Journal for Research in Applied Sciences and Biotechnology

www.jrasb.com

ISSN: 2583-4053

Volume-3 Issue-3 || June 2024 || PP. 185-193

https://doi.org/10.55544/jrasb.3.3.29

Pharmacological Activities, Phytochemistry and Traditional Uses of *Moringa oleifera*

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www.jrasb.com || Vol. 3 No. 3 (2024): July Issue

Received: 20-06-2024	**Revised:** 30-06-2024	**Accepted:** 01-07-2024

ABSTRACT

***Moringa oleifera* Lam., more commonly referred to as munga, is a plant that is widely cultivated in India and is used for medicinal purposes. In the family Moringaceae, it is classified as a member. The fact that this plant possesses a multitude of advantageous pharmacological effects, including as anti-diabetic, hepatoprotective, anti-inflammatory, anti-fertility, anti-cancer, anti-microbial, and antioxidant qualities, makes it an appealing nutritional herb. Different names for this species include the horse radish tree and the drumstick tree, to mention only two of them. Each and every part of this plant contains a component that can be utilised for medical purposes. Milk protein, vitamin A, and vitamin C are all found in high concentrations in this food. There are many different chemicals that are considered to be active phytoconstituents. These substances include proteins, quinine, saponins, flavonoids, tannin, steroids, glycosides, fixed oils, and lipids. This plant also has a home in the tropical regions of the world. These are some extra components that are included: both niazinin A and niazinin B, as well as niazimicin A and niaziminin B. In the fight against malnutrition, the plant's high phytonutrient concentration makes it an effective natural integrator that complements other natural remedies. The findings of studies that investigated the phytochemistry of different plant parts have shown that plants contain a large quantity of organic molecules, which include both primary and secondary metabolites. After doing research on the pharmacological and nutraceutical properties of the plant, it has been determined that it can be utilised in the treatment of a variety of ailments. Through this review, the phytochemical composition of the plant, as well as its therapeutic applications and pharmacological effects, are discussed in depth.**

Keywords- *Moringa oleifera*, Pharmacological activity, Phytochemistry, Traditional uses.

I. INTRODUCTION

It is believed that Afghanistan, Bangladesh, India, and Pakistan were the original habitats of the *Moringa oleifera*, also known as the "miracle tree," despite the fact that it is now found growing in practically every tropical and subtropical region across the globe[1]. Out of the thirteen species that make up the Moringa

ISSN: 2583-4053

Volume-3 Issue-3 || June 2024 || PP. 185-193

https://doi.org/10.55544/jrasb.3.3.29

family—*Moringa oleifera*, *M. arborea*, *M. rivae*, *M. ruspoliana*, *M. drouhardii*, *M. hildebrandtii*, *M. concanensis*, *M. borziana*, *M. longituba*, *M. pygmaea*, *M. ovalifolia*, *M. peregrina*, and *M. stenopetala*, *Moringa oleifera* has garnered widespread recognition for its versatility as a producer of biogas, as well as a fertiliser, and other applications[2][3]. Moringa is unique in that it is the only plant that can survive in dry environments. Based on the findings of study, *M. oleifera* is considered to be one of the most inexpensive and beneficial solutions for a balanced diet[4]. Almost every part of the tree contains the nutrients that you require, and you can obtain them from it. The leaves of *Moringa oleifera* contain a significant amount of beta-carotene, minerals, calcium, and potassium. These amounts are highly noteworthy[5]. The dried leaves contain roughly 70 percent oleic acid, which makes them an excellent component for use in cosmetics that are designed to moisturise the skin. Among the beverages that are created from the powdered leaves, "Zija" is the most well-known Indian beverage[6]. The bark of the tree has been shown to be effective in treating a wide variety of medical ailments, including mouth ulcers, toothaches, and high blood pressure[7]. On the other hand, it has been shown that roots can be utilised to aid in the treatment of toothaches, helminthiasis, and paralysis. Every single one of the aphrodisiac chemicals, ulcer remedies, and enlarged spleen remedies are all made from the flowers. There is a possibility that the miraculous healing properties of the tree can provide relief to nursing mothers and infants who are suffering from malnutrition[8]. The purpose of this study is to attempt to combine the most recent results on the ethnomedicinal, toxicological, pharmacological, and phytochemical features of Moringa oleifera, as well as its pharmacological activity and research analysis on a global scale.

As a result of the rapid growth of herbal medicine over the course of the last several decades, Moringa oleifera has quickly gained popularity in industrialised nations. This is mostly due to the fact that it is completely natural and has a limited number of adverse effects[9]. Traditional medicinal practices such as Unani, Siddha, Yoga, Homoeopathy, Naturopathy, and Ayurveda are just few of the numerous alternative medical practices that place a significant emphasis on herbal remedies and the components that comprise them. Nearly seventy percent of the population engages in this complimentary and alternative medicine practice[10]. There are a few different names for this plant, including the horse radish tree, the drum stick tree, and *Moringa oleifera*. *Moringa oleifera*, often known as the munga plant, is a member of the moringaceae family and was initially cultivated in the sub-Himalayan regions of Afghanistan, Pakistan, Bangladesh, and India. Rapid growth is characteristic of this tree, which can either be an evergreen or a deciduous species. It often reaches a maximum height of between 10 and 12 metres. Munga plants contain a high concentration of a number of different compounds, including zeatin, quercetin, beta-sitosterol, kaempferol, and caffeoylguinic acid[11]. The *Moringa oleifera* plant contains a wide variety of important elements, including but not limited to iron, potassium, calcium, copper, zinc, magnesium, manganese, and a great deal more. According to their significance and value, the following Moringa species are the most important: *M. oleifera*, *M. arborea*, *M. drouhardii*, *M. ovalifolia*, *M. longituba*, *M. rivae*, *M. borziana*, *M. corcanensis*, *M. hildebrandtii*, *M. ruspoliana*, *M. stenopetala*, *M. peregrine*, and *M. pygmaea* are the species that are included in this group for the species. The many components of the plant include a wide variety of phytoconstituents, some of which include roots, immature pods, terpenoids, alkaloids, tannins, steroidal aglycones, and reducing sugars. These are just a few examples. Amino acids, which can be found in plant leaves, are exceptionally important for the development of robust and healthy bodies. Because of their nutritional content, capacity to filter water, and water-compelling qualities, *Moringa oleifera* leaves have been used for a long time in traditional medicine, notably in the ayurvedic tradition, for the treatment and prevention of illness. This is due to the fact that they have been used for medicinal purposes[12]. The nutritional profile of plant leaves is abundant, consisting of vitamins, minerals, and essential amino acids; yet, they are quite small, difficult to harvest, and can be quite pricey. One hundred grammes of dried *Moringa oleifera* leaf contains nine times as much vitamin A, fifteen times as much potassium, seventeen times as much calcium, twelve times as much vitamin C, and twenty-five times as much iron as spinach. This is in comparison to other fruits and vegetables because spinach contains twenty-five times as much iron. Antioxidants such as beta-carotene, vitamin C, quercetin, and chlorogenic acid are among the compounds that may be discovered in the leaves of the munga plant. These compounds are a genuine treasure trove. Using chlorogenic acid, it is possible to lower the amount of sugar that is present in the blood. One piece of encouraging information is that the leaves and seeds of *Moringa oleifera* Lam. have the potential to offer some protection against the potentially detrimental effects of arsenic toxicity. Another big problem that affects public health all around the world is the poisoning of groundwater supplies with arsenic contaminants. It has been demonstrated through research that the seeds of *Moringa oleifera* are superior to other approaches for the purification of water. From an anatomical point of view, the plant *Moringa oleifera* Lam. is abundant in fibres that, according to ancient sources, perform the function of a mop in your intestines, sweeping away any excess grime that may be caused by a diet that is high in fat. Isothiocyanates, which are found in the plant, possess antibacterial qualities and have the potential to assist in the elimination of H. pylori, the bacteria that is responsible for gastritis, ulcers, and stomach cancer[13].

Journal for Research in Applied Sciences and Biotechnology

www.jrasb.com

ISSN: 2583-4053

Volume-3 Issue-3 || June 2024 || PP. 185-193

https://doi.org/10.55544/jrasb.3.3.29

II. TAXONOMICAL CLASSIFICATION

Kingdom	Plantae
Sub kingdom	Tracheobionta
Super division	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Sub class	Dilleniidae
Order	Capparales
Family	Moringceae
Genus	Moringa
Species	Oleifera

Morphology[14]

Moringa oleifera is a small growing evergreen or deciduous tree that can grow to a height of 10–12 metres. It is a tree that is fast expanding. In contrast to its spreading, delicate branches and fluffy tripinnate leaf foliage, its bark is a whitish-gray colour but has a distinct appearance.

Leaves

It is possible for the bipinnate or tripinnate leaves to reach a length of 45 centimetres, and the upper surface of these leaves is hairless and green. These are compound leaves that have leaflets that are between one and two centimetres in length, and the twigs are leafy and green in colour.

Flowers

Fragrant, bisexual, yellowish-white blooms are held in place by hairy stalks that are arranged in spreading or drooping axillary panicles that are 10–25 centimetres in length. Each blossom measures approximately 0.7 to 1 centimetre in length and 2 centimetres in width. This flower has five petals that are spathulate, sparsely veined, and irregularly formed. The petals range in colour from yellowish-white to white. A single-celled ovary and a thin style are the components that make up the pistil. The flower contains a total of five stamens, five of which are considered to be sterile and reduced in size.

Fruits

The month of March and the month of April are typically when the fruits are produced. The fruits are capsules that have three lobed edges; they are brown, triangular, and hang down; when they are dry, they divide lengthwise into three halves; and their width is 1.8 centimetres. Approximately 26 seeds are contained within fruits as they go through the process of development. When they are juvenile, pods include a green colour, but when they reach maturity, they change colour to brown.

Seeds

The seeds are round and have a diameter of one centimetre. They have a brownish semi-permeable shell and three wings that are papery in appearance. There is a wide range of possible colours for the hulls, ranging from brown to black. In situations where the kernels are not viable, the hulls may even be white. It is possible for a tree to establish anywhere from fifteen thousand to twenty-five thousand seeds during a span of two weeks. The average weight of a seed is approximately 0.3 grammes.

Pharmacological activity

Recent studies in the field of pharmacology have demonstrated that a number of extracts derived from *M. oleifera* possess a wide range of pharmacological properties. These properties include, but are not limited to, antibacterial, antifungal, anti-inflammatory, antioxidant, anticancer, and fertility characteristics[15].

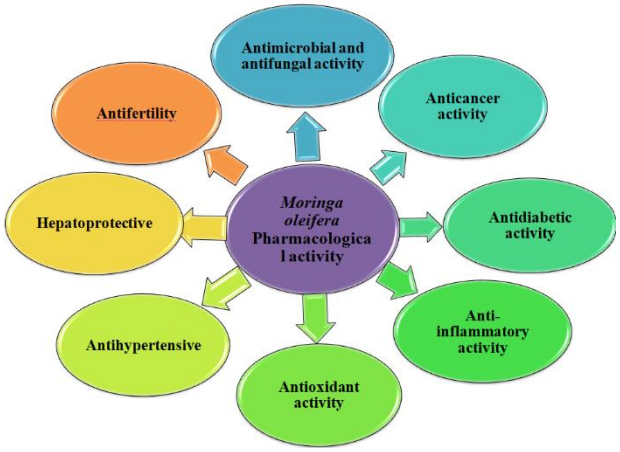

Figure 1: Pharmacological activities of *Moringa oleifera*

Antimicrobial and antifungal activity

The ethanolic root extract of *Moringa oleifera* contains a component known as N-benzylethyl thioformate, which is an aglycone of deoxyniazimincin[16]. This component is responsible for the antibacterial and antifungal activities that it possesses against a wide range of microbes and fungi. The methanolic leaf extract of *Moringa oleifera* has the capacity to inhibit the growth of Gram-negative and Gram-positive bacteria that are responsible for urinary tract infections (UTIs). These bacteria include Klebsiella pneumoniae, Staphylococcus aureus, Escherichia coli, and Staphylococcus saprophyticus[17].

Fungal strains including Aspergillus flavus, Aspergillus terreus, Aspergillus nidulans, Fusarium solani, Fusarium sclerotigenum, Penicillium sclerotigenum, Cladosporium cladosporioides, Trichophyton mentagrophytes, Pullarium species, and Fusarium solani have all been shown to be inhibited by *M. oleifera* extracts taken from the plant's leaves, seeds, and stems. It is believed that the active components of M. oleifera seeds, which are 4-(alpha-L-rhamanosyloxy) benzyl isothiocyanates, are responsible for the antibacterial effect of the seeds. There is a possibility that the antibacterial properties of moringa leaf juice could be beneficial to humans[18]. There is a necrotrophic plant fungus known as Botrytis cinerea, and the methanolic leaf extract is able to inhibit it by approximately 99%. By

ISSN: 2583-4053

Volume-3 Issue-3 || June 2024 || PP. 185-193

https://doi.org/10.55544/jrasb.3.3.29

denaturing the protein or preventing spore germination through the use of the steroid ring, the alkaloids, flavonoids, and steroids that are present in the fruit of M. oleifera are able to inhibit the growth of Candida albicans in culture[19].

When treated to moringa seed kernel extract, it was discovered that some species of Aspergillus, Bacillus cereus, Staphylococcus aureus, and Mucor exhibited significant inhibitory effects. Nevertheless, the treatment for E. coli and P. aeruginosa was not as successful as it may have been. This indicated that moringa seed kernel extract could be utilised for the treatment of infections caused by the aforementioned species, with the exception of E. coli and P. aeruginosa. An research that was conducted not too long ago found that the only extract that displayed anti-microbial activity against Gram-positive bacteria was an apolar extract that was obtained from *M. oleifera* seeds[20].

Anticancer activity

The creation of tumours was greatly slowed down by extracts of fruits and leaves, regardless of whether they were alcoholic or hydromethanolic, according to research conducted using a mouse model of melanoma tumour proliferation[21]. Additionally, when the leaf extract was allowed to interact with A549 lung cells, the cells demonstrated antiproliferative activity. The researchers that explored their effects on cancer metastasis requirements discovered that injecting leaf extract into the chick chorioallantoic membrane had an antiangiogenic effect that was dose dependent[22]. This was a demonstration of the enormous anticancer potential that these substances possess. In a different investigation, the researchers found that the use of pod extract prevented colon damage in male mice from the Institute of Cancer Research (ICR) that had been produced by azoxymethane and dextran sodium sulphate[23][24]. Ovarian cancer cells, breast cancer cells, hepatocarcinoma cells, and colorectal cancer cells were all susceptible to the potentially lethal effects of root and leaf extracts when tested in vitro[25][26][27]. According to these findings, MO may also have the ability to regenerate tissue in addition to its properties that make it effective against cancer[28]. It was discovered that the floral extract may stimulate cell proliferation in normal cells, but it did not have this effect on cancer cells[29]. In contrast, the leaf extract shown substantial anticancer and hepatoprotective activities after being tested. Niazimicin, carbamates, thiocarbamate, nitrile glycosides, and other phytoconstituents, such as quercetin and kaempferol, are some of the phytoconstituents that are responsible for the anticancer effects of this plant[30][31][32].

Antidiabetic activity

The anti-diabetic effect and control of diabetes that the aqueous extract of Moringa oleifera leaves demonstrates is evidence of the glycemic control that it possesses. The antioxidant and anti-diabetic effects of Moringa oleifera pod methanol extracts were evaluated in rats that had been given streptozotocin (STZ). It was found that the extracts were effective[33]. The antidiabetic effects were evaluated by analysing the changes in serum and pancreatic biochemical markers that occurred in diabetic rats following a treatment period of 21 days with either 150 or 300 mg/kg of extract. Following the administration of the extract, the course of diabetes was significantly slowed down[34]. The rats that were given the extract had a considerable reduction in the levels of nitric oxide and glucose in their blood with both doses of the extract, while simultaneously experiencing an increase in the levels of insulin and protein in their blood. In order to determine whether or not Moringa seed powder had any anti-diabetic properties, researchers examined the effects of 50 and 100 mg/kg of Moringa seed powder on male rats that had been treated with STZ to develop diabetes. The diabetes positive group displayed elevated levels of IL-6, lipid peroxide, and antioxidant enzyme in both the blood and kidney tissue homogenate. This was in contrast to the negative control group, which did not demonstrate any of these characteristics[35].

Anti inflammatory activity

The presence of inflammation is a symptom that is shared by a number of chronic diseases. It is the natural defence mechanism of the body that protects the tissues from damage caused by items such as physical trauma, toxins, or bacteria[36]. By reducing inflammation, anti-inflammatory medications help decrease pain, which in turn contributes to an improvement in health. The care of inflammatory illnesses frequently requires the utilisation of non-steroidal anti-inflammatory drugs (NSAIDs), which can result in a variety of unfavourable side effects, such as discomfort in the gastrointestinal tract, ulcers, and other complications[37]. Due to the fact that it is both safe and effective, the use of anti-inflammatory medications that are produced from medicinal plants is taken into consideration as a sensible and practical alternative[38]. It is said that the M. oleifera tree has thirty-six distinct compounds that have the ability to reduce inflammation. Their inhibition of carrageenan-induced edoema in rats indicated that the anti-inflammatory effects of *M. oleifera* aqueous root extracts (750 mg/kg) were comparable to those of the strong anti-inflammatory drug indomethacin. This was proved by the fact that the extracts were found to be effective in reducing inflammation. An 85% reduction in inflammation was observed in mice with carrageenan-induced hind paw edoema when they were given crude ethanolic seed extracts at a dosage of 3 mg/kg body weight[39]. On the other hand, the same treatment with ripe seeds resulted in a 77% reduction in edoema. It was observed that the bark, seeds, flowers, roots, and leaves all exhibited the same effect when they were infused with hot water. It has been demonstrated that the anti-inflammatory activity is caused by active molecules that are beneficial in the treatment of both acute and chronic inflammatory illnesses. The RAW 264.7 cell line, which is a lipopolysaccharide (LPS)-induced murine macrophage, was used to study the anti-inflammatory

ISSN: 2583-4053

Volume-3 Issue-3 || June 2024 || PP. 185-193

https://doi.org/10.55544/jrasb.3.3.29

effects of four phenolic glucosides that were obtained from the ethyl acetate extract of *M. oleifera* fruits. The results of this study were presented. Certain bacterial endotoxins, such as LPS, are responsible for activating macrophages during the inflammatory process, which then results in the production of a number of other chemicals. Out of all of these, nitric oxide (NO) stands out as a significant participant in the processes that cause inflammation. It is well-known for its part in the activation of T lymphocytes and the subsequent rise in vascular permeability that it causes[40]. Based on the findings, it was observed that 4-[(2′-O-acetyl-α-L-rhamnosyloxy)benzyl]-isothiocyanate exhibited a significant nitric oxide inhibitory activity against LPS-induced nitric oxide release, with an IC50 value of 1.67 μM. Additionally, 4-[(3′-O-acetyl-α-L-rhamnosyloxy)benzyl] isothiocyanate had an IC50 value of 2.66 μM, and 4-[(4′-O- acetyl-α-L-rhamnosyloxy) benzyl] isothiocyanate had an IC50 value of 2.71 μM. Finally, 4-[(α-L-rhamnosyloxy) benzyl] isothiocyanate had an IC50 value of 14.43 μM. In the course of the research, it was discovered that these compounds are the ones responsible for the NO-inhibitory activity that *M. oleifera* fruits are associated with.
It was determined in vitro whether or not the *M. oleifera* seed extracts and lectins had any anti-inflammatory properties by using LPS-stimulated murine peritoneal macrophages as the test subjects. When compared to cells that were only exposed to lipopolysaccharide, macrophages that were stimulated with lipopolysaccharide and were exposed to both lectins shown a reduction in the production of nitric oxide (NO). According to these findings, the aqueous seed extract and both lectins have an anti-inflammatory impact in vitro. This effect might be largely attributable to the fact that they are able to regulate the formation of negative oxygen species (NO). It was observed that the levels of TNF-α and IL-1β that were produced by macrophages that were activated by LPS were significantly reduced ($p < .05$) by the aqueous seed extracts and the diluted seed extracts. In a separate piece of research, the anti-inflammatory properties of *M. oleifera* seeds were investigated in rats that had been given acetic acid to induce colitis. Both the chloroform fractions of M. oleifera and the seed hydro-alcoholic extracts (MSHE) of M. oleifera were efficient in treating experimental colitis and lowering inflammatory activity when administered in modest dosages. Possibly due to the fact that the two fractions include key components that are comparable to one another, biophenols and flavonoids. A conclusion was reached by the researchers that MSHE, even when administered in modest dosages, has the potential to be an effective alternative therapy option for inflammatory bowel disease (IBD) and the prevention of its recurrence[41].

Antioxidant activity

Studies have been conducted to investigate the reactive oxygen spice characteristics of bioactive compounds that are produced from Moringa pods. These substances consist of a variety of different compounds, such as flavonoids, glycosylates, isothiocyanates, and thiocarbamates[42]. It has been established through research that the extract contained in water is capable of successfully neutralising free radicals. Research has indicated that kaempferol, a chemical that is mostly found in the leaves of plants, may be the component that is responsible for the antioxidant capacity[43]. Moringa, piperine, and curcumin all worked synergistically to protect Wistar rats from the oxidative stress that was caused by beryllium. In isolated lenses taken from goat eyes, the alcoholic extract of the plant was able to regulate the levels of glutathione (GSH), which in turn prevented the development of cataracts caused by glucose. It has been proven that myricetin, an antioxidant that is derived from Moringa seed extract, has greater performance when compared to butylated hydroxytoluene (BHT) and alpha-tocopherol. Following treatment with M. oleifera leaf extract and various compounds, including isoquercetin, astragalin, and crypto-chlorogenic acid, HEK-293 cells exhibited a decrease in the amount of reactive oxygen species (ROS)[44]. In healthy people, moringa has been shown to successfully reduce plasma monoaldehyde (MDA) levels in fasting plasma glucose (FPG) concentration. This is in comparison to the results obtained from giving warm water[45]. The alcoholic plant extract was able to enhance GSH levels and decrease MDA levels in a dose-dependent way up to 100 mg/kg without generating any toxicity despite the fact that it was administered[46].

Antihypertensive

High blood pressure that is maintained over time is one of the symptoms of hypertension, which is a condition that affects the cardiovascular system. An increased risk of cardiovascular disease, renal failure, and stroke are all potential repercussions that could lead to adverse outcomes. For the purpose of demonstrating the efficacy of *M. oleifera* seed oil, Randriamboajonvy and colleagues utilised spontaneous hypertensive rats (SHR) as their experimental experimental paradigm. After taking the drug for ten days, there was no change in the diurnal heart rate; however, there was a significant decrease in the nocturnal heart rate. The capacity of the left ventricle in SHR rats was dramatically reduced during diastole when compared to the capacity of WKY rats, which served as the control group. However, this improvement was reversed when seed oil was added to the SHR process[47]. Both the control group and the seed oil-treated SHR group showed considerably reduced ejection fractions when compared to the WKY rats. Ejection fractions are indications of systolic ventricular function. Based on these findings, it is clear that the SHR did not see an improvement in their systolic ventricular performance after receiving seed oil treatment. After being treated with seed oil, the high isovolumic relaxation time, which indicates that diastolic function is impaired in SHR, was completely removed. This indicates that SHR is a form of heart failure. Smaller cardiomyocytes were observed in

ISSN: 2583-4053

Volume-3 Issue-3 || June 2024 || PP. 185-193

https://doi.org/10.55544/jrasb.3.3.29

the hearts that were treated with M. oleifera seed oil in comparison to the hearts that were treated with SHR control. A further question that was examined in this work was whether or whether the protective effect of seed oil against cardiac fibrosis in SHR is mediated through peroxisome proliferator-activated receptor (PPAR) signalling pathways. A thorough evaluation of the expression of PPARα and PPARδ in cardiac tissue revealed that rats who were fed with SHR seed oil exhibited a greater degree of staining in the left ventricle compared to rats that were treated with SHR controls. Based on the findings, it can be concluded that the seed oil of *M. oleifera* has a beneficial impact on the structure and function of the heart in patients with SHR. Furthermore, it has been observed that it enhances the levels of the PPAR-α and δ signalling pathways. Researchers Acuram et al. investigated the effects of methanol and ethyl acetate extracts on blood pressure and the antihypertensive effects of these extracts in relation to the suppression of ACE. In order to induce hypertension in mice, Nπ-nitro-L-arginine methyl ester, also known as L-name, was administered. In compared to the methanol extract, the findings demonstrated that ethyl acetate strongly suppressed ACE and brought about a reduction in blood pressure on the final day[48].

Hepatoprotective

The hepatoprotective effects of an ethanol extract obtained from Moringa oleifera leaves were investigated by Pari and Kumar in a study that was conducted on rats that had been poisoned with anti-tubercular medications such as isoniazid (INH), rifampicin (RMP), and pyrazinamide (PZA). When taken orally, this extract was found to have a considerable protective effect on a number of markers, which suggests that it has strong protective properties[49]. The levels of hepatic lipids and peroxidation, as well as bilirubin, alkaline phosphatase, glutamic oxaloacetic transaminase, and glutamic pyruvic transaminase (alanine and aspartate aminotransferases, respectively), as well as the blood levels of these enzymes, were all components of this. This study was conducted by Khalid and colleagues to explore the effects of M. oleifera leaf powder and an ethanol extract with a concentration of 70% on female albino mice that had been induced to develop liver and kidney failure due to polycystic ovarian syndrome (PCOS). During the course of thirty-five days, an intramuscular injection of testosterone enanthate at a dosage of one milligramme per one hundred grammes of body weight was administered in order to induce polycystic ovarian syndrome (PCOS). In order to determine the levels of the oxidative stress biomarker malondialdehyde (MDA), the researchers assessed the RFT, LFT, and serum levels at intervals of 0 days, 7 days, and 14 days. The mice that were given M. oleifera showed a significant reduction in total bilirubin, urea, creatinine, alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), and urine when compared to the mice that were given PCOS-induced controls. The levels of albumin, globulin, and the ratio of albumin to globulin (A/G) all increased significantly, although the levels of total protein remained unchanged. Decreases in oxidative stress levels were brought about by a number of factors, including the effectiveness of the treatment, the duration of exposure, and the synergistic effect. Based on the findings of this study, it was shown that female albino mice with PCOS-induced dysfunction could potentially benefit from the use of Moringa oleifera leaf powder or extract in order to reduce oxidative stress and improve hepatic and renal function[50].

Antifertility

When Mekonnen investigated the effects of an ethanolic extract of *M. stenopetala* leaves, he discovered that the extract had a 73.3% reduction in fertility. During the course of the experiment, the extract demonstrated oxytocic effect on the uteri of both mice and guinea pigs. Additionally, the extract increased the amount of smooth muscle in the uteri of the mice, which raised the possibility of contractions and implantation rejection. A further finding was that the stem bark of M. concanensis blocked implantation by 46% when administered at a dose of 400 mg/kg. A significant part of the reaction was played by the solvent. On the basis of a comparison with chloroform, petroleum ether, and an extract of ethanol, it was discovered that the ethyl acetate fraction exhibited the least amount of anti-implantation properties. Following the administration of *M. oleifera* leaf extract, it was discovered that seven rats had undergone a complete miscarriage. After mating, the extract was administered anywhere from five to ten days later. Attempts to improve uterine conditions for egg implantation with the plant's root extract that was water-based were unsuccessful. The development of deciduoma was prevented in rats that were given a high dose of the root extract, which was 600 mg/kg. This finding suggests that the root extract has an anti-progestational acting effect. In addition, it reduced the amount of uterus-forming proteins in the substance[51].

Phytochemistry

An extensive amount of study has been conducted on *Moringa oleifera* and the chemicals that have been synthesised from it. In the genus Moringa, there are over ninety different compounds that have demonstrated potential for use as therapeutic agents. Some of the main categories that are covered by these isolated synthetic chemicals include proteins and amino acids, phenolic acids, carotenoids, alkaloids, glucosinolates, flavonoids, sterols, terpenes, tannins, saponins, fatty acids, glycosides, and polysaccharides.

These are just a few examples. In instance, the leaves of *Moringa oleifera* contain a significant amount of flavonoids and phenolic acids. Not only does it include phenolic acids such as cinnamic, sinapic, syringic, gentisic, gallic, ferulic, protocatechuic, vanillin, caffeic, o-coumaric, p-coumaric, and epicatechin, but it also contains flavonoids like as quercetin, catechin, myricetin,

ISSN: 2583-4053

Volume-3 Issue-3 || June 2024 || PP. 185-193

https://doi.org/10.55544/jrasb.3.3.29

and kaempferol, all of which have significant therapeutic qualities. There is a significant amount of the pigment lutein found in the leaves of the *Moringa oleifera* plant. The plant's therapeutic activity can be attributed to a number of important chemicals, including palmitoyl chloride, cis-vaccenic acid, 5-O-acetyl-thio-octyl, pregna-7-dien 3-ol-20-one, γ-sitosterol, β-l-rhamnofuranoside, and tetradecanoic acid, which were found using gas chromatography-mass spectrometry research[52].

Marumoside A and marumoside B are two unique alkaloids that are created by the leaves of the plant. These alkaloids are produced in addition to aurnatiamide acetate. Moringin and moringinine are among the alkaloids that can be found in the stem of the plant. When it comes to the several glucosinolates that can be discovered in M. oleifera, the glucomoringin is the most abundant of these. Both seeds and leaves contain the sterol isolate known as β-sitosterol, whereas the sterol glycoside known as β-sitosterol-3-O-β-D-galactopyranoside is generated from the bark of the plant. There are also terpenes and diterpenes present in the leaves, however phytol is one of the most prominent diterpene alcohols that can be found there. Terpenes and compounds that are produced from them are also present, albeit in extremely minute quantities.

The pharmacological effects of M. oleifera are determined by the phytochemicals that it contains. According to the findings of previous study, some parts of M. oleifera are specifically responsible for the production of one or more chemical families. The flowers contain a high concentration of flavonoids, alkaloids, and sucrose, in addition to a number of amino acids, including kaempferitrin, isoquercitrin, and rhamnetin. As an additional point of interest, the stem contains many alkaloid compounds, such as octacosanoic acid, 4-hydroxymellein, β-sitosterol, as well as moringinine and moringin. Despite the presence of cytokines in the fruit, the seed contains a significant amount of benzylglucosinolate carbamate, 4-(α-l-rhamnosyloxy) benzylisothiocyanate, 4-(α-l-rhamnosyloxy) benzyl, and O-ethyl-4-(α-l-rhamnosyloxy) benzyl. It was also observed that the entire pods exhibited selectivity for O-[2′-hydroxy-3′-(2″-heptenyloxy)-].Propyl undecanoate, methyl-p-hydroxybenzoate, thiocarbamates, isothiocyanate, nitrile, and O-ethyl-4-[(α-l-rhamnosyloxy)-benzyl] carbamate are the five compounds that are included in this list[53]. M. oleifera seeds contain 144.07 mg/kg of total flavonoids, 145.16 mg/100 g of total polyphenols, and 140.49 mg/kg of proanthocyanidines. These numbers are based on the total flavonoids content. In addition, the oil of M. oleifera contains 18.24 mg of rutin equivalent per hundred grammes of total flavonoids, 37.94 mg of ascorbic acid equivalent per hundred grammes of total antioxidant capacity, and 40.17 mg of GA equivalent per hundred grammes of total phenols[54]. As stated in this description, the following are some of the structures that are associated with the phytochemical components that may be found in M. oleifera[55].

Is the essence of phenolic Using ethanol and butanol, the leaves and seeds of Moringa oleifera were extracted in order to obtain nizadirin during the extraction process. It was discovered that it blocked the activity of α-glucosidase, with an IC50 value of 382.2 µM. In order to accomplish this task, it is feasible to extract caffeine, 4-O-caffeoylquinic acid, 4-O-β-D-glucopyranoside benzoic acid, and 5-O-caffeoylquinic acid from the leaves of Moringa oleifera by using ethyl acetate and butanol. Additionally, vanillin, caffeic acid, gallic acid, and p-coumaric acid are all examples of phenolic compounds that could be isolated from various parts of the *Moringa oleifera* plant mentioned in Figure 2[56].

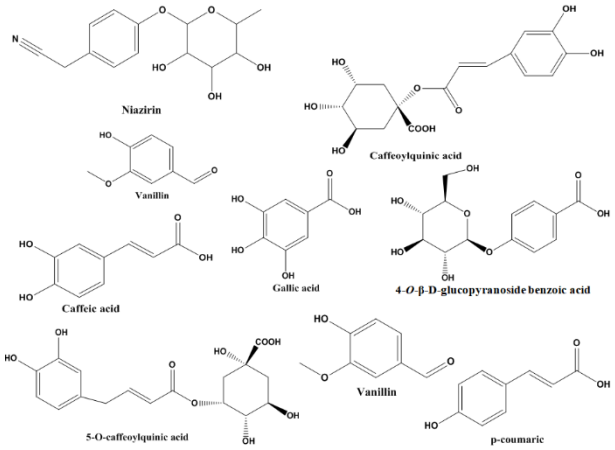

Figure 2: Phenolic compounds in ethanol and butanol extracts of seeds, leaves and other parts of *M. oleifera*

It was demonstrated in that glucosesinolate molecules may be isolated from ethanol extracts of *Moringa oleifera* seeds. Some of these compounds are included in the following list: A number of structures are depicted in figure 3, which includes glucomoringin, 4-(α-L-rhamnosyl) benzyl ethyl ester, moringaside C, F, D, and E, and moringin[57].

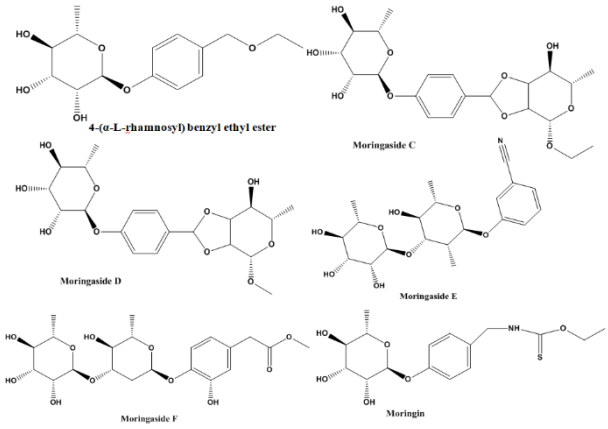

Figure 3: Glucosinolate compounds of seed ethanol extract of *M. oleifera*

Journal for Research in Applied Sciences and Biotechnology

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ISSN: 2583-4053

Volume-3 Issue-3 || June 2024 || PP. 185-193

https://doi.org/10.55544/jrasb.3.3.29

As can be seen in Figure 4, the leaves, barks, and seeds of *M. oleifera* contained a wide range of flavonoid chemicals[58]. The flavonoids that were included in this group were astragalin, isoquercitrin, kaempferol, kaempferol 3-O-glucoside, kaempferol acetyl glycoside, kaempferol-3-O-(6″-malonyl-glucoside), quercetin, quercetin 3-O-β-D-glucopyranoside, and quercetin-3-acetyl-glucoside. In the study, it was discovered that these flavonoids possess the ability to inhibit CYP3AP, with IC50 values of 65.5 and 60 µM, respectively[59].

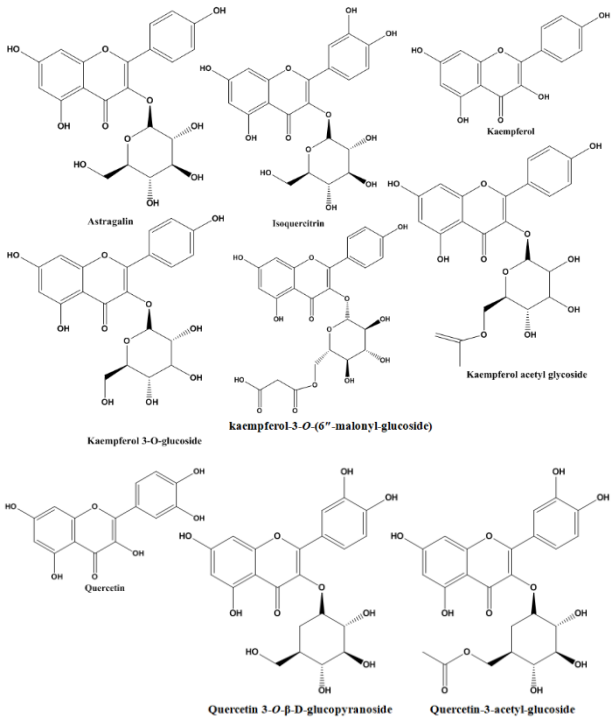

Figure 4: Flavonoid compounds of leaves, barks and seeds of *M. oleifera*

Alkaloids can be found in the roots, seeds, and leaves of *M. oleifera*, as can be shown in the figure 5[60]. The extraction of butanol could be able to supply some of them. A few of the alkaloids that can be discovered in M. oleifera are as follows: Marumoside A, marumoside B, aurantiamide acetate, hostine D, and pyrrolemorine A are some of the structures that are depicted in figure 5[61]. Through the application of a concentration of 0.1 µM, they were able to successfully decrease the expression of NF-Kb and diminish the damage that was produced to PC12 cells by oxygen glucose deprivation[62].

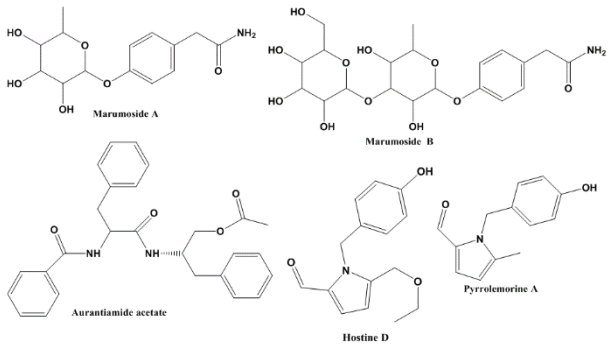

Figure 5: Alkaloids compounds of roots, seeds and leaves of *M. oleifera*

III. TRADITIONAL USES

Diuretic, expectorant, stimulant, and antispasmodic are some of the traditional applications of the plant. It also has antispasmodic properties. The raw root has a flavour that is comparable to horseradish in that it is bitter and vinegary[63]. When used orally, it possesses effects that are classified as stimulant, diuretic, and antilithic. The gum is gentle and mucilaginous in texture. Seeds have an acidic pH, which helps to stimulate the neurological system. Furthermore, the bark is an emmenogogue in addition to possessing antibacterial and antifungal effects[64]. As a result of their cholagogue, stimulant, tonic, and diuretic properties, flowers have the ability to facilitate an increase in the flow of bile. In addition, the herb possesses qualities that are antimicrobial and invigorating to the cardiovascular system[65]. It is recommended that diabetics try frying some pods because they contain qualities that are both antipyretic and anthelmintic. One of the uses for root juice is as an antiepileptic, and another is as a heart tonic[66]. In addition to its use as a diuretic, it is also employed in the treatment of neurological illnesses, asthma, enlarged liver and spleen, chronic inflammation, and calculus affection[67][68]. Make sure to gargle with some decoction if you get a sore throat or a hoarse voice. Root and fruit are two examples of foods that provide antiparalytic effects[69]. The administration of cooked leaves is used to treat influenza and catarrhal disorders, while the use of leaf juice to treat hiccups (in large quantities) is considered to be more emetic[70][71][72]. In addition to its antiviral and anti-inflammatory qualities, the root bark also has analgesic activity. The glucose levels in flowers and stem bark are relatively low[73][74]. Due to the fact that seed infusion possesses anti-inflammatory, antispasmodic, and diuretic characteristics, it is an effective treatment for venereal infections[75]. Dried root bark is listed as a cure for lipid issues, goitre, glycosuria, and piles in the Ayurvedic Pharmacopoeia of India. It is also listed as a treatment for internal abscesses and piles that are caused by leaves, seeds, root bark, and stem bark. This is in addition to its many other therapeutic applications[76].

ISSN: 2583-4053

Volume-3 Issue-3 || June 2024 || PP. 185-193

https://doi.org/10.55544/jrasb.3.3.29

IV. CONCLUSION AND FUTURE PROSPECTS

Moringa is a remarkable plant due to the fact that it may be adapted to a broad variety of situations and utilised for a variety of purposes. Between the years 2019 and 2022, a substantial amount of research was conducted in significant regions such as India, Nigeria, Brazil, and China. This research lends support to the current evaluation of its status, which indicates that it has the potential to be utilised in a wide variety of biological applications, animal husbandry, and pharmaceutical activities. A wealth of information is contained within this large body of work, which is a treasure trove for academics from all around the world.

An extensive amount of research on *M. oleifera* has revealed a great deal of information that is beneficial to human health. Because of its rich nutritional and phytoconstituent content as well as its great antioxidant qualities, the plant is excellent for human consumption and has numerous applications in formulations. The anti-aging, anti-cancer, and wound healing treatments that are included in these formulations are readily available. Furthermore, fertilisers that are derived from *M. oleifera* also perform admirably. In spite of the fact that it has a great deal of beneficial applications, it is essential to be aware that excessive usage of it may result in adverse effects that are both poisonous and might cause abortion. This comprehensive analysis covers every facet of *Moringa oleifera*, including studies conducted all over the world, ethnopharmacology, pharmacological activity, phytochemistry, phytopharmaceutical formulations, clinical trials, toxicity, and several other areas. There are a number of significant components that can be discovered in *M. oleifera* that have medicinal properties. These components include alkaloids, phenolic acids, glycosides, sterols, glucosinolates, flavonoids, terpenes, and fatty acids. The amount of vitamins, minerals, and carotenoids that the plant possesses contributes to the plant's standing as a superfood and further enhances its medically beneficial properties.

Pharmacological tests have demonstrated that the plant has the potential to alleviate a variety of ailments, including neuropathy, cancer, high blood pressure, and diabetes, but these are just some of the conditions. It is possible that certain phytochemicals possess therapeutic qualities; nevertheless, additional research is required in this field. Not only is *M. oleifera* useful for medical purposes, but it is also a low-cost biostimulant that can be utilised by farmers. Although there has been a significant amount of work done in the field of preclinical research, the focus of future efforts should be on conducting clinical trials on a broad scale, particularly in relation to major diseases such as AIDS, cancer, and epidemics caused by the coronavirus. In addition, mechanistic experiments are recommended in order to uncover the components of the plant that participate in synergy or activity. When everything is taken into consideration, the "Miracle tree," also known as *Moringa oleifera*, is demonstrating substantial potential as a phytopharmaceutical and functional food. Continuous use provides a safer alternative for medical professionals to consider in a variety of therapeutic settings, and it has the potential to treat a wide spectrum of chronic illnesses.

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ISSN: 2583-4053

Volume-3 Issue-3 || June 2024 || PP. 185-193

https://doi.org/10.55544/jrasb.3.3.29

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