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Medicinal and Ethnobotanical Utilities of *Moringa oleifera* Lam. (Sahjan)

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Abstract
Moringa oleifera Lam., commonly called Sahjan in India and commonly known as the drumstick tree or horseradish tree in English, is a fast-growing tropical tree that is highly nutritionally dense and has a long history of both medicinal and culinary use throughout South Asia, sub-Saharan Africa and some regions of Southeast Asia. Folk and Ayurvedic medicine have used practically all parts of the plant, such as the leaves, immature pods, seeds, flowers, bark, and roots to treat diseases including inflammation and infection, diabetes, anaemia, and malnutrition in children. This review compiles an ethnobotanical record, and laboratory evidence on *Moringa oleifera*, its taxonomy, phytochemical composition, and the pharmacological actions that have been reported to date on it, including its antioxidant, anti-inflammatory, antidiabetic, antimicrobial, hepatoprotective, and cardioprotective activities. A nutritional profile of the leaves, which is a source of significant levels of protein, carotenoids and minerals, is described, the growing contribution of the tree to food security programmes and in low-cost water purification using its seed proteins. Special attention is paid to safety considerations, as preparations made of the root and bark have known toxicity risks recorded, which are not always recognised by traditional practice. In spite of the fact that animal and *in vitro* research confirms a considerable portion of the conventional arguments concerning this plant, there are a limited number of controlled trials in human groups, and filling that gap was defined here as the primary research objective in the future.

Keywords: *Moringa oleifera* Lam., Moringaceae, Sahjan, Ethnomedicine, Drumstick.

Introduction

Hardly any plant stands as high in the ethnobotanical history of South Asia as does *Moringa oleifera* Lam. (Sahjan), of the monogeneric family Moringaceae. It is an indigenous species thriving in the sub-Himalayan tracts of northern India, Pakistan, Bangladesh, and Afghanistan, but it has since been introduced into the tropics and subtropics and is currently growing as far away as sub-Saharan Africa, the Philippines, the Caribbean, Central America (Anwar *et al.*, 2007). It is referred to in Hindi and Urdu as Sahjan; in English as the drumstick tree, the name being given to it because of the shape of its long, ridged pods or the horseradish tree, so called because of the pungent flavor of its ground root. Local names continue to multiply, including Moringa in most of East Africa, Malunggay in the Philippines and Munagakaya in south-eastern India, to name but a few.

The reputation attaching to this plant, is not due, however, to any one, dramatic, curative quality, but rather to the mere extent of little, utilitarian applications to which rural families have over the ages applied its name. It is used as a vegetable and a supplementary food to nursing mothers and young children: the leaves are cooked and served to the children; the pods are consumed as a component of a curry; the seeds are pressed to make oil or crushed and dropped into jars full of muddy water to clear it; preparations of the bark, gum, and root are used in local remedies, against toothache, rheumatism, and everything in between (Kasolo *et al.*, 2010; Popoola and Obembe, 2013). It is a traditional body of knowledge which has attracted the interest of pharmacologists and nutrition scientists over the last 20-30 years, and a strong literature of laboratory studies has accumulated around the phytochemistry and biological activity of the plant (Fahey, 2005; Leone *et al.*, 2015).

There are three objectives of this review. It begins by giving an overview of what has been known about the taxonomy, botany, and geographic distribution of *Moringa oleifera*, along with the variety of common names applied to it. Second, it surveys the traditional and modern medicinal uses reported of its various parts of the plant, positioning folk practice in juxtaposition with the pharmacological evidence

which has since been produced too much of the same. Third, it looks at the greater socio-economic value of this specific plant, such as its contribution to nutrition security, rural lives and water treatment, and ends with a candid description of what is unknown, especially regarding toxicity and lack of clinical information in humans.

Botanical Description and Distribution

Moringa oleifera Lam. is a fast growing, short-lived, deciduous tree, which grows up to five to ten metres high in favourable conditions though. We have a corky, soft, corky bark, an open crown, umbrella-shaped, and swollen, tuberous taproot in young forms, which yields to a more usual root structure as the tree grows old. The leaves are tripinnately compound, appearing feathery and suspended on long petioles; the small, cream-to-white, fragrant, flowers are found in axillary panicles more or less the year round in warm climates. The most prominent characteristic of the tree fruit is its fruit, a three-sided longitudinally ridged pod,with an average length of thirty to forty-five centimetres when mature, which divides the length to disperse winged seeds (Anwar *et al.*, 2007).

The species is taxonomically a member of the genus Moringa, the only genus within the family Moringaceae, which consists of about a dozen known species found all over Africa, Madagascar, and southern Asia (Leone *et al.*, 2015). The most thoroughly researched of these is, by far, *Moringa oleifera*, which is in part due to its ability to tolerate poor soils, drought and a broad temperature range, making it an appealing agro forestry species in marginal land. It is now naturalised long outside of its natural range, and is now grown commercially in India, the Philippines, some African nations, and even in Central and South America, typically as a small-scale crop in home gardens or as a living fence, but not in large plantations.

Nutritional Composition of *Moringa oleifera* Lam. (Sahjan)

The nutritional case of *Moringa oleifera* Lam. (Sahjan) lies on the fact that the nutrient is especially abundant in its leaves whose protein, calcium, iron content and carotenoids as provitamin A make it an unusual leafy vegetable regarding nutrients (Oduro *et al.*, 2008). These nutrients are more concentrated in dried leaf powder than in unprocessed leaf, as drying water causes them to remain, with most of the mineral content and much of the vitamin content being preserved, and these are some of the reasons why leaf powder has been promoted as a supplement to young children and pregnant or lactating women in low-diversity regions (Gopalakrishnan *et al.*, 2016).

The unripe pods, which are eaten as a vegetable in most cuisines, contain a fair amount of vitamin C and dietary fibre, but less protein and mineral content than the leaves on a dry-weight basis. The seeds, however, are characterized principally by the amount of oil they contain with the oil in some cases being over a third of seed weight and is mostly oleic acid in nature, thereby giving the extracted oil, occasionally sold as ben oil, a fatty acid composition similar to that of olive oil on the whole (Anwar and Bhanger, 2003). This oil has been used as an edible product and also as a cosmetic ingredient and its relatively high oxidative stability has been credited to the presence of tocopherol that goes along with the oil. Flowers are also consumed locally, and provide lower amounts of calcium and potassium, and relative lack of systematic nutritional research has been done on them.

There are two caveats to reading this nutritional literature. The reported values differ significantly across studies based on cultivar, growing conditions, plant age, and the method of analysis, so the repeatedly cited comparisons that *Moringa oleifera* Lam. (Sahjan) leaves have, in weight, many times the vitamin C of oranges or the calcium of milk must be viewed as rough indications, not as exact equivalents (Gopalakrishnan *et al.*, 2016). Second, bioavailability does not equal raw nutrient content and how much the minerals and carotenoids in the dried leaf powder is actually absorbed and used by the human body has been researched less than the composition of the plant itself.

Ethnobotanical Significance

There are a great number of ethnobotanical surveys in Nigeria, Uganda, or India and elsewhere in the tropics, and these all demonstrate a similar pattern: *Moringa oleifera* Lam. (Sahjan) is not so much a medicine in the strict sense, but rather an everyday multipurpose resource, food, fodder, fencing, and remedy combined (Popoola & Obembe, 2013). In a Ugandan survey of the rural communities, leaf decoctions were also reported to be popular home remedies against malaria-like fevers, general weakness, and hypertension, leaving other plant parts to treat digestive issues and skin infections (Kasolo *et al.*, 2010). Corresponding patterns of leaf, seed and bark utilisation have also been observed in ethnobotanical studies conducted in Nigeria where it was observed that understanding of the plant use varied somewhat by region and with the age of interviewees, older informants tended to report more uses than younger ones did (Popoola & Obembe, 2013).

The ethnobotanical status of the plant is further supported by its presence in the classical Ayurvedic and Unani texts, with different parts of the plant attributed various therapeutic effects, such as root and bark as a rubefacient and stimulant, the leaves as a tonic and galactagogue, and the seeds and gum in various preparations of seeds and gum as a joint palsive. This written school of tradition lies alongside, and, in most families, in practice intermingles with, oral folk knowledge passed on in an informal way between generations, and it is hard in practice to draw the line between codified Ayurvedic use and generic folk medicine when writing up how the plant is really used in any particular village.

What comes out of this survey work is neither one origin story of the medicinal reputations of the plant but a mosaic of practices developed locally and which fortuitously overlap over many of the same parts of the plant and, in a few cases, over remedies to many of the same types of complaint, most notably fevers, digestive disturbances, and wound care. One of the reasons pharmacologists have developed enough concern about the plant to subject it to lab tests is this convergence in geographically and culturally disparate communities, which is, of itself, no more than a weak indicator of whether a remedy will be pharmacologically active.

Traditional Medicinal Uses

The conventional *Moringa oleifera* Lam. (Sahjan) uses vary significantly depending on the part of the plant. The most commonly used part as a general tonic, with lactating mothers, and as a laxative to regulate slight fevers and debilitating symptoms, is in the form of leaves, cooked as a vegetable, a powder, or a tea. In certain communities, flowers are used as an aphrodisiac preparation and to address inflammation of the spleen, but such assertions are basically a matter of oral tradition with little pharmacological research

done. In addition to their culinary consumption, sometimes pods are used to treat digestive and liver issues.

Seeds and the oil extracted out of them are used in the treatment of joint pain and skin disorders as well as when crushed and dissolved in water as a traditional clarifying agent even before the ability of coagulants was described in scientific literature (Ndabigengesere *et al.*, 1995). They are used as rubefacients, as a toothache remedy, and, in certain cultures, as an abortifacient or emmenagogue (a role of which modern toxicology has historically linked to compounds with the ability to cause uterine contraction), a role which has demonstrated a clash with traditional practice and the presence of safety data, rather than a harmonious compatibility (Stohs and Hartman, 2015). In various local practices, gum exuded as a trunk has been used topically on wounds and dental issues.

Reading through these applications a pattern is found, where the leaves and pods, the most frequently used part as food, have the best-recorded lowest toxicity risk, and the broadest application to traditional use, whereas the root and the bark, used more selectively and against more particular complaints, have the highest recorded risk. This difference is important to the interpretation of the overall safety profile of the plant, as blanket assertions that *Moringa oleifera* is or is not safe hide a factual difference amongst the parts of the plant.

Pharmacological Properties and Bioactive Compounds

Since the early 2000s, the pharmacological literature on *Moringa oleifera* Lam. (Sahjan) has grown significantly, with much of this work advancing due to phytochemical studies to establish the compounds that mediate the purported actions of *Moringa oleifera* Lam. (Sahjan). The leaves also have significant amounts of flavonoids (primarily quercetin and kaempferol glycosides) and phenolic acids (chlorogenic and caffeoylquinic acid derivatives) that are responsible of providing modest antioxidant activity *in vitro* (Sreelatha and Padma, 2009; Vongsak *et al.*, 2013). Glucosinolates and corresponding hydrolysis products, the isothiocyanates, a type of sulphur-based compounds, also seem to be the basis of much of the anti-inflammatory, and some of the antimicrobial, action of this plant (Fahey *et al.*, 2018; Waterman *et al.*, 2014).

One of the most commonly reported results of studies of *Moringa oleifera* Lam. (Sahjan) leaf extracts is antioxidant activity; a variety of assays have been carried out, including the DPPH and total phenolic content, show activity that is proportional to the concentration of phenolics and flavonoids within the extract, and tends to be greater in extracts of older leaves than of very young shoots, contrary to what one would expect were young tissues considered the default choice of the bioactivity agent (Sreelatha & Padma, 2009). Cell-based tests have shown anti-inflammatory effects with isothiocyanate-enriched leaf extracts inhibiting the synthesis of inflammatory mediators like nitric oxide, and a series of cytokines in macrophage cultures stimulated (Waterman *et al.*, 2014).

Antidiabetic activities have also been explored in rodent models, in which aqueous leaf extracts reduced the level of fasting blood glucose in streptozotocin-induced diabetic rats, which was ascribed to a blend of elevated insulin discharge and decreased intestinal uptake of glucose, though the mechanism by which this occurs has yet to be fully unraveled (Jaiswal *et al.*, 2009). Extracts of the leaves, seeds, and bark have been reported as possessing antimicrobial and antifungal activity across a variety of bacterial and fungal organisms, with isothiocyanates again reported to have been involved in the activity, although activity varies widely in terms of the activity spectrum and the strength of the effects depending on the extraction medium and the microorganism challenged (Anwar *et al.*, 2007).

The protective effect of a well-cited rodent study where the hepatoprotective effect of a leaf extract was shown to reduce liver damage caused by acetaminophen overdose is associated with replenishing lost hepatic glutathione levels it would have otherwise caused by the toxic dose (Fakurazi *et al.*, 2008). Also noted are cardioprotective and antihypertensive effects, usually due to an interaction between antioxidant activity and direct actions on vascular smooth muscle, but this segment of the literature is smaller and less uniform than the antioxidant and antidiabetic literature (Mbikay, 2012).

Therapeutic Applications

There is a little caution needed when trying to translate this laboratory evidence into therapeutic recommendations as the vast majority of the pharmacological studies presented above were done in cell culture or in rodent models, on extracts at concentrations that are not necessarily the same as those that a person would obtain after eating the leaves of *Moringa oleifera* or after taking a commercial leaf-powder product. Nonetheless, the similarity of the antioxidant and anti-inflammatory results of independent laboratories, which use the plant material in the various countries, gives the underlying assertion more credence than a single study would (Vergara-Jimenez *et al.*, 2017).

In humans, in contrast, the clinical evidence is relatively thin. Some small pilot studies and pre-tests have tested the role of leaf powder supplementation in malnutrition, anaemia, and mild dyslipidaemia and generally show positive changes in nutritional outcomes, but sample sizes have generally been limited, and follow-up short, and blinding has often been not possible due to the visible characteristics of the intervention (Mbikay, 2012). Critics of this evidence base have always demanded larger and well-controlled human studies before therapeutic allegations on diabetes, high blood pressure, or high cholesterol levels can be considered proved as opposed to prospective (Stohs and Hartman, 2015).

Practically, the most justifiable medical application of *Moringa oleifera* nowadays is as a nutritional supplement, the leaf powder to the weaning foods or as a supplement in environments of nutritional deficiency, but not as a medicine to a particular diagnosed disease. Its adjunct status use because of chronic diseases like diabetes or hypertension indicates the current state of evidence balance, indicating the biological plausibility and preliminary benefit, but not yet the amount of evidence to justify the replacement of the existing pharmacological treatment.

Economic and Socio-Cultural Importance

Moringa oleifera Lam. (Sahjan) has gained legitimacy in the real economic sense in the areas of its cultivation in addition to its traditional medicinal value. Leaf powder is currently exported to other countries and health-food markets in North America and Europe have led to the demand of leaf powder as a dietary supplement, which has generated export earnings to smallholder growers in countries like India, Ghana and the Philippines. Seed oil, which is marketed as ben oil, has also found its way into cosmetics, but on a lesser scale, as specialty cooking oil, which provides an additional source of income on the same tree (Anwar and Bhanger, 2003).

To domestically grown trees, its low input needs make the tree a viable crop to smallholder and subsistence farmers: it

can withstand poor and marginal soils, requires relatively low water inputs after planting, and can be harvested over and over again to take leaves without felling, features which are conducive to agroforestry systems and home gardens in semi-arid areas (Leone *et al.*, 2015). In South Asia and sub-Saharan Africa, development and nutrition programmes have encouraged the *Moringa oleifera* cultivation, in particular as a low-cost intervention to child and maternal malnutrition, by including the leaf powder in supplementary feeding programs based on its nutrient content (Gopalakrishnan *et al.*, 2016).

The other more unusual economic use of the plant is in water treatment. The seeds are crushed and contain cationic proteins which serve as a natural coagulant, bringing together the suspended particles and some microorganisms in turbid water, which form clumps and settle down, which was reported in classic work on the coagulation of *Moringa oleifera* Lam. (Sahjan) seeds and has since been used in the clarification of low-cost small-scale water clarification in rural societies with limited access to conventional treatment chemicals (Ndabigengesere *et al.*, 1995). Although this method cannot eliminate pathogens or dissolved contaminants or be compared to complete water purification, it has some actual merit as a low-cost pre-treatment method, and serves as a good example of how a single traditional method can evolve into a documented, reproducible technology.

Safety, Toxicity, and Limitations

Data on the safety of *Moringa oleifera* Lam. (Sahjan) are significantly less than data on its efficacy and the limited available data indicates that there is a distinction between the plant parts. The foliage and pods have a long history of safe use and toxicological investigations of leaf extracts in animal models have typically taken very high doses before toxic effects are noticed (Stohs and Hartman, 2015). Preparations of roots and bark are another thing: they contain compounds that have also been linked with uterine stimulation and abortifacient action in animal testing, which is also consistent with their historical use, in some cultures, to induce an abortion, and this is one of the areas where the traditional use should evoke more concerns than a reader (Stohs and Hartman, 2015).

In the sparse human data available, reported adverse effects of large doses of *Moringa oleifera* Lam. (Sahjan) are mild gastrointestinal malady, and, with respect to overlapping pharmacological actions on blood glucose and blood pressure, there is hypothetical worry, supported by *in vitro* and animal studies, that *Moringa oleifera* plans may interact with various drugs, both those used to treat diabetes and hypertension (Mbikay, 2012). Root and bark preparations are particularly not recommended in pregnant women, but consumption of leaves in average amounts in the diet is not regarded as in the same category as risk.

Another shortcoming of this literature is lack of standardisation. Since most of the supportive evidence is in animal studies, using extracts prepared and dosed differently across different laboratories, there is no widely accepted dosage equivalent of any of the above therapeutic effects determined by clinical trials, and the labeling of commercial supplements tends to reflect manufacturers convention rather than the dose determined in clinical trials (Stohs and Hartman, 2015). This disparity between a plausible biological activity and a proven, safe therapeutic dose is perhaps the one greatest unsolved question in the area.

Future Prospects and Research Priorities

The following are some of the research priorities that follow reasonably on the above-identified gaps. The urgency of the former is the fact that larger and better-controlled clinical trials in human populations are necessary, especially the antidiabetic, antihypertensive, and anti-inflammatory claims which at the present are based almost exclusively on animal data (Mbikay, 2012; Vergara-Jimenez *et al.*, 2017). This would require specifying standardised procedures of extract preparation, and doses, as it seems that variation in the drying, extraction and storage of leaf material can significantly alter phenolic and glucosinolate concentrations, and cross-comparisons between the current bodies of literature would be challenging due to this inconsistency (Vongsak *et al.*, 2013).

A second priority is bioavailability and pharmacokinetics: the fact that a compound is found in the leaf and active in a cell-culture assay tells relatively little about the extent to which that compound survives digestion, enters the bloodstream, and is active in a living individual, and has relative lack of direct investigation of this question in *Moringa oleifera* as compared to the amount of research done on the raw phytochemical composition of the plant (Waterman *et al.*, 2014). Third, since root and bark preparations have been shown to be hazardous, this would be the point at which toxicological characterisation of root and bark preparations, including dose-response information in animal models, would be done to translate a qualitative safety warning into a quantitative actionable information to the traditional practitioners and supplement producers.

Lastly, it could also be more thoroughly researched on an agronomic and post-harvest level to know how the growing conditions, cultivar, and the processing technique influence the ultimate nutrient and phytochemical composition of commercially produced leaf powder, as its variability currently makes it hard to say with certainty what a customer who buys, say, a supplement is actually getting (Gopalakrishnan *et al.*, 2016).

Conclusion

Moringa oleifera Lam. (Sahjan) is in a curious position with respect to medicinal plants in that its reputation is on an anomalously wide and consistent foundation of traditional use on a multi-continental scale, and with a truly massive amount of laboratory data in confirmation of most, but not all, of the biological activities that traditional practice ascribes to it. The most remarkable feature of these plants is the nutritional and pharmacological properties of the leaves, among which there is quite solid evidence of antioxidant and anti-inflammatory activity, and moderate, as yet unclinically verified potential of antidiabetic and hepatoprotective activity. In comparison root and bark preparations however, show that traditional use is not in itself enough of a safety assurance and that the dangers given with these portions should be articulated more clearly than they are in much of the popular literature on the plant.

The field does not most urgently require additional confirmation that *Moringa oleifera* Lam. (Sahjan) possesses bioactive compounds, which at this point is already quite established, but a controlled human trial that can be able to test whether the compounds do exert clinically meaningful benefit when delivered in dosages that are safely and reliably administered. Until such evidence is gathered, the most justifiable application of this plant is as a nutritionally useful

food and dietary supplement and not as a replacement to medically established treatment protocol which in no way diminishes the actual value it has proven to confer to the food security and traditional medicine of those communities who have depended on it over the centuries.

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