An Updated review on the Bioactivities and Phytochemistry of the Nutraceutical Plant Moringa oleifera Lam (Moringaceae) as valuable phytomedicine of multi-purpose

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ABSTRACT

Aims: To critically summarize and provide update knowledge on phytochemistry and pharmacological activities of Moringa oleifera with a view to provide baseline data for medicinal food fortification formulation.

Study Design: Multidisciplinary advanced bibliographic surveys, utilization of ChemBioDraw software package and dissemination of the resulted knowledge.

Place and Duration of Study: Faculty of Science, University of Kinshasa, Department of Environmental Science, University of Gbadolite and Faculty of Science, University of Kisangani, the Democratic Republic of the Congo, between March and June 2018.

Methodology: A deep literature search was carried out to obtain information about the phytochemistry and pharmacognosy of M. oleifera from various established scientific databases such as PubMed, PubMed Central, Science Direct and Google scholar. The scientific name of this plant species was used as a keyword for the search, along with the terms phytochemistry and bioactivity or pharmacognosy. The chemical structures of the M. oleifera naturally occurring compounds were drawn using ChemBioDraw Ultra 12.0 software package.

Results: Comparative analysis of the literature revealed that Moringa oleifera is traditionally used to treat several ailments. This plant is reported to possess various pharmacological properties such as antioxidant, antibacterial, anti-inflammatory, antidiabetic, antifungal, antispasmodic, anticancer, antipyretic, anti-proliferative, wound healing, and antidyshlipidemic, CNS effects as well as its efficiency against infertility. These properties are due to the presence of numerous naturally occurring phytochemicals like tannins, alkaloids, phenols, glycosides, flavonoids and steroids while its proximate composition makes it very relevant in daily life as nutraceutical.

Conclusion: The present review can, therefore, help inform future scientific research towards the development of novel drugs of relevance from M. oleifera to improve human health and wellbeing. Especially, M. oleifera could serve as drug candidates for Sickie cell anemia treatment and others ailments of relevance in developing world like Democratic Republic of the Congo.

Keywords: Moringa oleifera, Phytomedicine, Phytoconstituents, Pharmacognosy

INTRODUCTION

Background

The World Health Organization (WHO) reported that 80% of the population living in developing countries relies on traditional medicine for their primary health care needs.1 In Democratic Republic of the Congo (DRC), medicinal plants such as M. oleifera represent the key product for both urban and rural populations for their health care needs because the costs of conventional drugs are often unaffordable. These plants have found to have great therapeutic significance for fighting major health problems.1,6

Moringa oleifera Lam. is a tropical deciduous perennial dicotyledonous tree.6 Sometimes called the Tree of Life or a Miracle Tree, but rather than being in reference to its potential medicinal usage, this refers to how this plant is a very valuable food crop (it is drought resistant, grows very fast, and is highly nutritious). Beyond being a food, it has many benefits for developing countries notably India, Pakistan, Philippines, Hawaii and many parts of Africa, having an ability to be used for some crafts (due to being a tree) and cleaning water.7 M. oleifera is a rich source of phenolics and

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glucosinolates, minerals, tocopherols, carotenoids, polyunsaturated fatty acids, ascorbic acid, folate, potassium (K), calcium (Ca), and magnesium (Mg).

M. oleifera tree, including roots, bark, leaves, flowers, fruits, and seeds are traditionally used for various therapeutic applications such as abdominal tumors, hysteria (a psychological disorder), scurvy, paralysis, helminthic bladder, prostate problems, sores and other skin infections. The present review aims to give updated information on the phytochemistry and pharmacognosy of this useful medicinal plant species.

Botanical description and distribution of M. oleifera Lam

M. oleifera Lam. is a tropical deciduous perennial dicotyledonous tree. The stem is brittle with a corky, whitish-gray bark, with drooping branches, pale green and bipinnate or more commonly tripinnate leaves (30-60 cm long) with opposite, ovate leaflets. M. oleifera, the native of the sub Himalayan mountains of northern India; is now cultivated for a variety of purposes in the whole tropical and subtropical regions of the world.

METHODOLOGY

A sound literature search was carried out in order to obtain information on the phytochemistry and bioactivities of M. oleifera from various electronic databases namely PubMed, PubMed Central, Science Direct and Google scholar. The scientific name of this plant species was used as the keyword for the search, along with the terms like phytochemistry, bioactivities, pharmacology and pharmacognosy. Different chemical structures of M. oleifera naturally occurring compounds were drawn using ChemBioDraw Ultra 12.0 software package.

RESULTS

Microscopic features

The transverse section of the bark showed cork, cork cambium and secondary cortex. The outermost 25-30 layered cork cells arranged in radial rows contain rectangular suberized walled cells arranged in layers. The cork layers are followed by 5-10 layered cork cambium containing multilayered thin walled rectangular cells. Secondary cortex is composed of thin walled parenchymatous cells containing calcium oxalate crystals, starch grains and oil globules.

Ethnobotany of M. oleifera

M. oleifera is often considered as an important famine food because of its high resistance to drought and arid conditions due to their tuberous roots. Almost each and every part of Moringa tree is useful for medicinal, functional food preparations, nutraceuticals, water purification, and biodiesel production; including roots, leaves, flowers, green pods, and seeds. The immature pods, flowers, and foliage of this tree are used for culinary purposes in different parts of the world.

Different parts of the M. oleifera tree (roots, bark, leaves, flowers, fruits, and seeds) are
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traditionally used in various therapeutic applications). It is known that it has a wide range of therapeutic properties namely abdominal tumors, antifungal, antitubercular, antispasmodic, abortifacient, antilithic, antifertility, anti-inflammatory, antitumors and as cardiotonic,\textsuperscript{19-21} hysteria (a psychological disorder), scurvy, paralysis, helminthic bladder, prostate problems, anti-hypercholesterolaemic,\textsuperscript{22} sores and other skin infections.\textsuperscript{13,24} The therapeutic potential and medicinal properties of \textit{M. oleifera} are extensively reviewed.\textsuperscript{13,14}

**Phytochemistry**

Several authors reported \textit{M. oleifera} to be a rich source of various phytochemicals, viz. the bark is reported to contain two alkaloids namely moringine and moringinine,\textsuperscript{25} phytosterols like β-sitosterol and β-sitostenone,\textsuperscript{24} glucosinolates like 4-(alpha-L-rhamnopyranosyloxy)-benzylglucosinolate.\textsuperscript{25} The seeds contain glucosinolates like 4-(alpha-L-rhamnopyranosyloxy)-benzylglucosinolate.\textsuperscript{25} O-ethyl-4-a-L-rhamnosoyloxy) benzylcarbamate.\textsuperscript{26} The leaves contain glucosinolates like 4-(alpha-L-rhamnopyranosyloxy)-benzylglucosinolate and three monoacetyl isomers of this glucosinolate,\textsuperscript{25} nitrile glycosides niaziridin and niazirin,\textsuperscript{27} isothiocyanate like 4-[(4’-O-acetyl-a-i-rhamnosyloxy)benzyl] acetilated glycosides bearing groups like thiocarbamate, carbamate or nitrile,\textsuperscript{29} thioleucamidate glycosides niaziminin A and B,\textsuperscript{24} phenols like quercitin-3-O-glucose and quercetin-3-O-(6”-malonyl-glucoside), kaempferol-3-O-glucoside, kaempferol-3-O-(6”-malonyl- glucoside), 3-caffeoylquinic acid and 5-caffeoylquinic acid.\textsuperscript{25}

It is also rich in compounds containing the simple sugar, rhamnose called glucosinolates and isothiocyanates. Purified, gum exudate from \textit{M. oleifera} has been found to contain Larabinose, galactose, glucuronic acid, and L-rhamnose, mannose, xylose and degraded-gum polysaccharide consisting of L-galactose, glucuronic acid and L-mannose has been obtained on mild hydrolysis of the whole gum with acid. Numerous antibacterial compounds have been isolated from \textit{M. oleifera}, including: glucosinolates, rhamanose, pterygospermin, and isothiocyanates. Specifically, these compounds include 4-(4’-O-acetyl-a-L-rhamnopyranosyloxy) benzyl isothiocyanate.\textsuperscript{30} The foliage of \textit{M. oleifera} has been established as a rich source of phenolics and glucosinolates, minerals,\textsuperscript{8} tocopherols,\textsuperscript{9} carotenoids,\textsuperscript{10} polyunsaturated fatty acids,\textsuperscript{11} ascorbic acid\textsuperscript{12} and folate.\textsuperscript{10} The chemical structures compounds isolated from \textit{M. oleifera} are given in figure 1.

The biological model used to study active compounds is presented in table 1 below.

**Proximate analysis and nutritional benefits of \textit{M. oleifera}**

Upadhay et al.\textsuperscript{41} reported that \textit{Moringa} leaves are extremely nutritious and contain larger amounts...
of several nutrients than the common food often associated with these nutrients. The presence of vitamin C in Moringa fights a host of illness which include colds and flu while vitamins A, act as a shield against eye and skin diseases, heart ailments, diarrhea, and many other diseases. Calcium builds strong bones and teeth and help prevent osteoporosis. Upadhay et al. showed that Moringa leaves contain more vitamin A than carrot, more calcium than milk, more iron than spinach, more Vitamin C than organs and more potassium than bananas; and that the protein quality of moringa leaves rivals that of milk and eggs. In fact the nutritional properties of Moringa are now so well-known seems to be little doubt of the substantial health benefit to be realized by consumption of Moringa leaf powder in situations where starvation is imminent. A large number of reports on the nutritional qualities of Moringa now exist in both the scientific and the popular literature.

Leone et al. showed that in the tissues of M. oleifera these minerals Potassium (K), calcium (Ca), and magnesium (Mg) are the predominant minerals. The highest content of K is found in the vegetative parts and immature pods while leaves and seeds are a rich source of Ca and Mg, respectively. However, M. oleifera is also recorded as having a rich source of iron (Fe) (17.5 mg/100 g DW). In a bioavailability study conducted on a rat model, Fe from the Moringa leaf was found to be superior compared to ferric citrate, in overcoming iron deficiency. Full-fat and defatted M. oleifera kernels are recorded as being rich in protein content and account for 36.18 and 62.76%, respectively. The concentrations of the other proximate constituents were found to be higher in defatted flour, compared to full-fat flour. Defatting also increased water absorption, fat absorption, foaming capacity and stability of the flour. Teixera et al. suggested that the M. oleifera kernel flour could be used as a valuable source of protein in food product formulation. In the proximate studies from Brazil, the dehydrated leaf powder was recorded to contain 44.4% of carbohydrate, 28.7% of crude proteins, 10.9% ash, 7.1% fat, 103.1 mg/100 g of Fe, and 3.0 mg/100 g Ca. Similarly, the protein profile showed 70.1% of insoluble proteins, 3.5% of glutelin, 3.1% of albumin, 2.2% of prolamin, and 0.3% globulins. Anti-nutritional compounds, such as, tannins (20.7 mg/g), trypsin inhibitor (1.45 TIU mg/g; Trypsin Inhibitor Units), nitrates (17 mg/g), and oxalic acids (10.5 mg/g) were documented as well.

The proximate composition of M. oleifera based on the fresh leaves (fresh weight) and the dried leaf powder Analyzed value of Moringa pods, fresh (raw) leaves and dried leaf powder has shown to contain the following per 100 grams of edible portion as presented in Table 2.

**PHARMACOLOGICAL PROPERTIES OF M. OLEIFERA LAM**

**Anti-proliferative activity**

The anti-proliferative assay was evaluated on three types of cancer cell lines: hepatocarcinoma (HepG2), colorectal adenocarcinoma (Caco-2) and breast adenocarcinoma (MCF-7), using 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl
tetrazolium bromide (MTT) reduction assay respectively. The *in vitro* cancer chemoprevention was performed using quinone reductase (QR) induction assay on hepatoma (Hepa-1c1c7). The chemopreventive activity of the extracts was expressed as concentration to double QR activity (CD value).  

Potent anti-proliferative and apoptotic properties of the *M. oleifera* leaf extract, rich in quercetin and kaempferol phenolics compounds, have been demonstrated using the human tumor (KB) cell line model. *M. oleifera* leaf extract has shown significant morphological changes and decreased cell viability, with increased inter nucleosomal DNA fragmentation and ROS generation in the KB cells.  

**Antioxidant activity**

Siddhuraju and Becker\(^4^9\) reported that the antioxidant activity in the oil from the dried seeds is higher than BHT and alpha Tocopheryl. Aqueous, methanol (80%) and ethanol (70%) extracts of dried leaves showed radical scavenging and antioxidant activities. The drumstick leaves are found to be a potential source of natural antioxidants. *M. oleifera* leaves extracted with methanol and dichloromethane were screened for the antioxidant activity and the methanol extract showed higher free radical scavenging activity than the dichloromethane extract (IC\(_{50}\) = 1.60±0.03 mg/mL in DPPH assay and IC\(_{50}\) = 1.02±0.06 mg/mL in ABTS assay).  

**Antibacterial activity**

Renata et al.\(^5^3\) reported the ethanol extracts at low (MOS-E) and high (MOS-ES) temperature are shown to be bioactive against 92% and 90% of the strains, respectively. The most efficient Minimum Inhibitory Concentration (MIC) levels of MOS-E and MOS-ES against a high percentage of strains were 32\(\mu\)g.mL\(^{-1}\). Bioguided screening of bioactive compounds showed that the ethyl acetate fraction from both extracts was the only one that displayed an antibacterial activity. *M. oleifera* roots have anti-bacterial activity and are reported to be rich in antimicrobial agents.\(^5^4\) These are reported to contain an active antibiotic principle, pterygospermin, which has a powerful antibacterial effect.

**Antifungal activity**

Ping et al.\(^3^7\) reported that the Ethanol extracts showed anti-fungal activities *in vitro* against dermatophytes such as *Trichophyton rubrum*, *Trichophyton mentagrophytes*, *Epidermophyton floccosum*, and *Microsporum canis*. GC-MS analysis of the chemical composition of the essential oil from leaves showed a total of 44 compounds.

**Antispasmodic activity**

The antispasmodic activity was demonstrated using isolated duodenum, oral anti-inflator activity by carrageenan-induced bindpaw edema. The seed infusion showed a significant inhibition of acetylcholine-induced contraction with an ED\(_{50}\), of 65.6 mg.mL\(^{-1}\) bath concentration, inhibition of carageenan-induced edema at 1000 mg/kg and diuretic activity at 1000 mg/kg.  

**Antitumor or Anticancer activity**

*M. oleifera* leaves extracted with methanol and dichloromethane were screened for anticancer activity. The IC\(_{50}\) of dichloromethane extract varied from 112 to 133 \(\mu\)g.mL\(^{-1}\) for HepG2, Caco-2 and MCF-7 cancer cells, but became more than
250 μg/mL for the methanol extract. In the chemo-preventive assay, the dichloromethane extract had capacity to induce QR activity significantly (CD value = 91.36±1.26 μg.mL⁻¹), while the methanol extract had no inductive effect.

*Moringa* leaves were found to be a potential source for the antitumor activity. O-Ethyl-4-(α-L-rhamnosylxy) benzyl carbamate together with 4(α-L-rhamnosylxy)-benzylisothiocyanate, niazipimicin and 3-O-(6′-Ooleoyl-β-D-glucopyranosyl)-β-sitosterol have been tested for their potential antitumor promoting activity using an *in vitro* assay which showed significant inhibitory effects on Epstein–Barr virus early antigen. It has been found that niaziminin, a thiocarbamate from the leaves of *M. oleifera*, exhibits inhibition of tumor-promoter-induced Epstein–Barr virus activation.

**Wound healing activity**

The leaf extract also poses wound healing activity. The leaf extract showed significant increase in wound closure rate, skin breaking strength, granuloma breaking strength, hydroxyproline content, granuloma dry weight and decrease in scar area.

**Antidyslipidemic effects**

The *Moringa* leaf water and methanol extract are also reported to have antidyslipidemic effects to lower the serum total cholesterol (TC), triacylglyceride (TG), very low-density lipoprotein (VLDL), low-density lipoprotein (LDL), and the atherogenic index, with increased high-density lipoprotein (HDL) in rats fed on a high-fat diet (HFD). A significant rise in the fecal excretion of cholesterol was observed in treated animals compared to the HFD control group. Similar antidyslipidemic effects were also documented in hyperlipidemic patients (TC [180 mg.dL⁻¹] and TG [140 mg.dL⁻¹]), fed with leaf tablets (4.6 g/day) for 40-50 days.

**Antidiabetic activity**

Several studies have shown that, *Moringa* can act as an anti-diabetic agent. A study has shown that the aqueous extracts of *M. oleifera* can cure streptozotocin-induced Type 1 diabetes and also insulin resistant Type 2 diabetes in rats. In another study, the researchers fed the STZ-induced diabetes rats with *M. oleifera* seed powder and noticed that the fasting blood glucose dropped.

Also, when the rats were treated with about 500 mg of *M. oleifera* seed powder/kg body weight, the antioxidant enzymes increased in the serum. This shows that the antioxidants present in this plant can bring down the ROS caused in

![Figure 1](https://example.com/image1.png)
the Beta-cells due to the STZ induction. STZ causes ATP dephosphorylation reactions and helps xanthine oxidase in the formation of superoxides and reactive oxygen species (ROS) in Beta cells. In hyperglycemic patients, the beta cells get destructed. Therefore, high glucose enters the mitochondria and releases reactive oxygen species. Since, beta cells have low number of antioxidants; this in turn causes apoptosis of the beta cells. This reduces insulin secretion leading to hyperglycemia and in turn diabetes mellitus Type-2. The flavonoids like quercitin and phenolics have been attributed as antioxidants that bring about a scavenging effect on ROS. It can be hypothesized that the flavonoids in Moringa, scavenge the ROS released from mitochondria, thereby protecting the beta cells and in turn keeping hyperglycemia under control.

Table 1 Biological Model systems used to study biologically active compounds isolated from M. oleifera

<table>
<thead>
<tr>
<th>Parts of plant</th>
<th>Biological activities</th>
<th>Biological model</th>
<th>Compounds isolated from the plant</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaves</td>
<td>Antioxydant activity</td>
<td>-</td>
<td>Glucosilate, Isothiocyanates,</td>
<td>[31, 32]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thiocarbonates</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Antiproliferative and apoptotic properties</td>
<td>KB Cells</td>
<td>Benzy nitrile, quercetin and kaempferol</td>
<td>[32]</td>
</tr>
<tr>
<td></td>
<td>Antifungicidal and antibacterial activities</td>
<td>-</td>
<td>Vitamin B et C</td>
<td>[33]</td>
</tr>
<tr>
<td></td>
<td>Antihypertensive activity</td>
<td>-</td>
<td>Amino acids, α-tocopherol, Fe, Ca, Phosphere, Cu, Dérivés de quercetol, Kaempferol</td>
<td>[33]</td>
</tr>
<tr>
<td></td>
<td>Cardio-protective activity</td>
<td>-</td>
<td>Fenilic and ellagic acids</td>
<td>[34, 34]</td>
</tr>
<tr>
<td></td>
<td>Hypolipidemic activity</td>
<td>Rat</td>
<td>-</td>
<td>[35]</td>
</tr>
<tr>
<td></td>
<td>Antitumor &amp; hepatoprotective activities</td>
<td>Rat</td>
<td>Quercetin</td>
<td>[22]</td>
</tr>
<tr>
<td></td>
<td>Antitumor and Anticancer Activities</td>
<td>Epstein–Barr virus</td>
<td>Niaziminin, thiocarbamate, 3-O-(6′-Ooleoyl-β-D-glucopyranosyl)-β-sitosterol</td>
<td>[36]</td>
</tr>
<tr>
<td></td>
<td>Anti-inflammatory activity</td>
<td>human pancreatic cancer cells (Panc-1, p34, and COLO 357)</td>
<td>Isothiocyanates [4-(aL-rhamnosyloxy) and 4-(40-O-acetyl-a-L-rhamnosyloxy)-benzyl isothiocyanate]</td>
<td>[36]</td>
</tr>
<tr>
<td>Seed</td>
<td>Inhibition of cutaneous carcinoma induced by phorbol</td>
<td>Trichophyton rubrum, Trichophyton mentagrophytes, Epidermophyton Xoccosum, and Microsporum canis</td>
<td>glucomoringine (glucosinolates)</td>
<td>[37]</td>
</tr>
<tr>
<td></td>
<td>Antibacterial and antifungal activities</td>
<td>Trichophyton rubrum</td>
<td>Glucosinolates</td>
<td>[38]</td>
</tr>
<tr>
<td>Root</td>
<td>Anti-analgegic activity</td>
<td>Rat</td>
<td>Moringine (Isothiocyanates), Oleic acid</td>
<td>[22]</td>
</tr>
<tr>
<td></td>
<td>Anti-inflammatory activity</td>
<td>Rat</td>
<td>Glucosinolates</td>
<td>[38]</td>
</tr>
<tr>
<td></td>
<td>Anti-urolithiasis activity</td>
<td>Rat</td>
<td>-</td>
<td>[39]</td>
</tr>
<tr>
<td></td>
<td>Anti-spasmodic activity</td>
<td>Rat</td>
<td>4-[ a -(L-rhamnosylxy) benzyl]-o-methyl thiocarabmate</td>
<td>[22]</td>
</tr>
<tr>
<td>Stem bark</td>
<td>Reduction of the expression of pro-inflammatory mediators</td>
<td>Macrophages</td>
<td>β-sitostérol, Benzyl glucosynolate</td>
<td>[22]</td>
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<tr>
<td>Fruit</td>
<td>Antioxidant activity</td>
<td>Murins</td>
<td>Stigmasterol</td>
<td>[40]</td>
</tr>
<tr>
<td>Flower</td>
<td></td>
<td></td>
<td>Quercétol, Kaempferol, Isoquercitrin</td>
<td>[22]</td>
</tr>
</tbody>
</table>

Diabetes leads to several complications such as retinopathy, nephropathy, atherosclerosis etc. Moringa can be used to prevent such ailments. When there is hyperglycemia, the blood glucose reacts with proteins and causes advanced glycated end products (AGEs). These AGEs bind to RAGE which gets expressed on the surface of immune cells. This interaction leads to increased transcription of Cytokines like interleukin-6 and interferons. At the same time, the cell adhesion molecules are expressed on the surface endothelium of arteries.
This facilitates the trans-endothelial migration which causes inflammation in the arteries and leads to atherosclerosis. *M. oleifera* is used as an anti-atherosclerotic agent.64 The anti-atherogenic nature can be accounted for by the antioxidant properties of *Moringa*. An extract from the *M. oleifera* leaf has been shown to be effective in lowering blood sugar levels within 3 hrs ingestion, though less effectively than the standard hypoglycemic drug, glibenclamide.65

Chronic hyperglycemia is an indicator of diabetes mellitus; similarly, chronic dyslipidemia is a potential risk factor for cardiovascular disease (CVD). In animal studies, *Moringa* leaf aqueous extract is found to control the fasting plasma glucose levels (FPG), postprandial blood glucose (PPPG), Blood glycated hemoglobin (HbA1c), and increased glucose tolerance, studied by the oral glucose tolerance test (OGTT), in streptozotocin (STZ)-induced diabetic rats65 and untreated diabetes mellitus patients.66

**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 rats.66

| Table 2  | Proximate composition and the nutritional Value of Leaves and Pods |
|---|---|---|
| Contents | Pods | Leaves | Leaf powder |
| Moisture (%) | 86.9 | 75.0 | 7.5 |
| Calories | 26.0 | 92.0 | 205.0 |
| Protein (g) | 2.5 | 6.7 | 27.1 |
| Carbohydrate (g) | 3.7 | 13.4 | 38.2 |
| Fiber (g) | 4.8 | 0.9 | 19.2 |
| Minerals (g) | 2.0 | 2.3 | - |
| Ca (mg) | 30.0 | 440.0 | 2.003 |
| Mg (mg) | 24.0 | 24.0 | 368.0 |
| P (mg) | 110.0 | 70.0 | 204.0 |
| Cu (mg) | 3.1 | 1.1 | 0.57 |
| Fe (mg) | 5.3 | 7.0 | 28.2 |
| S (mg) | 137.0 | 137.0 | 870.0 |
| Oxalic acid (mg) | 10.0 | 101.0 | 1.6% |
| Vitamin A - B carotene (mg) | 0.11 | 6.8 | 16.3 |
| Vitamin B - choline (mg) | 423.0 | 423.0 | - |
| Vitamin B1 - thiamin (mg) | 0.05 | 0.05 | 2.64 |
| Vitamin B2 - riboflavin (mg) | 0.07 | 0.05 | 20.5 |
| Vitamin B3 - nicotinic acid (mg) | 0.2 | 0.8 | 8.2 |
| Vitamin C - ascorbic acid (mg) | 120.0 | 220.0 | 17.3 |
| Vitamin E - tocopherol acetate (mg) | - | - | 113.0 |
| Arginine (g/16g N) | 3.6 | 6.0 | 1.33% |
| Histidine (g/16g N) | 1.1 | 2.1 | 0.61% |
| Lysine (g/16g N) | 4.3 | 4.3 | 1.32% |
| Tryptophan (g/16g N) | 0.8 | 1.9 | 0.43% |
| Phenylalanine (g/16g N) | 4.3 | 6.4 | 1.39% |
| Methionine (g/16g N) | 1.4 | 2.0 | 0.35% |
| Threonine (g/16g N) | 3.9 | 4.9 | 1.19% |
| Leucine (g/16g N) | 6.5 | 9.3 | 1.95% |
| Isoleucine (g/16g N) | 4.4 | 6.3 | 0.83% |
| Valine (g/16g N) | 5.4 | 7.1 | 1.06% |

(Source: Sunil et al.7,45)
Anti-hypertensive activity
The widespread combination of diuretic along with lipid and blood pressure lowering constituents make this plant highly useful in cardiovascular disorders. Moringa leaf juice is known to have a stabilizing effect on blood pressure. 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.67

Anti-inflammatory activity
The M. oleifera aqueous leaf extract down regulates a pro-inflammatory transcription factor (nuclear factor-kappa B; NF-kB) and increases the cytotoxic effect in apoptosis based chemotherapy, investigated in cultured human pancreatic cancer cells (Panc-1, p34, and COLO 357). The treatment of the extract (C0.75 mg/ml) induces a rise in the sub-G1 cell populations of the cell-cycle and reduces the expression of different subunits of NF-kB, namely, p65, p-IkBa, and IkBa. Also, the leaf extract synergistically enhances the cytotoxic effect of cisplatin on Panc-1 cells.68

Table 3  Extract, model system used, pharmacological action and plant part of biologically active compounds isolated from M. oleifera

<table>
<thead>
<tr>
<th>Extract</th>
<th>Parts of plant</th>
<th>Biological activities</th>
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<tr>
<td>Dichloromethane extract</td>
<td>Leaf</td>
<td>Antioxidant and anticancer activities</td>
<td>Caco-2, HepG2 and MCF-7 cancer cells</td>
<td>[46]</td>
</tr>
<tr>
<td>Methanol extract</td>
<td>Roots</td>
<td>Antidyslipidemic effects</td>
<td>Rats</td>
<td>[47]</td>
</tr>
<tr>
<td>Aqueous extract</td>
<td>Seed</td>
<td>Antifertility activity</td>
<td>Rats</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td>Leaf</td>
<td>Antioxidant activity</td>
<td>-</td>
<td>[49]</td>
</tr>
<tr>
<td></td>
<td>Leaf</td>
<td>Diabetic activity</td>
<td>(STZ)-induced diabetic rats</td>
<td>[43]</td>
</tr>
<tr>
<td></td>
<td>Seed</td>
<td>Diuretic activity</td>
<td>Human pancreatic cancer cells (Panc-1, p34, and COLO 357)</td>
<td>[49]</td>
</tr>
<tr>
<td>Ethanol extract</td>
<td>Seed and leaf</td>
<td>Antifungal activity</td>
<td>Trichophyton rubrum, Trichophyton mentagrophytes, Epidermophyton xoccousum and Microsporum canis</td>
<td>[37]</td>
</tr>
<tr>
<td>Petroleum ether extract</td>
<td>Seed</td>
<td>Antifertility activity</td>
<td>Rats</td>
<td>[48]</td>
</tr>
<tr>
<td>Solvent ether extract</td>
<td>Seed</td>
<td>Antipyretic activity</td>
<td>Rats</td>
<td>[51]</td>
</tr>
</tbody>
</table>

CNS activity
Studies have shown that leaf extract restores the monoamine levels of brain regions to near control levels. The leaf extract contains flavonoids which can easily cross the blood brain barrier and exert various effect on CNS via memory, cognition and neurodegeneration. Triterpenoid, saponins, flavonoids have an agonistic action on GABA receptor complex and hence may act like benzodiazepine like molecules. Thus, these compounds attribute for the CNS depressant and muscle relaxant activity of Moringa leaf extract.7

Antifertility profile of M. oleifera
An aqueous extract of M. oleifera roots was investigated for its estrogenic, anti-estrogenic, prostational and anti-progestational activities. Oral administration of extract progressively increased the uterine wet weight of bilaterally ovarietomized 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. In the deciduoma test, the highest dose of 600 mg/kg interfered with the formation of deciduoma in 50% of the rats, showing some anti-progestational activity. Doses up to 600 mg/kg
of the extract orally failed to induce a decidual response in the traumatized uterus of ovariectomized rats.48

Antisickling activity of M. oleifera

The Effects of M. oleifera leaves extracts on Sickle cell hemoglobin were evaluated by Nwoaguipke and co-workers. Based on various assays carried out by this research team, the leaves extracts were reported to inhibit sickle cell hemoglobin polymerization, improve the oxidant status of erythrocytes by increasing the Fe3+/Fe2+ ratio. The extracts were able to improve the oxygen affinity of the erythrocytes and equally reversed the sickling or gelation process. These authors explained that the improvement in oxygen affinity is a positive indicator of antisickling effectiveness.69

M. oleifera based-Food fortification property

It was reported that the food supplements bio-fortified by the leaves powder of Moringa oleifera helps to fight against chronic malnutrition in Malagasy rural households.70

CONCLUSION

The aim of this review was to provide highlight and updated information on the medically and scientific evidence supporting the multiple uses of M. oleifera in Traditional Medicine. Medicinal plant species are rich in secondary metabolites of pharmaceutical relevance. The advantages of their therapeutic uses in various ailments are their safety besides being economical, effective and their availability. Chemically, this plant contains a wide range of secondary metabolites as well as minerals which could be responsible for different reported therapeutic activities. Therefore, M. oleifera could be of considerable interest for the development of plant-based new anticancer and antisickling drugs for human health and wellbeing according to its richness in bioactive principle. The plant species M. oleifera is also good candidate for food fortification as well as its ability to clean water.

REFERENCES


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