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A Review of Biological and Therapeutic Activities of *Moringa Oleifera* Linn

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ABSTRACT

Moringa oleifera L. family *Moringaceae* has impressive range of medicinal uses with high nutritional value. Different parts of this plant contain a profile of important phytochemicals, minerals and good source of protein, vitamins, amino acids and various phenolics. In Africa, *Moringa oleifera* is known as 'mother's best friend'. It is a relatively fast growing tree with small leaves. The moringa is of economic importance in the production of several commodities and also provides rich and rare combinations of zeatin, quercetin, kaempferom and many other phytochemicals. The leaves of *M. oleifera* have also been known to contain a number of phytochemicals. Several biological activities have been reported in *M. oleifrera* which include biological coagulation in drinking water by its seeds. Antimicrobial activities of the plant have been reported so also are the immune-modulatory, anti-asthmatic antipyretic activities of the leaves. *Moringa oleifera* claimed to treat different ailments in the indigenous system of medicine. This review focuses on the biological activities of *Moringa oleifera* particularly on relatively little explored area of their microbiological, nutritional and pharmacological applications.

Keywords: *Moringa oleifera*, Therapeutic Activities, Antimicrobial,

INTRODUCTION

Ecological and Geographical Distribution

Moringa oleifera Lam is one of the best known, widely distributed and grown species of a monogeneric family *Moringaceae* (Anwar *et al*., 2007). It is native to the western and sub-Himalayan parts of Northwest India, Pakistan and Afghanistan. The species is now widely cultivated across some African countries, South America and South-East Asia. It is a drought tolerant plant that thrives best under the tropical climate and tolerates different soil types (Fahey, 2005). In South Africa, the plant is found in few localities: Limpopo, Kwazulu Natal and Mpumalanga Provinces (van Jaarsveld, 2006). It can tolerate wide range of rainfall requirements estimated at 250 mm and maximum at over 3000 mm and a pH of 5.0 to 9.0.

Description of the Plant

In Africa, *Moringa oleifera* is known as "mother's best friend". Moringa, drumstick tree in English is commonly called by different manes among different tribes in Ngeria; it is known as 'Zogale' in Hausa, 'Okwe Oyibo' in Igbo, 'Ewe Ile' in Yoruba (Ijeomah *et al*., 2012; Awanish *et al*., 2012). It is a relatively fast growing tree which can grow more than 10 metres high and is topped by a crown in the shape of an umbrella. The leaves are small (1-2 cm) Plate 1. The species is characterized by its long, drumstick shaped pods that contain its seeds. The pods are green and tender at first and then turn dark and solid on maturation. The benefits of *Moringa oleifera* are plentiful: Practically every part of the tree is beneficial. The bark is whitish and corky, the leaves are small and spicy, as are the roots which were used as a substitute for horseradish by Europeans in India (hence the name horseradish tree).

Plate 1: *Moringa oleifera* L. tree showing the pods and the flower

The Beneficial uses of *Moringa oleifera*

The plant provides a rich and rare combination of zeatin, quercetin, kaempferom and many other phytochemicals. The leaves have been known to contain a number of phytochemicals such as flavonods, saponins, tannins and other phenolic compounds that are antimicrobial in nature (Sato *et al*., 2004; Cushine and Lamb, 2005; Mboto *et al*., 2009). The mechanisms of actions of these compounds have been proven to be via cell membranes perturbations (Esimone *et al*., 2006). The extracts of the plants work synergistically with β-lactams on the trans-peptidation (Esimone *et al*., 2006; Chen, 2009). *Moringa oleifera* seeds had a synergistic potential to restore the effectiveness of β–lactam antibiotics against MRSA (Karthy *et al*., 2009). The synergistic properties could be attributed to β –lactamase inhibition by the Flo peptide (a specific polypeptide found in *Moringa oleifera* that is both a flocculent and a biocide). The cationic Flo peptide supposedly serves as a highly efficacious immunity response, interacting with the anionic cell membranes of bacterium (Fisch *et al*., 2004). This interaction

destabilizes the bacterial membrane, causing leakage of cytoplasmic content and killing the bacterial cell. Antimicrobial peptideshave been reported to act directly and non-specifically upon bacterial membranes, thus hindering their ability to develop resistance.

According to Dahot (1998), *M. oleifera* leaf extracts contain small peptides which play an important role by inhibiting the growth of microorganisms through diverse molecular modes, such as binding to chitin or increasing the permeability of the fungal membranes or cell wall (Chuang *et al*., 2007). Several biological activities of *M. oleifera* have been reported to have ntimicrobial (Jabeen *et al.*, 2008).

Major Phytochemical Constituents

Phytochemical studies on *M. oleifera* revealed major polyphenols such as rutin, quercetin, kaempferol glycosides and chlorogenic acids (Ndong *et al*, 2015). The researchers reported gallic acid, chlorogenic acid, ferulic acid, ellagic acid, vanillin quercetin, kaempferol (Singh *et al*, 2009).

The seeds of the plant contain 4(α-L-rhamnosyloxy) benzyl isothiocyanate, 4(-L-rhamnosyloxy) phenylacetonitrile 4-hydroxyphenylacetonitrile,4- (α-l-rhamnopyranosyl oxy)-benzyl glucosinolate, 4-hydroxyphenylacetamide, roridin E, veridiflorol, 9-octadecenoic acid, O-ethyl- 4-(α-l-rhamnosyloxy) benzyl carbamate, 3-O-(6'-O oleoyl- β-D-glucopyranosyl)-β-sitosterol and β-sitosterol-3-O-β-Dglucopyranoside, niazirin, niazimicin, β-sitosterol, glycerol-1-(9-octadecanoate) among others while the gum contains aldotriouronic acid (Fahey, 2005; Kesharwani *et al*., 2014; Muhammad *et al*., 2015). The leaf of the plant are rich in pterygospermin and other related compounds such as isothiocyanates which is used in the treatment of many skin infections because of its antibiotic and fungicidal properties (Price, 2007).

Major Phytochemical Constituents of *Moringa oleifera*

Compound	Potential application	Reference
4-(4'-O-acetyl-a-L-rhamnopyranosyloxy)benzyl isothiocyanate, 4-(a-L rhamnopyranosyloxy) benzyl isothiocyanate, niazimicin, benzyl isothiocyanate, and 4-(a-Lrhamnopyranosyloxy) benzyl glucosinolate, Anthonine and Spirochin	Antibacterial	Fahey (2005) and Nwosu and Okafor (1995)
Pterygospermin	Antibacterial and fungicidal	Rao *et al*. (1946)
Nitrile, mustard oil glycosides and thiocarbamate glycosides	Hypotensive	Anwar *et al*. (2007)
Alkaloid Moringine	Antiasthmatic	Agrawal and Mehta (2008)
Quecertin and kaempferol	Antioxidant, hepatoprotective	Bajpai *et al*. (2005), Selvakumar and Natarajan P (2008)
b-sitosterol	Cholesterol lowering	Ghasi *et al*. (2000)
Dark chocolate polyphenols and other polyphenols	Hypoglycemic	Grassi *et al*. (2005), Al-Awwadi *et al*. (2004), Moharram *et al*. (2003)
4- (alpha- L-rhamnosyloxybenzyl)-omethyl thiocarbamate, niazinin A, niazinin B, niazimicin etc.	Spasmolytic, hypotensive and bradycardiac	Gilani *et al*. (1994)
Niazimicin,	Anticancer	Guevaraa *et al*. (1999)

Nutritional facts

Moringa is a tree that grows in almost ramshackle areas of the earth. It seems that God packed this tree with almost all the essential nutrient and made to feed the poor of rural and barren areas. With more than 90 recognized nutrients, 36 anti-inflammatories, 46 antioxidants, *Moringa* is the most enzymatically active and nutrient-dense plant known to mankind (Mishra *et al*, 2011). It is analyzed scientifically that *Moringa* contains more than 539 biochemical activities that are absolutely beneficial to man (Debnath and Guha, 2007). A huge array of nutritional and medicinal qualities have been accredited to bark, roots, leaves, fruits, flowers and seeds.

Moringa oleifera L. family *Moringaceae* has impressive range of nutritional used apart from its high medicinal benefits. Different parts of this plant contain a profile of important minerals, and a good source of protein, vitamin, amino acids and various phenolics (Fozia *et al*., 2012). The economic importance of *M. oleifera* in the production of several commodities, such as oils, foods, condiments and medicines was reported by Makkar and Becker (1997). The leaves contain different amino acid which includes aspartic acid, alanine, threonine, glutamic acid, valine, glycine, isoleucine, leucine, lysine, histidine, tryptophan, phenylalanine, methionine and cysteine (Ganatra *et al*., 2012; Kesharwani *et al*., 2014).

Moringa oleifera has been reported to contain vitamin A, vitamin C and iron (Price, 2007), vitamin E and polyphenolics (Ross, 1999). Also it is a viable supplement of dietary minerals. The pods and leaves of moringa contains high amount of Ca, Mg, K, Mn, P, Zn, Na, Cu and Fe (Aslam *et al*., 2005).

Nutritional Benefits

A bulk of reports exists in literature on the nutritional values of *Moringa*. The nutritional contents include vitamin A, which provides protection against skin diseases, eye disease, gastrointestinal ailments, heart ailments and many other health problems; vitamin C, which enhances immunity during different complaints including flu and colds; Ca, which makes the teeth and bones strong and prevents osteoporosis and vitamin K, which is essential for proper brain functioning and proteins, the building blocks of cells of our body(Mahmood and Mugal, 2010; Mukunzi *et al*, 2011). *Moringa* leaves contained the variety of essential amino acids which are proteins sub-units.

Moringa fresh leaves were compared with other food products placed the *Moringa* on the top. It contains four times the Calcium Ca of milk, four times the vitamin A of carrots and three times the potassium K of bananas. But the dried leaves contain even more micro-nutrient content (17 times Ca of the milk, ten

times vitamin A of the carrots, 15 times K of the bananas and 25 times the iron of spinach). However, vitamin C drops to about half that of oranges (Mukunzi *et al*, 2011).

Keeping in view the nutritional facts, there is a great opportunity of its utilization in fortifying milk, juices, sauces, bread, spices and instant noodles. Many commercial products like tea, Zija soft drink and neutraceuticals are a few examples (Muhammad *et al.,* 2015).

Biological importance of *Moringa oleifera*

All parts of *Moringa* tree are edible. It is a rich source of carotenoids, calcium, iron and minerals. The seed kernel contains on an average 40 percent by weight of oil, with palmitic, stearic, behenic and oleic acids. *Moringa* species are rich in fairly unique group of phytochemicals, glucosinolates and isothiocyanates (Fahey, 2005).

Alternative Medicine for Human Pathogens

Out of the 250,000 to 500,000 species of plants on earth (Cowan, 1999), only 10% (*Moringa* inclusive) have been reported to have a profound potentials in pharmaceutical industry. They are sources of bioactive constituents most drugs.

Antibacterial Activity

Antimicrobial components of *M. oleifera* have been validated after the discovery of inhibitory activity against several microorganisms. In a recent study, aqueous extracts of *M. oleifera* was found to have inhibitory activity against many pathogenic bacteria, including multiple antibiotic resistant *Staphylococcus aureus, Bacillus subtilis, Escherichia coli* and *Pseudomonas aeruginosa* in dose dependent manner (Saadabi and Abu, 2011). *Moringa oleifera* extracts was also found to be inhibitory against *Mycobacterium phlei* and *B. subtilis* (Eilert *et al*., 1981).

The need for new antimicrobial agents is closely linked with the problem of emergence of strains that are resistant to most synthetic antibiotics. This has arisen due to extensive use of antibiotics, which renders most of the current synthetic antimicrobial agents inefficient in controlling some bacterial diseases (Gustavo *et al.,* 2010). *Moringa oleifera* has been the object of much research due to its multiple uses and well-known bactericidal potential (Suares *et al*., 2003; Suares *et al*.2005, Abdulmoneim and Abu, 2011; Abalaka *et al.,* 2012).

In a study on the antibacterial effect of *M. oeifera* leaves extracts prepared in different solvents, petroleum ether extracts demonstrated the highest activity against clinical and environmental isolates of *Proteus mirabilis* (Devendra *et al.,* 2011). However, in a separate study chloroform extracts (Dewangan *et al.,* 2010) showed broad spectrum potential than that of petroleum ether an indication of the presence of different active principles. *In vitro* studies on different extracts of the root bark of *Moringa oleifera* against *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa* among others showed that ethyl acetate and acetone extracts exhibited maximum activity as compared to other solvents (Renu *et al.,* 2010; Anitha *et al.,* 2011) which shows that active compounds are polar in nature. Antimicrobial activity studies of stem bark of *Moringa oleifera* against some human pathogens demonstrated methanolic extracts to be the most effective among other solvents used(Bolin *et al.,* 2011; Das *et al.,* 2012). Moyo *et al.* (2012) reported that acetone extract of leaf of *M. oleifera* at 5 mg/ml showed antibacterial activities against *E. coli* (ATCC 25922), *E. cloacae* (ATCC 13047), *P. vulgaris* (ATCC 6830), *S. aureus* (ATCC 6538) and *M. kristinae* at 0.5 mg/ml. The acetone extract had bactericidal effect on *E. coli* (ATCC 25922) and *M. kristinae*, while the effect was bacteriostatic on *S. aureus* (ATCC6538), *E cloacae* (ATCC 13047) and *P. vulgaries* (ATCC6830).

Compounds like pterygospermin, benzyl glucosinolate and benzyl isothiocynate have, however been isolated from *M. oleifera* leaves and these compounds have been reported to have antimicrobial properties against a wide range of bacteria this in part explains the observed bacteriostatic and bactericidal activity of the flora (Fahey, 2005).

Antibiofilm Activities

The phytochemicals of *M. oleifera* could also be tested against various biofilms of bacteria. Many reports had been documented that eradication bacteria are difficult to achieve due to their inherent resistance to antibiotic, biocides, and host defenses. There are several mechanisms explaining the resistance amongst is the biofilms formation by the pathogens (Joana *et al*; 2014). Biofilm makes the eradication of the forming organism very difficult and prediction of the physiology of the biofilm cells unpredictable. In the experiment performed by Sillankorva *et al.* 2004) showed after that biofilms (*E. coli* and *S. aureus*) were inoculated with phytochemicals at MIC and 5xMIC for h.

Onsare and Arora (2015) reported that the minimum inhibitory concentration (MIC) of flavonoids against bacteria and a fungus inhibited the initial cell attachment as well as disruption of preformed biofilms and metabolic activity of treated biofilms of the isolates. Extract from the plant disrupted the preformed biofilms as early as 4 h of exposure with 88% growth inhibition at the end of 24-h incubation.

Antifungal activity of *M. oleifera* against plant pathogenic fungi

Since fungicides are very expensive and cause serious side effects, control strategies are today directed towards replacing the use of hazardous fungicides by easily biodegradable ecofriendly natural products (Mamdouh and Eweis, 2007) .The plant world is a rich store house of natural chemicals that could be exploited for use against mycophytopathogens (Satish *et al.,* 2009). Botanicals are now emerging as safer and more compatible approach to control phytopathogens. Higher plants are known to express fungitoxicity against spore germination and mycelial growth of phytopathogenic fungi (Talreia, 2010; El-Mohamedy *et al*., 2013) .Fungal infections cause significant loss in many economic crops. Crop losses are estimated to be about 14% worldwide (Agrios, 2005).

Aspergillus niger was strongly inhibited followed by *Aspergillus oryzae*, *Aspergillus terreus* and *Aspergillus nidulan* on *M. oleifera* (Prashith *et al*., 2010). The fungicidal effect of *M. oleifera* extracts on some soil-borne fungi such as *Rhizoctonia*, *Pythium* and *Fusarium* has also been documented (Moyo *et al*., 2012). *Moringa oleifera* extracts (leaves, bark and seeds) 75 % (v/v) showed significant inhibition in the mycelial growth of *Fusarium solani* and *Fusarium oxysporum* f. sp. *lycopersici*. Leaves of *M. oleifera* are rich in zeatin, a cytokinin in addition to other growth enhancing compounds like ascorbates, phenolic and minerals like Ca, K, and Fe that makes it an excellent crop growth enhancer. *Moringa oleifera* provides a rich and rare combinations of zeatin, quercetin, b-sitsterol, caffeoylquinic acid and kaempferol which have antifungal activities (Anjorin *et al.,* 2010).

Moringa oliefera leaves extracts have been successfully used as seed treatment against some soil borne fungi (Talreia, 2010; Yasmeen *et al*., 2011; Foidle, *et al.,* 2001). The fruit extract of *Moringa oleifera* showed a broad-spectrum antifungal activity

against pathogenic fungi- *Alternaria* sp, *Colletotrichum* sp, *Curvularia* spp and *Fusarium* sp. (Mohammed *et al.*, 2012).

Efficacies of *M. oleifera* against animal pathogenic fungi

Moyo *et al*. (2012) reported that both acetone and aqueous extracts of *M. oleifera* have not exhibited any antifungal activity against *Candida albicans, Penicillium notatum, Aspergillus flavus* and *A. niger* even at 10 mg/ml concentration. Jamil *et al*. (2010) tested the efficacy of plants extract including *M. oleifera* and reported that selected plant extracts showed antifungal activity against *Mucar mucedo* and *Aspergillus niger* more strongly than *Aspergillus tamari* and *Rhizoctonia solani.*

Aflatoxin Removal

Aflatoxins, produced by *Aspergillus* fungi are common contaminants of livestock feeds. The most common aflatoxins in feed are aflatoxin B1 (AFB_1), aflatoxin B_2 (AFB_2), aflatoxin G_1 (AFG_1) and aflatoxin G_2 (AFG_2). Consumption of such contaminated feed affects liver and kidney and leads to damage. In poultry, oxidative stress and liver damage are the major causes of aflatoxin toxicity (Karaman *et al*, 2010). Supplementation of *M. oleifera* leaves to diet significantly reduced the adverse effects of aflatoxin on blood biochemical parameters and liver lipid peroxidation and antioxidant status and exerted protective effect against aflatoxin toxicity in broilers (Umaya and Parvatham, 2012).

Antiviral Activity

According to the report of Chollom *et al*. (2012), Antiviral assay of *M. oleifera* confirms that the plant had antiviral properties against new castle disease virus (NDV). This was revealed by the total inhibition of virus growth *in ovo* at 100, 200 and 250 mg/ml. At these concentrations, all the inoculated eggs had live embryos just as sera of hatched chicks had no antibodies against new castle disease virus. This is not strange considering the phytochemical composition of the seed and previous citations of the antiviral potentials of the agent against some human viruses: *M oleifera* against common cold virus (Fuglie, 2005), against Epstein Barr Virus (Murakami *et al*., 1998), against Herpes Simplex Virus (HSV-1), against Human immune deficiency virus (HIV) (Abrams *et al*., 1993) and against warts virus (Fuglie, 2000).

Newcastle disease is a highly infectious disease of domestic poultry and wild birds. It is caused by a virus and is widely regarded as one of the most important avian diseases. Although, most avian species are susceptible to infection with the virus that causes Newcastle disease, chickens are the most susceptible to clinical disease (Young *et al*., 2002). However, *M. oleifera* seed extract at 250 mg/ml, 200 mg/ml and 100 mg concentrations completely inhibited virus growth in embryonated eggs as revealed by the survival of embryos of the inoculated eggs.

Chollom *et al*., (2012), in his findings, observed that, HI test results showed increasing NDV antibody titre with decreasing extract concentration. This is a clear indication of a concentration-based antiviral activity of the plant against NDV. It is therefore safe to conclude that the higher the extract concentration, the more the antiviral activity. In what would be seen as a typical human system, an embryo death was recorded in group 6 within 24 h post inoculation. This of course was not due to viral activity as revealed by HA test. The embryo death could be well attributed to mechanical or physical factors around the experiment. These findings are scientific and relevant judging from the performance of the control groups.

Avian coccidiosis is one of the most important dreadful diseases of poultry worldwide. Coccidiosis caused by *Eimeria* species cause huge economic losses in poultry and this includes the costs for treatment of birds, reduced productivity and losses due to mortality of birds. Recently (Ola-Fadunsin and Ademola, 2013) studied the effect of acetone extract of *M. oliefera* to inhibit coccidiosis. The findings revealed improved body weight and increase in the values of their haematological parameters on supplementation of *M. oliefera* in *Eimeria* infected birds.

Antiplasmodial Properties of *M. oleifera*

In the study conducted by Olasehinde *et al.* (2012), the *in vivo* anti-plasmodial activity of crude ethanolic and n-hexane seed extracts of *M. oleifera* was determined. Positive activity against *P. berghei* was observed at three different concentrations that is, 50, 100, 200 ml/kg. The ethanolic extracts cleared the parasite completely at 200 ml/kg as observed in the case of positive control chloroquine diphosphate, a standard antimalarial drug, administered at a daily dose of 25 mg/kg body weight.

The relatively high antiplasmodial activity of the seed extracts of *M. oleifera* probably explains its widespread use in herbal medicine. The extract can hence be standardized and packaged to be used as phytomedicine. Emmanuel *et al.* (2015) thus carried out to determine the fortunes of *Moringa oleifera* Lam, as a candidate plant for traditional management of malaria infection and potential source for future antimalarial agents.

Larvicidal Activity of *Moringa oleifera*

In vitro studies depicted antiprotozoal effect of *M. oleifera.* The soluble lectin from the seed extract showed larvicidal activity by delaying larval development and promoting mortality in *Aedes aegypti*, possibly on account of its hemagglutinating activity (Kohler *et al.*, 2002; Coelho *et al*, 2009; Ferreira *et al*, 2009). Paulo *et al.* (2009) documented in their findings that the crude Water extract of *Moringa oleifera* seed at 5-200 µg/mL (soluble solids) caused 99.2 ± 2.9% mortality of 3rd instar larvae within 24 h and toxic effects were still observed in lower concentrations, showing an increasing progression toward larvae death in a dose-dependent manner.

Antihelmintic Effects of *Moringa oleifera*

Moringa leaves and flowers are able to control parasitic worms (Bhattacharya *et al*., 1982) It has also been reported to inhibit Indian earthworm *Pheritima posthuma* with *M. oleifera* leaves ethanolic extracts (Rastogi *et al*., 2009).

Antihypertensive and diuretic Activity of *Moringa oleifera*

Moringa leaves contain several bioactive compounds, the extract exert direct effect on blood pressure, and thus these can be used for stabilizing blood pressure. *M.oleifera* compounds leading to blood pressure lowering effect includes nitrile, mustard oil glycosides and thiocarbamate glycosides present in *Moringa* leaves (Anwar *et al*., 2007).

Cholesterol Lowering Activities of *M. oleifera*

Different parts and products of *M. oleifera* viz: roots, leaves, flowers, seeds and gum contain bioactive phytoconstituents (like b-sitosterol) have cholesterol lowering attributes (Morton, 1991). This compound is capable to reduce cholesterol level from the serum of high fat diet fed rats (Ghasi *et al*., 2000).

Cardiac and circulatory stimulant ability of *M. oleifera*

In addition to earlier mentioned bradycardiac effect of *Moringa oleifera* leaves, all parts of *Moringa oleifera* are reported with somewhat cardiac and circulatory stimulant activity. Root bark of *Moringa* contains alkaloid moringinine which acts as cardiac stimulant through its effect on sympathetic nervous system (Duke, 2001). The aforementioned effects can also result due to the prevention of hyperlipidemia. It has been demonstrated that *Moringa oleifera* prevent hyperlipidemia in male Wister rat due

to iron deficiency (Ndong *et al*., 2007). During a study performing comparison of *Moringa oleifera* leaf extract with antenolol (a selective β1 receptor antagonist drug, used for cardiovascular diseases) on serum cholesterol level, serum triglyceride level, blood glucose level, heart weight and body weight of adrenaline induced rats, it was found that *Moringa oleifera* leaf extract cause significant changes in cardiovascular parameters (Ara *et al*., 2008).

Moringa oleifera also causes cardio protective effects in isoproterenol (ISP)-induced myocardial infarction in male Wistar albino rats. Moreover, it also prevents histopathological damage and ultra-structure perturbation caused due to ISP induced myocardial infarction (Nandave *et al*., 2009).

Antispasmodic (drug for controlling muscle spasm) activity

The roots as well as ethanol extract of the leaves of *M. oleifera* showed antispasmodic action, possibly through calcium channel blockade. Spasmolytic activity exhibited by the constituents of the plant provides a scientific basis for the traditional uses of the plant in gastrointestinal motility disorders (Pal *et al*., 1995; Anwar and Rashid, 2007).

Another research shown by Fozia *et al.* (2012) that *Moringa* root and leaves contain several compounds with spasmolytic activity. These compounds include 4-(alpha-L-rhamnosyloxybenzyl)-o-methyl thiocarbamate which is possibly affected through calcium channel blockade, niazinin A, niazinin B, niazimicin, etc. The spasmolytic activity of different constituents support for traditional uses of this plant in gastrointestinal motility disorder (Gilani *et al*., 1994). Methanolic extract of *M. oleifera* was also enhances healing process of chronic gastric lesions induced by acetic acid in experimental animals (Pal *et al*., 1995).

Anti-inflammatory and anti-ulcer effects of *M. oleifera*

Moringa methanol extract provides significant protection against indomethacin acetylsalicylic acid and serotonin induced gastric in experimental rat (Pal *et al*, 1995). Anti-ulcer effect of Moringa leaves aqueous extract is also reported on adult Holtzman Albino rats (Duke, 2001). Moringa plant parts have substantial anti-inflammatory activity. For instance, the root extract exhibits significant anti-inflammatory activity in carrageenan induced rat paw oedema (Khare *et al*., 1997). The crude methanol extract of the root inhibits carrageen an induced rat paw oedema in a dose dependent manner after oral administration. Amelioration of inflammation associated chronic diseases can be possible with the potent anti-inflammatory activity of *M. oleirera* bioactive compounds (Muangnoi *et al*., 2011).

Immunomodulatory activity of *M. oleifera*

Immuno-deficiency disorders impair the immune system ability to defend the body against foreign or abnormal cells. This is a major drawback in conventional therapy (radiotherapy and chemotherapy) of cancer (Jame, 2007). Modulation of immune responses by various plant materials, for alleviation of diseases has been an interesting approach since ancient time and also the basic concept of 'rasayana' in Ayurveda (Gokhale *et al.*, 2003).

Moringa oleifera commonly known as drumstick has been reported to exhibit chemomodulatory (Bharli *et al.*, 2003) and antioxidant activities. Moreover, it also regulates thyroid status and cholesterol levels (Tahiliani and Kar 2000). Immunomodulatory activity of *M. oleifera* has not been reported so far. However Anamika *et al.* (2010) has documented the immunomodulatory effects of *M. oleifera* extract on cyclophospsamide-induced toxicity in mice and concluded that immunomodulatory activity of *M. oleifera* extract significantly increased the white blood count (WBC) and percent neutrophils of normal mice in a dose related manner. *Moringa oleifera* was also capable of significantly reduce the leucopenia induced by sub-lethal dose of cyclophosphamide in mice as well as stimulating the haemopoetic system.

Moreover, Anamika *et al.* (2010) also noted that the administration of the plants extract also stimulated the increase in size and weight of spleen as well as thymus in both normal and immune suppressed mice. Finally, *Moringa oleifera* extract can be used to restore the production of immune cells, which was decrease by cyclophosphamide. Thus, it can be used to stimulate carbon clearances that remove carbon from the blood by increasing or production of phagocytic cells.

Anti-asthmatic activity of *M. oleifera*

It has been reported that moringa alkaloids closely resemble ephedrine in action and can be used for the treatment of asthma. Alkaloid moringine relaxes bronchioles (Kirtikar and Basu, 1975). The seed kernels of *M. oleifera* also showed promising effect in the treatment of bronchial asthma, during a study to analyze efficacy and safety of seed kernels for the management of asthmatic patients. The study showed significant decrease in the severity of asthma symptoms and also concurrent respiratory functions improvement (Agrawal and Mehta, 2008).

Analgesic activity of *M. oleifera*

The analgesic activity of Moringa has been reported in several *Moringa* species. In a study using ethanolic extracts of *Moringa concanensis* tender pod-like fruits in experimental animals, a significant analgesic activity was observed (Rao *et al*., 2008). Furthermore, alcoholic extract of the leaves and seeds of *M. oleifera* also possess marked analgesic activity as evidenced through hot plate and tail immersion method (Sutar *et al*., 2008).

Antipyretic activity of *M. oleifera*

As a result of anti-inflammatory action of *Moringa* bioactive constituents, the antipyretic activity can be hypothesized. A study was designed to assess antipyretic effect of ethanol, petroleum ether, solvent ether and ethyl acetate extracts of *M. oleifera* seeds using yeast induced hyperpyrexia method. Paracetamol was used as control during the study. Not surprisingly, ethanol and ethyl acetate extracts of seeds showed significant antipyretic activity in rats (Hukkeri *et al*., 2006).

Antidiabetic activity of *M. oleifera*

Several medicinal plants have been evaluated for their potential as therapeutic agent for diabetes. *Moringa oleifera* is also an important component in this category. *Moringa oleifera* leaves significantly decrease blood glucose concentration in Wistar rats and Goto Kakizaki (GK) rats, modeled type 2 diabetes (Ndong *et al*., 2007). Another study indicated that the extract from *Moringa* leaf is effective in lowering blood sugar levels within 3 h after ingestion (Mittal *et al*., 2007). As a mechanistic model for antidiabetic activity of *M. oleifera*, it has been indicated that dark chocolate polyphenols (Grassi *et al*., 2005) and other polyphenols (Al-Awwadi *et al*., 2004; Moharram *et al*., 2003) are responsible for hypoglycemic activity. Thus, potential antidiabetic activity of *Moringa oleifera* can be commercialized through the development of suitable technology with achieving anti-diabetic activity up to conventional drugs.

Hepatoprotective Activity of *M. oleifera*

Moringa oleifera has shown significant hepatoprotective activity in several studies. *Moringa oleifera* leaves ethanolic extracts

showed significant protection against liver damage induced by antitubercular drugs [isoniazid (INH), rifampicin (RMP), and pyrazinamide (PZA)] in rats. It was found that hepatoprotective activity of *Moringa oleifera* is medicated by its effect on the levels of glutamic oxaloacetic transaminase (aspartate aminotransferase), glutamic pyruvic transaminase (alanine aminotransferase), alkaline phosphatase, and bilirubin in the serum; lipids, and lipid peroxidation levels in liver (Pari and Kumar, 2002).

Moreover, methanolic and chloroform extracts of *M. oleifera* leaves also showed significant protection against CCl_4 induced liver damage in albino rats. Besides hepatoprotective activity of *Moringa oleifera* leaves, its root and flowers also possess strong hepatoprotective activity. *Moringa* flowers contain a well-recognized flavonoid (Quercetin), which may be responsible for its potent hepatoprotective activity (Selvakumar and Natarajan, 2008). In a recent study evaluating the effect of *Moringa oleifera* seed extract on liver fibrosis, it was found that *Moringa oleifera* seed extract has the ability to subside liver fibrosis. This study involved CCl4 induced liver fibrosis and concurrent administration of *Moringa oleifera* seed extract. *Moringa oleifera* seed extract control the elevation of serum aminotransferase activities and globulin level induced by CCl_4. Moreover, immunohistochemical studies also showed that *Moringa oleifera* reduces liver fibrosis (Hamza, 2010).

Action on Central Nervous System (CNS) of *M. oleifera*

Aqueous (100-450 mg/k, oral) and methanolic (350-700 mg/kg, intraperitoneal) root extracts of *M. oleifera* reduced locomotor activity of rats and the number of seizures induced by penicillin and strychnine (Ray *et al*., 2003). Aqueous extract also amplified rates of 5-HT and reduced levels of dopamine in the brain cortex, cerebellum and caudate nucleus and noradrenaline measure in the cerebral cortex (Ray *et al*.,2003). Methanol extract produced CNS depression, decreases the mortality of strychnine- and leptazol-treated animals, increased the sleeping time, caused analgesia and potentiated morphine analgesic effects. This sleepiness extension and anticonvulsant and analgesic activities can be justified by the 5-HT brain rising.

More recently, discoveries also showed that ethanol extract from *M. oleifera* leaves (250-2000mg/kg) caused decreasing in rearing, grooming, head dips and locomotion of mice, enhanced learning and memory, increased anxiogenic effect and reduced convulsions induced by pentylenetetrazol, though it has no effect on picrotoxin and strychnine induced convulsion. In this event, it is possible that these activities are mediated through the enhancement of central inhibitory mechanism involving release γ-amino butyric acid (GABA) (Bakre *et al*., 2013). These findings partially justified the traditional use of *M. oleifera* parts for the treatment of epilepsy.

Antitumor activity of *M. oleifera*

Moringa oleifera has been found as a potent anticancer plant and several bioactive compounds with significant antitumor activity have been discovered from *M. oleifera*. Among bioactive compounds from *M. oleifera*, niazimicin, a *Moringa oleifera* leaves thiocarbamate was found to have potent anticancer activity (Guevara *et al*., 1999). Furthermore, niazimicin also shows the inhibition of tumor promoter teleocidin B- 4-induced Epstein-Barr virus (EBV) activation (Murakami *et al*., 1998). Another study involving 11 plants used in Bangladeshi folk medicine, *Moringa oleifera* was considered as potential source of anti- cancer compounds. The plant extracts were analyzed for cytotoxicity through brine shrimp lethality assay, sea urchin eggs assay, hemolysis assay and MTT assay using tumor cell lines. This also indicated the potential cytotoxic effects of *Moringa oleifera* leaf extract on human multiple myeloma cell lines. Beside leaves, *Moringa oleifera* seed extracts also have anticancer activity through its effects on hepatic carcinogen metabolizing enzymes, and antioxidant property (Bharali *et al*., 2003; Parvatham and Umamaheshwari, 2012).

Antifertility activity of *M. oleifera*

Moringa oleifera plant also has pertinent antifertility activity. The aqueous extract obtained from root and bark of *Moringa oleifera* showed post-coital antifertility effect in rat and also induced foetal resorption at late pregnancy (Prakash *et al*., 1987). Moreover, aqueous extract of *Moringa oleifera* roots was also evaluated for estrogenic, anti-estrogenic, progestational and antiprogestational activities. During another study analyzing anti reproductive potential of folk medicine plants, *Moringa oleifera* leaf extracts were found to be 100% abortive with doses equivalent to 175 mg/kg of starting dry material (Nath *et al*., 1992).

Antithyroid activity of *M. oleifera*

Tahiliani and Kar (2000) studied the role of *M. oleifera* leaf extract in the regulation of thyroid hormone status in adult Swiss rats and found that it plays an inhibitory role in the peripheral conversion of tetraiodothyronine (T4) to triiodothyronine (T3). Lower concentrations of this extract can be used to check hyperthyroidism (Tahiliani and Kar, 2000).

Antioxidant activity of *M. oleifera*

Moringa oleifera is a rich source of antioxidant (Chumark *et al*., 2008). It has been reported that aqueous extracts of leaf, fruit and seed of *Moringa oleifera* act as an antioxidant (Singh *et al*., 2009). During a study reporting antioxidant property of freeze dried *Moringa* leaves from different extraction procedures, it was found that methanol and ethanol extracts of Indian origin *Moringa oleifera* have the highest antioxidant activity with 65.1 and 66.8%, respectively (Siddhuraju and Becker, 2003). It was also reported that the major bioactive compounds of phenolics, such as quercetin and kaempferol are responsible for antioxidant activity (Bajpai *et al*., 2005). During another study, quercetin and kaempferol have shown good antioxidant activity on hepatocyte growth factor (HGF) induced Met phosphorylation with IC50 value for 12 and ~6 μM/L, respectively (Labbe *et al*., 2009).

Haematological activity of *M. oleifera*

Auwal *et al.* 2013) shown in his finding that There was significant ($P<0.05$) increase in Packed cell volume (PCV), red blood cell count (RBC), white blood cell count (WBC), neutrophils, eosinophils, basophils and monocyte count, except lymphocytes throughout 21 days of administration of 100 - 400mg/kg of *Moringa olefera* extract when compared to the rats in control groups, this effect could be due to the presence of high amount of flavonoids in the seeds of *Moringa oleifera* though, Ajibade *et al.* (2012) reported significant decrease in white blood cells count, neutrophils and monocytes count and insignificant changes in PCV, Hb, MCV, MCH and MCHC on using 800 and 1600 mg/kg methanol seed extract administered for 21 days.

Auwal *et al.* (2013) concluded that flavonoids in the seeds of *M. oleifera* may be the reason for the leucocytosis observed, since flavonoids has been reported to increase intracellular vitamin C synthesis, leucocytosis, decrease capillary permeability, fragility and have antioxidants property (Lee *et al*., 2003). The seed extract of *Moringa oleifera* increases significantly red blood cells, packed cell volume and white blood cells count based on the result of the differential leucocytic count obtained, though the

seed had no effect on lymphocyte production (Auwal *et al,* 2013).

Wound Healing Activities of *M. oleifera*

The aqueous extract of *M. oleifera* leaves and ethyl acetate extract of dried leaves was found to possess significant wound healing potential. Also about 10 % of *M. oleifera* extract applied on excision, incision and dead space (granuloma) wound models in rats showed a possesses would healing properties (Hukkeri *et al.*, 2006; Rathi *et al.*, 2006). The crude extracts of *M. oleifera* seeds have also been reported to have antiseptic and coagulative properties (Nwaiwu *et al.,* 2012).

***Moringa oleifera* in the management of ocular diseases**

Vitamin A deficiency is a major cause of blindness, which ranges from impaired dark adaptation to night blindness. Consumption of *Moringa oleifera* leaves, pods and leaf powder which contain high proportion of vitamin A has been proposed to help to prevent night blindness and eye problems in children. Ingesting drumstick leaves with oils can improve vitamin A nutrition and can delay the development of cataract (Pullakhandam and Failla, 2007). The use of *Moringa oleifera* as a supplementary food was highly accepted for integrated child development scheme supplementary food (ICDS-SFP) for its potential as vitamin A source (Nambiar *et al*., 2003).

***Moringa oleifera* for Water Treatment**

The frequency of life threatening infections caused by consumption of untreated water has increased worldwide and is becoming an important cause of mortality in developing countries (Al-Bari *et al*., 2006). Microorganisms contaminating water can cause gastroenteritis or inflammation of the stomach and intestinal lining. These include typhoid caused by *Salmonella typhii*, gastroenteritis caused by *Escherichia coli* and cholera caused by *Vibrio cholerae*. Conventional water disinfectants like chlorine have been used, but due to high cost and unavailability, households in developing countries such as Kenya use unpurified water leading to increased cases of water borne diseases (Ouma *et al.*, 2005).

The need for alternative safe and inexpensive water clarifiers cannot be gainsaid. *Moringa* species preparations can be used as a cheaper alternative to the conventional disinfectants (Gassenschmidt *et al*., 1995; Oluduro and Aderiye (2007). The reason for the usability of the *Moringa oleifera* seeds for water purification purposes is that they "contain a cationic polyelectrolyte that has proved efficient in water treatment, as a substitute to aluminium sulphate and other flocculent. There is a dual advantage to this property as it can be used as a locally-produced substitute for imported flocculent, thus reducing expenditure of foreign currency reserves by third world countries and *Moringa* flocculent, unlike aluminium sulphate, is completely biodegradable. This aspect may be particularly interesting to developed countries (Sixl-Daniell *et al*., 2011).

Moringa in Food Preservation

In recent years; consumers are demanding partial or complete substitution of chemically synthesised preservatives due to their possible adverse health effects. This fact has led to an increasing interest in developing more natural alternatives in order to enhance shelf-life and safety of the food (Irokanulo *et al.*, 2015). Though not so extensive work in this field in regard to the plant under review, a recent study indicated that *M. oleifera* seeds exhibited the potential as sanitizers/preservatives by inhibiting the growth of organisms such as *E. coli, S. aureus, P. aeruginosa, S. typhi, S. typhimurium* and *E. aerogenes* which range from pathogenic to toxigenic organisms liable to cause food-borne illnesses to spoilage-causing organisms liable to spoil food products.

***Moringa oleifera* leaves and production performance**

Moringa oleifera aqueous leaf extract given at concentrations 30 ml, 60 ml and 90 ml via drinking water has been shown to significantly improve the actual live weight, feed conversion ratio and return of investment of Cobb broilers (Portugaliza and Fernandez, 2012). Inclusion of *M. oleifera* meal as protein supplement in broiler diets at 25% inclusion level produces broilers of similar weight and growth rate compared to those fed under conventional commercial feeds. Furthermore, the inhibition of lipid peroxidation in chicken liver homogenates has been reported by the whole plant extract of *M. oleifera,* indicating their antioxidant effect in preserving chicken meat.

According to Oluduro and Aderiye *et al.* (2009), *M. oleifera* seed-treated well water administered at concentrations ≥ 2 mg/ml to the rats lowered the activities of the enzymes aspartate aminotransferase AST, alanine transferase ALT, alkaline phosphatase ALP and acid phosphatase ACP in only the liver tissues but, considerably increased the activities of these enzymes in the serum. They concluded that the potentials of prolonged consumption of water treated with ≥ 2 mg /ml of *M. oleifera* seed to constitute liver infarction.

The use of *M. oleifera* in bio-synthesis of nanoparticles

In addition to above searches, the possibility of using *Moringa* in nanotechnology is being explored for useful products. Nanoparticles are defined as particulate dispersions or solid particles with a size in the range of 10- 1000nm. Metal nanoparticles which have a high specific surface area and a high fraction of surface atoms have been studied extensively because of their unique physicochemical characteristics including catalytic activity, optical properties, electronic properties, antibacterial properties and magnetic properties (Howey *et al.*, 1994).

The ideal nanoparticle materials are those which do not undergo chemical changes, satisfy the conditions of biodegradability, biocompatibility and delivery speed of the drug (Langer, 2006; Balantrapuy and Goia, 2009). Generally metal nanoparticles are synthesized and stabilized by using chemical methods such as chemical reduction (Kuber and Souza, 2006; Tripathi *et al.*, 2010) which are too costly and hazardous.

It can be easily scaled up for large scale synthesis and there is no need to use high pressure, energy, temperature and toxic chemicals. In this regard, investigations in the biofabrication of Ag nanoparticles using *M. oleifera* leaves extract revealed the leaves to have the potential of producing Ag nanoparticles extracellularly by rapid reduction of silver ions (Ag^+ to Ag^0) which were quite stable in solution (Khanuja *et al.,* 2005; Lengke *et al.,* 2006; Prasad and Elumalai., 2011). In subsequent testing for antimicrobial activity against a number of pathogens, this Ag nanoparticles suspended hydrosol showed considerable antimicrobial activity in comparison to chloramphenicol and ketoconazole antibiotics.

Bio-Enhancing Properties of *M. oleifera*

Some parts of this genus have also been associated with bio-enhancing properties. Bio-enhancers are molecules which do not possess drug activity of their own but promote and augment the biological activity or bioavailability or the uptake of drugs in combination therapy, resulting in reduced drug associated toxicity, reduced cost and duration of chemotherapy. Isolated plant biomolecules or their semisynthetic derivatives have provided useful clues in the production of medicines (Pal *et al.,*

2010). Recently, in a pre-clinical study on the influence of *Moringa oleifera* pods on Pharmacokinetic disposition of rifampicin using HPLC- PDA method established that the active fraction isolated from air dried pods of the plant when mixed with rifampicin and administered to the experimental animals enhanced systemic availability of the drug and suppression of the drug metabolizing cytochrome P-450.

In another study, a bioenhancing property of *M. oleifera* pods extract was reported. It was found that niaziridin rich fraction of *M.oleifera* pods enhances the bioactivity of commonly used antibiotics such as rifampicin, tetracycline and ampicillin against Gram positive and Gram negative bacteria. It also facilitated the absorption of drugs, vitamins and nutrients through the gastrointestinal membrane thus increasing their bio-availability (Pal *et al.*, 2010).

Application in *M. oleifera* in pest control

The practice of using plant derivatives or botanical insecticides in agriculture dates back to at least two millennia in ancient China, Egypt, Greece, and India (Thacker *et al.*, 2002). What is clear from recent history is that synthetic insecticides effectively relegated botanicals from an important role in agriculture to an essentially trivial position in the marketplace among crop protectants. However, history also shows that overzealous use of synthetic insecticides led to numerous problems unforeseen at the time of their introduction: acute and chronic poisoning of applicators, farm workers, and even consumers; destruction of fish, birds, and other wildlife; disruption of natural biological control and pollination; extensive groundwater contamination, potentially threatening human and environmental health; and the evolution of resistance to pesticides in pest populations (National Research Council, 2000)
Moringa oleifera for agricultural and industrial use have shown that the leaves of this plant contains a bioactive substance which when sprayed on crops indicates accelerated growth of young plants, which become more resistant to pests and diseases (Ernst, 1998)

Toxicological activities of *M. oleifera*

In vitro data showed a significant inhibitory effect which might lead to a potential risk of interaction, on concomitant administration of *M. oleifera* leaf extract with antiretroviral drugs to HIV/AIDS patients (Monera *et al*, 2008). A 4-(alpha-L-rhamnosyloxy) phenylacetonitrile, and 4-hydroxyphenyl acetamide exhibited mutagenic activities, when subjected to micronucleus test (Villasenor *et al*, 1989). The root bark extracts causes severe skin inflammations and skin dermatitis and may cause violent uterine contractions that can be fatal (Katewa *et al.*, 2008).
The interior flesh of the plant can also be dangerous if consumed too frequently or in large amounts. Even though the toxic root bark is removed, the flesh has been found to contain the alkaloid spirochin, which can cause nerve paralysis (Berger *et al.*, 1984). Prolonged consumption of *M. oleifera* seed has also reported to constitute liver infarction (Oluduro and Aderiye (2009).
Moringa oleifera is in no doubt a 'wonder plant' that can be used to cure different animal and human ailments. It is a biosynthetic laboratory for the production of pharmacologically relevant compounds. It has enormous potential for development of new drugs and secondary metabolites. It helps animals/man to develop defense against pathogens reduces the effect of chemical toxicity among others.

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