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Moringa pterydosperma (Moringa): A Wonder Tree with Enriched Medicinal Value

Shailja Choudhary, Gitika Chaudhary and Hemlata Kaurav*
Shuddhi Ayurveda, Jeena Sikho Lifecare Pvt. Ltd. Zirakpur 140603, Punjab, India.

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***Corresponding Author Email:** shuddhi.research@jeenasikho.co.in

Abstract
Moringa oleifera is also known as the miracle tree, drumstick tree or horseradish tree is a plant of great medicinal significance and is associated with nutritional value too. From ancient times, the *M. oleifera* plant is used for medicinal purposes to treat various diseases. Different parts of the plant are associated with various chemical constituents such as phenolic acids, tocopherols, carotenoids, and flavonoids. These chemical constituents of the plant show various therapeutic and pharmacological properties such as anti-inflammatory, cardioprotective, hepatoprotective, anticancer, antimicrobial, antioxidant, and other properties. The plant extracts are mainly beneficial in malnutrition, lactating mothers, general weakness, menopause, osteoporosis, and depression. In the traditional medicinal system such as Ayurveda, folklore, Unani and Siddha, *M. oleifera* plant alone or in combination with other herbal plants are used in various herbal formulations to treat cough, fever, skin disorders, respiratory disorders like asthma, ulcers, eyes disorders and other diseases. The seed oil of the plant is used in various cosmetics (skin and hair care products), food industry (used in bread, yogurt, cheese, etc.), pharmaceutical industries as a fertilizer and in the preparation of biodiesel fuel. Also, the leaves of the plant are used as livestock fodder. In this review article, the traditional usage of the plant such as ayurvedic and folk uses, and the pharmacological properties of the plant are briefly described.

Keywords
Moringa, Ayurveda, Rasapanchak, Folk uses, Pharmacological properties

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INTRODUCTION
Moringa Oleifera Lamm. (Synonym *Moringa Pterydosperma)* is a small, medium-sized Indian medicinal herb that belongs to the *Moringaceae* family. It is an umbrella-shaped tree which is also known as a miracle tree because of its health benefits [13]. This plant commonly called a drumstick or horseradish tree is mainly grown in tropical and subtropical regions and is a native of sub-Himalayan regions of North-West India. In the prehistoric period, the Moringa tree was introduced in the Philippines from tropical Asia and Malaya [1]. The moringa plant is cultivated for various purposes such as vegetable, spice, cooking and cosmetics [2]. The plant is mainly used as a remedy for malnutrition as it is a rich source of multiple nutrients present in every part of the plant such as proteins, fibers, and minerals [3,4]. It is also said that the plant provides Vitamin C more than Oranges, calcium 17 times more than milk, vitamin A more than carrots, iron 25 times more than spinach, proteins more than yogurt and potassium 15 times more than bananas [5]. In Indigenous medicinal systems like Ayurveda and Unani, each part of the plant is used to treat various diseases and ailments. Traditionally, every part of the plant is used to treat diseases like blood impurities, skin infections, blackheads, bronchitis, catarrh, asthma, chest congestion, anxiety, anemia, cholera, pimples, psoriasis, scurvy, semen deficiency, tuberculosis, joint pain, hysteria, sore throat, diabetes, lactations, fever, ear infections and to treat intestinal worms [6,7]. The Moringa oil carries

significant cosmetic and medicinal value and is used in various ointment and skin preparations since Egyptian times [8,9]. Also, the seeds oil of the plant known as Ben oil is used for fine machine lubrication, hair care products and in manufacturing of perfumes [10]. The plant is associated with various pharmacological and therapeutic properties because of the presence of several phytochemical constituents in every part of the plant. These properties include anti-inflammatory, antimicrobial, antioxidant, antidiabetic, anti-hyperlipidemia, antineoplastic, antiulcer, antipyretic, cardioprotective and hepatoprotective [11,12,13]. Table no. 1 & 2 represents the vernacular names [14] and taxonomical classification [15] of the plant.

Table 1 Vernacular names

Arabic	Rawag
Assamese	Saijna, Sohjna
Bengali	Sajina
Burmese	Daintha, dandalonbin
Hindi	Mungna, Saijna, Shajna
Kannada	Nugge
Malayalam	Murinna, sigru
Nepali	Shobhanjan, sohijan
Oriya	Sajina
Portuguese	Moringa, moringueiror
Punjabi	Sainjna, Soanjna
Sanskrit	Shobhnajna, Sigru
Tamil	Moringa, Murungai
Telugu	Mulaga, munaga, tellamunaga
Urdu	Sahajna
Gujarati	Midhosaragavo, Saragavo
Marathi	Achajhada, Shevgi
English	Ben tree, drumstick tree, Horseradish tree

Table 2 Taxonomical Classification of Moringa plant.

Taxonomical Rank	Taxon
Kingdom	Plantae
Sub-kingdom	Tracheobionta
Superdivision	Spermatophyta
Division	Magnoliphyta
Class	Magnoliopsida
Order	Brassicales
Family	*Moringaceae*
Genus	*Moringa*
Species	*M. pterydosperma*
Common name	Moringa, drumstick tree

BOTANICAL DESCRIPTION

It is a small, medium-sized, evergreen, deciduous, fast-growing tree that belongs to the *Moringaceae* family. Usually, the height of this plant reaches up to 10-12 m. The plant consists of a fragile, spreading, open crown of drooping-like branches while it bears corky, thick whitish bark. The leaves of the plant are 45 cm long, binate or most commonly tripinnate leaves and are arranged in spirally, alternate twigs. The twigs are green, hairy and become brown. The leaflets are green, finely hairy 0.6-1.0 cm wide and 1.2-2.0 cm in length, lateral leaflets are elliptic, finely hairy, paler, hairless on the upper surface and red-tinged mid-veins are present in lower surface. The flowers are oblique, stalked, yellowish-white, fragrant, bisexual, densely pubescent joined beneath the apex and are present in a cluster form [16,17,18]. The fruits are linear three-sided pods, pendulous with nine longitudinal ridges with length 20-50 cm and breadth 2.0-2.5 cm. Each pod contains up to 26 seeds that are dark green during development and turns brown on maturity. Seed are globular, 3-winged on the angle, scarious, 2-2.5 cm long and 0.4-0.7 cm broad. The diameter of the seeds is 1 cm [19,20].

GEOGRAPHICAL DISTRIBUTION

Moringa tree is distributed in the countries like India, Nepal, Pakistan, Sri Lanka, Afghanistan, Southeast Asia, West Asia, West Indies, East and West Africa, Mexico, Central and South America, Arabian Peninsula, Paraguay and Brazil [21-24]. The plant is indigenous to the Himalayan foothills of South Asia from northeastern Pakistan (330N, 730E) to northern West Bengal State in India and Northeastern Bangladesh. The plant grows up to an altitude of 1400 m above sea level. In India, the plant is mainly found in Assam, Peninsular India and Bengal [25].

PHYTOCHEMICAL CONSTITUENTS OF MORINGA PLANT

Moringa oleifera is a rich source of phytochemical constituents mainly tocopherols (alpha, beta and gamma) [26], carotenoids [27], flavonoids, phenolic acids [28,29], polyunsaturated fatty acids [30], folate [31] and various minerals [32]. The leaves of the plant contain a total of 35 chemical constituents. These include n-hexadecanoic acid, cis-vaccenic acid, tetradecanoic acid, octadecanoic acid, beta-1-rhamnofuranoside, palmitoyl chloride, gamma-sitosterol, 5-O-acetyl-thio-octyl and prega-7-diene-3-ol-20-one [33]. The most abundant carotenoid found in the leafage of the plant is E-lutein. The roots of the plant contain Spirochin and anthonine chemical constituents that are known for the antibacterial activity [34]. The plant's radical consists of 4-(alpha-1-rhamnopyranosyloxy)-benzyl glucosinolate and benzyl glucosinolate [35]. The peduncle part of the plant contains beta-sitosterone, beta-sitosterol, vanillin, 4-hydroxymellein and octacosanoic acid while 4-(alpha-1-rhamnopyranosyloxy)-benzylglucosinolate) is found in the crust part of the plant. The stem of the plant consists of alkaloids (moringine and moringinine), octasanoic acid, 4-hydroxymellein and beta-sitosterol [36,37]. 1-rhamnose, 1-arabinose, d-xylose, d-mannose, d-galactose and d-glucuronic acid are present in the gum exudates of the *M. oleifera* plant [38]. Another vital component present in the gum exudates is leucodelphinidin-3-O-B-D-galactopuranosy (1>4)-O-B-D-glucopyranoside [39,40]. The fruits of the plant contain cytokines while ethyl-4-[(alpha-1-rhamnosyloxy)-benzyl], methyl-p-hydroxybenzoate, isothiocyanate, thiocarbamates, nitrile and O-[2-hydroxy-3-(2-heptenyloxy)]-propyl undecanoate are present in whole pods of the plant [41]. The flowers of the plant contain alkaloids, flavonoids such as rhamnetin, isoquercitrin and kaempferitin, sucrose, amino acids [42]. The seeds of the plant consist of O-ethyl-4-(alpha-1-rhamnosyloxy) benzyl carbamate and a high concentration of benzyl glucosinolate, 4-(alpha-1-rhamnosyloxy) benzyl isothiocyanate, 4-(alpha-1-rhamnopyranosyloxy)-benzyl glucosinolate and 4-(alpha-1-rhamnosyloxy) phenyl acetonitrile [43-46]. Figure no. 2 represents the chemical structures of some major phytochemicals of *M. oleifera* plant.

TRADITIONAL AND MODERN VIEW

Ayurvedic View:

The different parts of the *M. oleifera* plant i.e. bark, leaves, flowers, root bark, essential or volatile oils and fruits are used in an ayurvedic medicinal system to treat various types of diseases [47]. These parts of the plant are used in various ayurvedic formulations such as Shobhanjanadi lepa and Shyamadi churna [48]. The leaves and bark of the plant in paste form are useful in burning sensation, abscesses, wound healing and inflammatory conditions. Also, the plant acts as an antispasmodic, abortifacient, stimulant, expectorant and diuretic agent [49]. The plant is mentioned as Svedopaga group of herbs that are used in Svedana i.e. a preparatory procedure for Panchkarma, Krimghna group of herbs that are used to cure worm infestation, katuka Skandha group of herbs which consists of pungent smell and bitter taste and Shirovirechanopaga group of herbs that are used as nasal snuff in Nasya treatment [50]. In Ayurveda, the dried root bark of the plant is used in goiter, glycosuria, heart disorders, tridosha fevers, inflammation, bronchitis, throat, piles, urinary discharges and obstinate asthma [51] and lipid disorders. It is also used to treat diseases like asthma, eye diseases, skin disorders, headache, fever, kidney stones, arthritis and hemorrhoids [52,53,54]. Also, the plant parts are used to treat diseases like diabetes, asthma, cardiovascular diseases, sickle cell anemia, mood disorders, cancer, edema ad liver disorders [55]. The rasapanchak (properties) of the plant are shown in table no. 3.

Table 3 Rasapanchak (properties) of the *M. oleifera* plant

Sanskrit / English	Sanskrit / English
Veerya / Potency	Ushna / Hot
Vipak / Metabolic property	Katu / Bitter
Guna / Physical property	Laghu / Light, Ruksha / Dry, Tikshna / Astringent
Rasa / Taste	Katu / Bitter, Tikta / Astringent

Figure 1 ***Moringa oleifera (Moringa pterydosperma)***

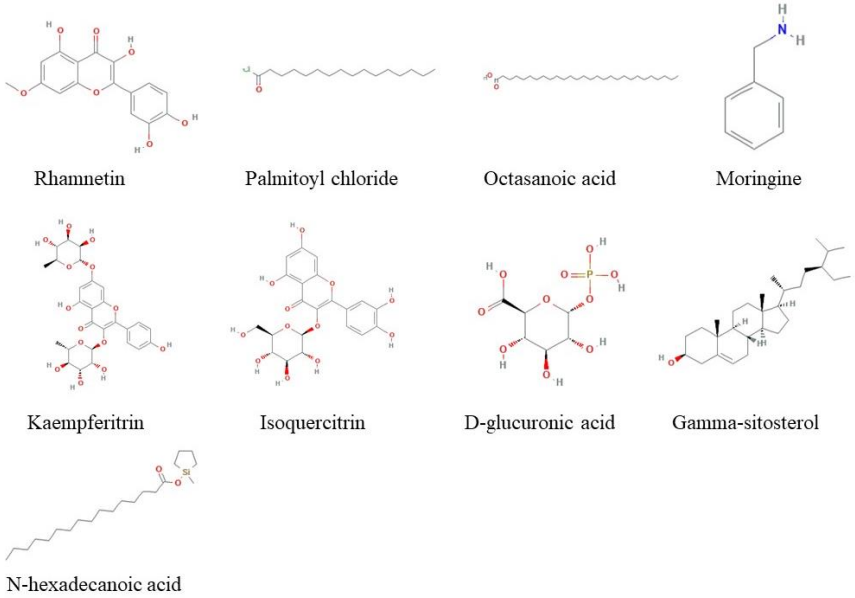

Figure 2 The chemical structures of some major phytochemicals of *M. oleifera* plant

Formulations of Moringa:

The ayurvedic formulations of *M. oleifera* plant include Sarasvata Ghrta, Ratnagiri Rasa, Sarsapadi Pralepa, Sudarsana churna, Vistaimduka Taila, etc. [56]

Actions and Properties

Kaphavatashamak:

It balances the aggravated Kapha and Vata components of the body.

Sansthanik Karam:

The external application of the paste of bark and leaves of the plant are used to reduce inflammation, headaches and are associated with wound healing and anti-inflammatory properties.

Abhyantarnadisansthan:

It increases the blood flow, heart rate and contracts the blood vessels of the heart. It is used to treat nervine disorders, paralysis and facial paralysis.

Paachansansthan:

It increases the digestive fire to absorb the excessive moisture of the intestinal mucosa. It is used to cure abdominal disorders, anorexia and helps in relieving pain. It acts as an appetizer.

Raktavahsansthan:
It increases the blood flow and helps to cure cardiovascular disorders.
Kaphaghna:
It is associated with a mucolytic property.
Mutravahsansthan:
It acts as a diuretic agent and helps to cure the micturition problem.
Prajanansansthan:
It regulates the menstrual cycle and is used to treat amenorrhea and dysmenorrhea disorders.
Satmikaran:
It is associated with anti-venom and anti-obesity properties.
Twacha:
It induces sweating and cure skin disorders.
Taapkram:
It acts as an antipyretic agent.
Netra:
The seeds of the plant are beneficial to the eyes and are used to treat certain eye disorders.
Folk View
Moringa oleifera plant is used for various purposes such as food, animal fodder, natural medicine, forestry products, living fence, fertilizer, fuel and alley cropping [57,58]. In Nigeria, leaves of *M. oleifera* plant in combination with other plants are used to cure hypertension, high blood pressure and HIV/AIDS [59] The different parts of the plant are used to treat anemia, anxiety, skin infections, blood impurities, bronchitis, catarrh, asthma, chest congestion, cholera blackheads and other ill-effects in various cultures and communities of the world [60]. In India, Pakistan, Hawaii and other countries, various parts of the *M. oleifera* plant i.e. leaves, fruits, flowers and immature pods of the tree are used as a highly nutritive vegetable [61,62,63]. The roots and leaves of the Moringa plant are used to cure constipation [64,65]. The seed extracts of the plant are used for skincare, hair strengthening and hair nourishment [66]. In the West, the seed powder of the plant is used to flocculate contaminants and purify drinking water [67]. Also, the seeds of the plant are used in curries, steeped for tea and are utilized in the roasted and powdered form [68,69,70]. It is known as the mother's best friend and is utilized in the Philippines to enhance woman's milk production. In the folklore medicinal system, the leaves of the plant are used to treat typhoid fever, malaria, arthritis, swellings, cut, skin disorders, diabetes, hypertension and genito-urinary ailments [71]. The paste of the young leaves of the plant in combination with curd is externally used for strains and internally for stomachache. The bark paste or leaf juice of the plant is beneficial for piles and constipation [72,73]. The leaves of the plant are aphrodisiac, anthelmintic and are used to treat hiccough, dry tumors and asthma. The external application of the seed oil is helpful in leprous ulcers and rheumatism [74]. The seeds and roots of the plant are used to cure scorpion stings and snakebites [75].
Modern View
Adulteration is the major problem faced by the herbal drug industry in the present scenario. It is not only affecting the herbal drug industry but also the life of a well–being [76]. Adulteration can be done by substitution or addition of the toxic materials which results in the degradation of the quality of the original herbal medicines [77]. Due to the increased demand for herbal products, the risk with the herbal medicines also rises as the quality of the end product compromises because of the contaminated raw material with toxic metals, microbes, and other residues, adulteration (addition of fake or inferior plant material, orthodox drugs, foreign material) which results in the poor quality of raw material and end product. Lack of standardization techniques is also responsible for the poor quality of drugs as it fails to detect the original drug which exploits its usage in the conventional system of medicines. So, it is necessary to develop an Herbal Authentication System (HAS) which can serve as a regulator and also helps in improving the quality of herbal trade [78].
REPORTED PHARMACOLOGICAL AND THERAPEUTIC PROPERTIES
Various experimental and clinical studies were conducted on *M. oleifera* plant to demonstrate its pharmacological and therapeutical properties. Some of the reported studies of *M. oleifera* plant are discussed below.
Anticancer:
The alcoholic and hydro-methanolic extracts of the leaves and fruits of the plant were examined for anticancer activity in the mouse melanoma tumor model. Results showed a significant delay in the growth of tumor kinetics in the mouse model [79,80]. Also, the crude aqueous leaf extracts of the plant showed anti-proliferative effects against A549 lung cells [81,82]. The root and leaf extracts of the plant exhibit cytotoxic activity against hepatocarcinoma, breast cancer and colorectal cancer cells *in vitro* and cisplatin-resistant ovarian cancer cells [83,84,85]. The pod extract was found to suppress dextran sodium-induced colon destruction and azoxymethane in male mice [86].
Antioxidant:
The antioxidant activity of the leaf and fruit extracts of the plant was examined against a standard *in vitro* model. The ethanolic extract of the plant exhibit

significant metal chelating properties with the potential to protect against DNA nicking [87]. The ethanolic and aqueous extract of the plant showed antioxidant effect which was measured by the modified diphenyl-2-picryl hydrazyl (DPPH) method [88]. The leaf extract of the plant showed Nephroprotective action against the acetaminophen-induced nephrotoxicity model in male BALB/c rats in a dose-dependent manner [89,90,91]. Also, the leaves of the plant contain phenolic contents that are associated with free radical scavenging property [92,93]. The methanolic extracts of the plant showed the highest free radical scavenging activity in the DPPH assay and IC50 11.73 µ g/mL in the ABTS assay [94].

Wound healing:

The ethanolic extracts of the leaves of the plant were demonstrated for the wound healing property against the Sprague Dawley rat's palate. The 4% ethanolic extract of the leaves showed a significant difference in the wound closure rate on days 3 and 14 as compared to the control samples [95]. A significant increase in wound closure rate, granuloma-breaking strength, increase in hydroxyproline content and decrease in skin-breaking strength in the incision, dead space, excision and decrease in scar area was also observed in the rat model by the aqueous extracts of dried pulp and seed extracts of the plant [96,97,98]. Another study was conducted against diabetic rats in which the leaf extract of the plant showed down-regulated inflammatory mediators and a reduction in wound size [99]. Also, the aqueous and ethyl acetate extracts of the leaves showed significant wound-healing effects when tested against the rat model when applied in ointment form [100,101].

Antidiabetic:

The aqueous leaf extract of the plant showed significant antidiabetic activity when tested against Wistar rats [102]. The methanolic extracts of the pods of *M. oleifera* plant were examined for *in vivo* antidiabetic effects in streptozotocin (STZ)-induced diabetic albino rats at the dosage of 150-300 mg/ kg. Results showed a significant reduction in diabetes, serum glucose and nitric oxide with the enhancement in the serum insulin and protein levels [103]. The seed powder of the plant at a dosage of 50 and 100 mg/kg body weight significantly reduced the lipid peroxide levels in streptozotocin-induced diabetic male rats. It was also found that the higher dosage i.e. 100 mg/kg was more efficient than that of the lower dose i.e. 50 mg/kg b.w. [104].

Cardiovascular and Antihypertensive:

The ethanolic extract of the leaves of *M. oleifera* exhibits anti-hypertensive or hypotensive activity when tested in an animal's heart [105]. It was found that isothiocyanate glycosides and thiocarbamate were associated with the hypotensive activity.

Anti-inflammatory:

The aqueous and methanolic extracts of the leaves, flowers and seeds showed anti-inflammatory activity in the carrageenan-induced paw edema model and compared with 25 mg/kg diclofenac sodium as a standard drug [106]. The oral administration of the crude methanolic extracts of the roots of the Moringa plant inhibits carrageenan-induced rat paw edema in a dose-dependent manner. Also, the n-butanol extract of the seeds of *M. oleifera* plant showed anti-inflammatory activity against ovalbumin-induced airway inflammation in guinea pigs [107]. The anti-inflammatory activity of the crude ethanolic extract of the dried seeds of the plant inhibits 85% of inflammation in the carrageenan induced inflammation in the hind paw mice at a dosage of 3 mg/kg body weight and inhibits 77% edema at the same dose [108,109].

Anti-asthmatic:

The ethanolic extracts of the seeds of *M. oleifera* plant inhibit the immune-mediated inflammatory responses in toluene diisocyanate-induced asthma in Wistar rats. Also, the TNF-alpha and IL-4 were found to reduce serum and bronchoalveolar fluid. The inhibitory effect on airway inflammation was also reported by the n-butanol extract of the seeds [107]. In another study, the n-butanol seed extract of the plant showed protective effects against acetylcholine-induced bronchoconstriction and airway inflammation in the guinea pig by improving the tidal volume, enhancing respiration rate, differential cell counts in blood and bronchoalveolar lavage fluid [107].

Antipyretic:

The oral administration of the ethanolic extracts of the seeds results in the reduction of normal body temperature and yeast-induced pyrexia in albino rats in a dose-dependent manner [110].

Antimicrobial:

The aqueous extracts of the seeds and the leaf juice of the plant showed significant inhibitory action in the growth of *S. aureus, P. aeruginosa* and *B. subtilis*. In another study, the various extracts of the plant showed *in vitro* antifungal activity against dermatophytes like *Trichophyton mentagrophytes, Trichophyton rubrum, Microsporum canis Aspergillus, Penicillin species* and *Epidermophyton floccosum* [111,112].

Hepatoprotective:

The ethanolic leaf extracts of the plant were examined for the hepatoprotective effect in Wistar rats at the dosage of 500 mg/kg. Results showed a

significant reduction in the necrotic cell damage and wider sinusoidal spaces [113]. In another study, the hepatoprotective activity of methanolic extract of the leaves and flowers of the plant was examined in carbon tetrachloride (CTL)-induced hepatotoxic rats using histopathological parameters. A significant protective effect was observed after the oral administration of the extract at 250 mg/kg of dosage [114]. The ethanolic and crude aqueous extracts were tested in different doses on carbon tetrachloride hepatocyte-induced injury in rats and compared with the standard drug silymarin concentration of 0.001, 0.005 and 0.01 mg/ml. It was found that the extracts were effective in decreasing CCl_4-induced enhanced activities of glutamic oxaloacetic transaminase (GOT), lipid peroxidation, glutamate pyruvate transaminase (GPT) and percentage viability [115]. Another study was conducted against cadmium-induced toxicity in Wistar albino rats to examine the hepatoprotective activity of leaf extract. The model was compared with the control group rats administered with cadmium chloride while the experimental rats were co-treated with plant extracts at 500 mg/kg of dosage and cadmium chloride for 28 days. The rat model treated with plant extract showed a significant reduction in the elevated aspartate aminotransferase (AST), alkaline phosphatase (ALP), alanine transaminase (ALT), lipid peroxidation (LPO) and increase in superoxide dismutase levels (SOD) [116].

Antifertility:

The ethanolic leaves extract of the plant was examined for the antifertility activity in female Wistar rats. The extracts were administered in three groups (6 in each group) of rats at a dosage of 100, 250 and 500 mg/kg and were evaluated on fertility, implantation, decidualization and local cytokine signaling during decidualization in female Wistar rats and the control group of rats with 0.5% gum acacia for 5 to 9 days. It was found that the extracts of the plant showed antifertility activity by interfering with the implantation and decidualization process [117]. Another study was conducted in female albino rats in which it was found that the alcoholic stem bark extracts of the plant showed antifertility activity [118].

Antibacterial:

The aqueous and ethanolic leaf extract of the plant exhibits antibacterial activity against *Salmonella spp*. The acetone extract of the leaf showed antibacterial activity against E. *coli, Proteus Vulgaris, Micrococcus kristinae* and *Enterobacter cloacae* at the dosage of 5 mg/ml [119]. The ethanol, chloroform and aqueous extracts of the plant exhibit significant antibacterial activity against *Staphylococcus aureus, Enterobacter spp., Salmonella typhi* and *E. coli* at a dosage of 200 mg/L [120,121].

TOXICITY

The acute toxicity study of the dried leaf powder of plant extracts was carried out in the Sprague Dawley rat model. The model was administered with dried powder with a high dosage of 2000 mg/kg. The animal model was observed hour to an hour for 14 days in step 1. In step 2, the animals were observed for the next 7 days again as there were no toxic effects observed in step 1. No toxic signs of the powdered extract were observed in the rat model [122]. In another study, the root bark extracts of the plant cause severe skin inflammation, skin dermatitis and also causes violent uterine contraction that can be fatal [123]. Also, the interior flesh of the plant can be toxic if consumed in large amounts as it contains alkaloid spirochin that can cause nerve paralysis [124,125].

CONCLUSION

Moringa oleifera is a widely explored plant that is used in various experimental and clinical studies. Different parts of the plant are associated with nutritive and medicinal value in terms of vitamins, minerals and other antioxidants. The use of Moringa oil is mentioned in ancient scriptures. The composition of Moringa oil is the same as that of olive oil and is used as a moisturizer for body and hair care. Besides this, there are some reported pharmacological and therapeutic properties of the plant which include anticancer, anti-inflammatory, antimicrobial, antioxidant, hepatoprotective and many more. Also, the plant is effective against HIV/AIDS, malnutrition, diabetes, tuberculosis, hypertension, and other sexually transmitted diseases. Also, the plant is used as a source of biodiesel, bio-pesticide and as a fertilizer. Although, the plant needs more investigation and studies to find its more pharmacological properties which can lead to the development of new drugs for several diseases and disorders.

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CONFLICT OF INTEREST

None

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