Muangnoi *et al*., 2011).

3.4 Hypocholesterolemic Activity

Moringa leaves contain phytosterols (Jain *et al*., 2010); that seem to be implicated in the reduction of cholesterol uptake by the intestines (Lin *et al*., 2010). It is possible that this could result in a decrease in cholesterol levels and an increase in excreted cholesterol seen in experimental rodents (Mehta *et al*., 2003; Jain *et al*., 2010). The high-fiber content (12% w/w) may also play a role in the hypocholesterolemic effect due to enhanced excretion/gastric emptying (Bortolotti *et al*., 2008; Joshi and Mehta, 2010).

3.5 Anti-asthmatic Activity

The *Moringa* alkaloid moringine closely resembles ephedrine, inducing relaxation of the bronchioles (Kirtikar and Basu, 1975). The seeds and kernels of *Moringa* have been used successfully for the treatment of bronchial asthma, by decreasing the severity of the symptoms, resulting in the improvement of respiratory problems in patients (Agrawal and Mehta, 2008).

3.6 Analgesic Activity

Ethanolic extracts of *Moringa* fruits have shown good analgesic properties when tested in Male Sprague-Dawley rats (Rao *et al*., 2008). The authors used the Ugo Basile 37215 analgesia-meter to evaluate pain and adjuvant-induced arthritis to evaluate anti-inflammatory properties. They found strong analgesic activity and anti-inflammatory properties in this plant. Sutar et al. (2008) used Wister male albino rats and tested pain threshold using the licking or paw/jumping response of the animal and the tail immersion method. The authors

found that *Moringa* seems to have a strong analgesic activity. There is a great potential for this plant to be used by people that may not have access to more expensive analgesics but have the plant available for their use. In addition, extracts of this plant could eventually be commercialized for medicinal uses.

3.7 Antidiabetic Activity

Experiments in Wistar and Goto-Kakizaki (GK) rats with type 2 diabetes show a positive effect of *Moringa* leaves, with a significant decrease in blood glucose levels (Ndong *et al*., 2007). In addition, in high-fat-diet mouse models, the extracts of this plant have shown improved glucose tolerance (Jaja-Chimedza et al., 2018). The lowering blood sugar levels within 3 h after ingestion has been observed (Mittal *et al*., 2007) and is likely to be due to extracts' inhibitory activity against α-Glucosidase enzyme (Natsir et al., 2018). It is possible that polyphenols such as 3-glycoside, kaempferol glycosides and others (Ndong *et al*., 2007) could have an effect in this antidiabetic activity. Studies have shown the antioxidant activity of Moringa can rescue apoptosis of beta cells, therefore preventing damage to these cells, leading to the beneficial properties against diabetes (Al-Malki et al., 2015; Mbikay, 2012; Kaneto et al., 1999). Additional studies may lead to the commercialization of *Moringa* extracts for conventional treatment of diabetes.

4. Conclusion

This review shows that different parts of *Moringa* (leaves, flowers, fruits and seeds) possess a great variety of compounds with high nutritional and medicinal content that could make it an ideal complementary and alternative medicine and/or nutritional supplement. The presence of antimicrobial compounds could lead to the development of alternative treatments against infectious diseases. Research has shown that every part of the plant has some medicinal application that could be further develop to produce more affordable medicines. *M. oleifera* is nutritional and medicinally very active against free radicals formed during oxidative stress due to the strong phytochemical constituents present in virtually all parts of the plant. There is a great potential for the widespread use of this plant.

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