

Bioactivity of *Moringa oleifera* and its Applications: A Review

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In this paper, antimicrobial and antioxidant properties of *Moringa oleifera* plant are reviewed along with their potential application in food and medical industry. This tree is a source of healthy compounds contributing to human's health and acts as a good source of natural antioxidants. It also inhibits bacterial growth assisting longer shelf life of food in preservation. The parts of the plant that had been reviewed are *M. oleifera* roots, leaves, barks and seeds. Each specific part was studied using different types of extraction methods for their microbial inhibition of Gram positive and Gram negative bacteria. Aqueous extract, alcohol extract and crude extracts (petroleum ether extract, chloroform extract, ethyl acetate extract and carbon tetrachloride extract) has been used for *M. oleifera* roots, barks and seeds. While *M. oleifera* had been extracted as powder, fresh leaf juice and water extract. *M. oleifera* is one of the best examples of plants which represent an emerging and interesting direction in food safety and production in the food industry. As consumers nowadays prefer essential products, use of these plant sources is now a new trend.

Keywords: *Moringa oleifera*, antimicrobial agents, antibiotics, antioxidants.

Nowadays, food production industries are more concerned in providing natural and healthy products which are also safe to consume for the public. With new researches emerging, it has been discovered the benefits of using natural antimicrobial agents in contributing to higher levels of food safety and avoidance of microbial proliferation. In research, one of the important approaches is the development of new antimicrobials. People try to minimize the use of commercial antibiotics applied in the treatment of foodborne illnesses. This is highly possible thru discovery of multiple drug/chemical resistance in both human and plant pathogenic microorganisms⁸. People in the Philippines living in remote areas

prefer using medicinal plants to treat various types of diseases. The use of plants provides an interesting and largely unexplained source for the development of potential chemotherapeutic drugs that can help overcome the problems of microbial resistance and toxicity as consumer misuse drugs. The use of antimicrobials of plant origin is gaining popularity among users as more and more continue to derive the benefits of using these plants against a number of infectious diseases.

Moringa oleifera, also known as drumstick tree, is one of the commonly found tree and vegetable in the Philippines, primarily serves as part of the meal on the table. With preliminary evidences, it was suggested that this tree, specifically its leaves has also an antioxidant and anti-inflammatory potency¹⁶. This type of plant contains alkaloids which commonly found to have antimicrobial properties due to their ability to intercalate with DNA of the microorganisms²⁵.

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According to ethanobotanical studies, its roots are bitter, acrid, thermogenic, digestive, carminative, anthelmintic, constipating, anti-inflammatory, diuretic, ophthalmic, expectorant and stimulant. They are useful in dyspepsia, anorexia, diarrhea, colic, flatulence, paralysis, inflammations, amenorrhea, dysmenorrheal fever, strangury, vesicle and renal calculi. It is used in cough, asthma, bronchitis, pectoral diseases, splenomegaly, epilepsy and cardiopathy. Leaves are anti-inflammatory, anodyne, anthelmintic, ophthalmic and rich in Vitamin A and C. They are useful in scurry, wounds, tumors, inflammation and helminthiasis. Seeds are acrid, bitter, anodyne, anti-inflammatory, purgative, antipyretic and ophthalmic. They are useful in neuralgia, inflammations, intermittent fevers and ophthalmopathy. Bark is regarded as an anti-scorbic, and it exudes a reddish gum sometimes used for diarrhea²⁸.

The specific components of *Moringa* preparations that have been reported to have hypotensive, anticancer, and antibacterial activity include 4-(4'-O-acetyl- β -L-rhamnopyranosyloxy) benzyl isothiocyanate, 4-(α -L-rhamnopyranosyloxy) benzyl isothiocyanate, niazimicin, pterygospermin, benzyl isothiocyanate, and 4-(α -L-rhamnopyranosyloxy) benzyl glucosinolate. It is also rich in a number of vitamins and minerals as well as other more commonly recognized phytochemicals such as the carotenoids³⁸.

Thus, this review paper will provide necessary baseline data for researchers to find out the bio-activity of *M. oleifera* focusing in its antimicrobial and antioxidant properties and various applications of this versatile and functional food in medicine and food processing industry.

Bioactivity of *Moringa oleifera*

M. oleifera Lam (syn. *M. Pterygosperma Gaertn.*) is one of the best known and most widely distributed and naturalized specie of a monogeneric family *Moringaceae*³³. Among 14 species of *Moringa* tree, *M. oleifera* is the best being studied due to its potential medicinal uses and identification of potential therapeutic importance. It is found wild and cultivated throughout the plains, especially in the hedges and in house yards and thrives best under the tropical insular climate and is plentiful near sandy beds of rivers and streams⁴³.

M. oleifera is an important food commodity which has had enormous attention as the 'natural nutrition of the tropics'. The leaves, fruit, flowers and immature pods of this tree are used as a highly nutritive vegetable in many countries, particularly in India, Pakistan, Philippines, Hawaii and many parts of Africa⁴. *M. oleifera* leaves have been reported to be a rich source of α -carotene, protein, vitamin C, calcium and potassium and act as a good source of natural antioxidants; and thus enhance the shelf-life of fat containing foods due to the presence of various types of antioxidant compounds such as ascorbic acid, flavonoids, phenolics and carotenoids³⁹. In the Philippines, it is known as 'mother's best friend' because of its utilization to increase woman's milk production and is sometimes prescribed for anemic individuals³⁹.

M. oleifera has a number of uses such as for human consumption and is a plant rich in antioxidant compounds which are of great importance in preventings tress causing several degenerative diseases²¹. Food antioxidants are important human nutrition, decreasing oxidative damage to lipids, proteins and nucleic acids induced by free radicals. A research conducted by Amaglo, *et al.*,³ showed that tissues of *M. oleifera* had a relatively complex flavonoid profile consisting of glucosides, rutinoides, malonylglucosides and traces of acetylglucosides of kaempferol, quercetin and isorhamnetin. As this multi-purpose plant contains essential amino acids, carotenoid in leaves and components with nutraceutical properties, it can be used as a nutritional supplement or constituent in food preparation. Usually, antioxidant properties of plant extracts have been attributed to the presence of polyphenolic compounds, which have great potential as antimicrobial agents⁴⁵.

A number of medicinal properties have been referred to various properties of this esteemed tree. The leaves, roots, barks, seeds and seed oils have been used for various ailments in South Asia, including the treatment of inflammation and infectious diseases along with cardiovascular, gastrointestinal and hematological diseases. With their phytochemical and antimicrobial properties, this multipurpose tree is able to support various applications in the industry. Other purposes include water coagulant using *M. oleifera* seeds

which assists in water clarification inhibiting microorganisms, such as bacterial pathogens.

***Moringa oleifera* Roots**

M. oleifera roots have antibacterial activity³⁴ and are reported to be rich in antimicrobial agents. These are reported to contain an active antibiotic principle which has a powerful antibacterial and anti-fungicidal effects³⁶. The root extract also possesses antimicrobial activity attributed to the presence of 4- α -L-rhamnosyloxy benzyl isothiocyanate¹³. The aglycone of deoxyniazimicine isolated from the chloroform fraction of an ethanol extract of the root bark was found to be responsible for the antibacterial and antifungal activities³⁰.

A study from FAO (2012), tested the antibacterial potential of *M. oleifera* root extracts in gram-positive (*Staphylococcus aureus* and *Bacillus subtilis*) and gram-negative (*Escherichia coli* and *Salmonella typhi*) bacteria using various extractions of the root. The aqueous (distilled water) and alcohol (95% ethyl alcohol) root extracts of *M. oleifera* exhibited antibacterial activity against *S. aureus* and *S. typhi*. On the other hand, only the alcohol extract showed antibacterial activity against *B. subtilis*. Moreover, some studies showed that the antibacterial activity of alcohol root extract was significantly higher than that of aqueous in *S. aureus* and *B. subtilis*. However, both extracts did not show any antibacterial activity against *E. coli*⁷.

Torres *et al.*,⁴⁵ conducted an experiment and have shown the phytochemical constituents present in aqueous and ethanolic root extracts of *M. oleifera* detected by basic colored-reactions. Root extracts have the presence KMNO₄-reacting polyphenolic compound. No presence of saponins and tannins were detected in the same plant part used. They have shown very low amounts or total absence in such organs.

***Moringa oleifera* Seeds**

M. oleifera seeds also possess antimicrobial properties with a recombinant protein which is able to flocculate Gram-positive and Gram-negative bacterial cells⁵. Microorganisms can be removed by settling in the same manner as the removal of colloids in properly coagulated and flocculated water²⁰. The seeds may also act directly upon microorganisms and result in growth inhibition. Antimicrobial peptides are thought to

act by disrupting the cell membrane or by inhibiting essential enzymes. The replication of bacteriophages can also be inhibited by *Moringa* seeds⁴². The antimicrobial effects of the seeds are attributed to the compound benzyl isothiocyanate.

Like the roots, researchers extracted *Moringa oleifera* seed into various methods. *Moringa oleifera* seed ethanol (MSE) extract was active against three bacterial isolates with *S. aureus* (10mm) and *E. coli* (07mm) being sensitive to the lowest concentration of 50mg/ml. *S. typhi* (10mm) was only sensitive to the extract at 200mg/ml concentration. *Enterobacter spp*, *Shigella spp*, *P. aeruginosa* and *S. typhi* were not sensitive to any of the concentrations tested. *Moringa oleifera* seed chloroform (MSC) extract was active against two bacterial isolates with *E. coli* (09mm) and *S. typhimurium* (09mm) only sensitive to concentration of 100mg/ml. *Enterobacter spp*, *S. aureus*, *Shigella spp*, *P. aeruginosa*, and *S. typhi* were not sensitive to any of concentrations tested. This showed that MSC was the least extract with activity on the tested organisms. Its low antibacterial activity might be linked to its phytochemical contents as the result of phytochemical screening indicated that it possesses only saponins as stated by Singh and Brad³³. On the other hand, a study conducted by³⁷ showed that the ethanolic and saline extracts of *M. oleifera* seeds viewed the presence of their compounds such as phenols, flavonones, flavonoids, xanthonones and pentacyclic triterpenes.

The antibacterial and antioxidant activities of *M. oleifera* seed has been highlighted by many authors. The antimicrobial activity of *M. oleifera* seed is due to the presence of an array of phytochemicals, but most importantly due to the activity of a short polypeptide named 4 (α - L - rhamnosyloxy) benzyl-isothiocyanate. The peptide may act directly on microorganisms and result in growth inhibition by disrupting cell membrane synthesis or synthesis of essential enzymes⁶.

***Moringa oleifera* Bark**

The stem bark has been reported to contain two alkaloids, namely, moringine and moringinine, vanillin, β -sitosterol, β -sitostenone, 4-hydroxymellin, and octacosanoic acid and phenolics. It has also shown high contents of KMNO₄-reacting polyphenolic compound and presence of saponins and tannins similar with the

root parts⁴⁵. Several procyanidin and 4-(-l-rhamnopyranosyloxy)-benzylglucosinolate also reported from the same. Its bark possesses antibacterial activities against varieties of both gram-positive and gram-negative bacteria, antifungal and antioxidant. The bark was found to be safe in animal toxicity study⁴⁰.

A study from Bangladesh, used different types of crude extracts (petroleum ether extract, chloroform extract, ethyl acetate extract and carbon tetrachloride extract) obtained from *M. oleifera* were screened for their antibacterial activity against human pathogenic bacteria. Among the four extracts, only chloroform and ethyl acetate extracts exhibited good antibacterial activity against all the bacterial strains tested. But the petroleum ether and carbon tetrachloride extracts did not show any activity against the bacterial strains. The chloroform extract exhibited zones of inhibition from 10 to 17 mm in diameter. In case of ethyl acetate extract, the zones of inhibition varied from 08 to 21 mm in diameter. The ethyl acetate extract exhibited the largest zone of inhibition against *S. sonnei*³².

Another study indicated that *E. coli* was found to be equally sensitive to ethyl acetate, acetone and chloroform extracts and had the

maximum antibacterial activity among the extracts. *S. aureus* was sensitive to all the extracts studied. The ethyl acetate had maximum antibacterial activity against *S. aureus* in comparison to the other extracts. The study revealed that *S. gallinarum* was also sensitive to all the extracts showing maximum antibacterial activity with ethyl acetate extracts and moderate and equal sensitivity to methanol and chloroform extracts. The ethyl acetate, acetone and methanol extracts showed maximum and equal antibacterial activity against *P. aeruginosa*. The disc diffusion study revealed that both the Gram positive and Gram negative organisms showed variable sensitivity to different extracts of *M. oleifera*. In general, ethyl acetate and acetone extracts showed maximum antibacterial activity against *E. coli*, *S. aureus*, *S. gallinarum* and *P. aeruginosa*. The antibacterial potential of different extracts of *M. oleifera* specially of those of ethyl acetate and acetone extracts, demand further *in vitro* and *in vivo* studies to exploit their antibacterial action in the treatment of bacterial diseases of man and animals²⁶.

***Moringa oleifera* Leaves**

Most Asian countries have believed that *M. oleifera* leaves are useful in improving human

Table 1. The antimicrobial inhibition of each *M. oleifera* part

Plant Part	Bacterial Inhibition	References
Roots	<i>S. aureus</i> , <i>B. subtilis</i> , <i>E. coli</i> , <i>Salmonella typhi</i>	[7]
Leaves	<i>E. coli</i> , <i>S. shinga</i> , <i>P. aeruginosa</i> , <i>S. sonnei</i> , <i>Pseudomonas spp.</i> , <i>S. aureus</i> , <i>B. cereus</i> , <i>S.-B-hemolytica</i> , <i>B. subtilis</i> , <i>S. lutea</i> , <i>B. megaterium</i>	[29], [31]
Bark	<i>S. sonnei</i> , <i>S. aureus</i> , <i>E. coli</i> , <i>S. gallinarum</i> , <i>P. aeruginosa</i>	[26], [31]
Seeds	<i>S. aureus</i> , <i>S. typhi</i> , <i>E. coli</i> , <i>S. typhimurium</i>	[5], [40]

Table 2. The compounds present in each *M. oleifera* part

Plant Part	Presence of Compounds	References
Roots	KMNO – reacting polyphenolic compounds	[45]
Leaves	FeCl ₃ -reacting-polyphenolic compounds, KMNO – reacting polyphenolic compounds, flavonoids, alkaloids, ascorbic acid, avo-noids, phenolics and carotenoids	[22], [45]
Bark	KMNO ₄ – reacting polyphenolic compounds, alkaloids, namely, moringine and moringinine, vanillin, â-sitosterol, â-sitostenone, 4-hydroxymellin, and octacosanoic acid and phenolics, procyanidin and 4-(-l-rhamnopyranosyloxy)-benzylglucosinolate	[40], [45]
Seeds	Saponins, phenols, flavonones, flavonoids, xanthenes, pentacyclic tritterpenes	[33], [37]

vision and prevention of any eye diseases²⁴ and due to high content of B-carotene, it helps to prevent development of Vitamin A deficiency¹⁹. These leaves can also be a good substitute to dietary protein in Nile Tilapia without any significant reduction in growth³⁵. Leaves of *M. oleifera* have demonstrated the highest antioxidant properties due to the high levels of polyphenolic and flavonoid compounds. Leaf extracts showed a more diverse phytochemical composition with the presence of alkaloids, FeCl₃-reacting polyphenolic compounds and flavonoids⁴⁵. Also, the presence of KMNO₄-reacting polyphenolic compounds was registered. In addition to this, leaves have shown a high antioxidant capacity and are rich in total polyphenol content, quercetin, kaempferol and β -carotene. Phenolics and polyphenolic compounds constitute the main class of natural antioxidants and are believed to be responsible for the antioxidant activity of plant materials²².

In a study conducted by Rahman, *et al.*, the use of leaf juice and extracts of *M. oleifera* provided antibacterial activity against various pathogenic bacteria. Results have shown that powder from fresh leaf juice has greater antibacterial activity than fresh leaf juice, ethanol and water extracts while fresh leaf juice and ethanol extract of fresh leaves showed higher antibacterial potential than the corresponding water extracts³¹. Highest zones of inhibition were found in powder from fresh leaf juice against all the bacteria tested which were more than one and a half to twice as much effective as known antibiotic tetracycline while fresh leaf juice showed relatively higher inhibitory potency on all tested bacteria. In their study, it was observed that powder from fresh leaf juice, ethanol and cold water extracts of fresh leaves were most active against all the Gram-negative bacteria tested along with employed Gram-positive bacteria. This has displayed a relatively better antibacterial effect against *S. shinga*, *P. aeruginosa*, *S. sonnei*, *Pseudomonas spp.* and *S. aureus*, *B. cereus*, *S.-B-hemolytica*, *B. subtilis*, *S. lutea*, *B. megaterium*³¹. It was also suggested that *M. oleifera* leaves used contain bio-components whose antibacterial potentials are highly comparable with that of the antibiotic tetracycline against all Gram-negative and Gram-positive bacteria tested. According to Vaghasiya *et al.*, the activity of plants against Gram-negative and Gram-

positive bacteria may be indicative of the presence of broad-spectrum antibiotic compounds in the plant. *Moringa* leaves have been reported to be a good source of natural antioxidants such as ascorbic acid, avo-noids, phenolics and carotenoids^{10,46}.

On the other hand, Moyo *et al.* noted that difference in bacterial response was due to the nature of the bacterial species such as the acetone extract of *M. oleifera* leaves exhibiting antimicrobial effect against both Gram-positive and Gram-negative bacteria²⁹. Compounds like tannins and polyphenol which are found in *M. oleifera* are soluble in acetone and have been reported to possess antibacterial activity²³. With this, the acetone extracts had bactericidal properties against *E.coli* which was tested in high concentrations. Gram-negative bacteria have been known to be generally less sensitive to the activity of plant extracts due to permeability barrier provided by the cell wall or to the membrane accumulation mechanism².

Compounds like pterygospermin, benzyl glucosinolate and benzyl isothiocyanate have been isolated from *M. oleifera* leaves are reported to have antimicrobial properties against a wide range of bacteria which could partly explain the observed bacteriostatic and bactericidal activity¹⁷. These leaves also contain phytochemicals such as flavonoids, saponins, tannins and other phenolic compounds that have antimicrobial activities. Their mechanisms have been proved via cell membranes perturbations coupled with the action of β -lactams on the transpeptidation of the cell wall could lead to an enhanced antimicrobial effect of the combinations¹⁵. The proteins/ peptides are believed to be involved in a defense mechanism against phytopathogenic fungi 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 walls.

Applications of *Moringa oleifera*

Based on the review studied, it was shown that each part of the *Moringa oleifera* tree is beneficial to mankind most especially in food and medical industry. The leaf extracts of *M. oleifera* showed varying antimicrobial activity on wide range of microorganisms. The extract was more effective than traditional antibiotics to combat the

pathogenic microorganisms studied. The chance to find antimicrobial activity made the plant to be a source of new antibiotic compound. Further work is needed to isolate the secondary metabolites and study of metabolic interchanges in bacterial metabolic pathways when applying this extract. This demonstrated that folk medicine can be as effective as modern medicine to combat pathogenic microorganisms. The use of these plants in folk medicine suggests that they represent an economic and safe alternative to treat infectious diseases⁹.

Despite this array of uses to which parts of *Moringa* tree are put to, other available uses of *M. oleifera* plant parts are sanitizers or preservatives in foods. However, a very important step in the screening of a plant material for sanitizing/preservative activity is to evaluate its antimicrobial activity against food – borne microorganisms⁶. The determination of a plant's antimicrobial profile against food – borne microorganisms may promote the plant to further tests geared towards its evaluation as a sanitizer or preservative in foods.

The antimicrobial activity of the extracts tested, which revealed bioactivity on organisms is encouraging as these organisms range from pathogenic and toxigenic organisms liable to cause food – borne illnesses to spoilage-causing organisms liable to spoil food products. The control of these organisms by the extracts in foods would reveal the potentials of these extracts as preservatives. The findings add impetus to the clarion call by consumers and authorities in food industries for the replacement of chemically synthesized sanitizers/preservatives with “naturally derived” ones¹⁴.

Suarez, M., *et al.* found that *M. oleifera* seeds contain polypeptides which act as a water clarification agent that coagulates particles and bacteria in suspension⁴¹. The study showed that it also possesses an antibiotic activity that leads to growth inhibition and killing of bacteria, including antibiotic resistant human pathogens, and it might represent environment-friendly substitute to commonly used disinfecting agents. This was corroborated by later findings of Bukar, *et al.* and Thilza, *et al.*^{6,44}. Aside from water clarification agent, *M. oleifera* seeds extract oils which are being an interest nowadays in the industry. This represents an alternative source of superior oil with high

stability and good characteristics toward prevention of cholesterol and heart disease. This seed oil is a peanut-like flavor with similar compositions resembling an olive oil used in culinary purposes. Due to its high iodine value and low melting point, it displays a limiting application in food products like margarine and shortenings. Thus, modification thru combining with other oils can improve its characteristic and improve its functionality. According Dollah *et al.*, physicochemical properties of other oil blends can be used to develop new food formulations for *M. oleifera* seed oil¹¹. It has been blended with Virgin Coconut Oil, Palm Oil, Palm Kernel Oil and Palm Stearin. These are examples of having fully natural component used for making edible products with modified physical and chemical properties. This study appeared that proper blending of high melting point oils meeting nutritional needs and as an alternative for hydrogenated foods.

The use of antimicrobial plant such as *M. oleifera* can be used as in-feed additives. They can replace antibiotics and provide perceived natural protection for food animal production. This could avoid development of resistance in addition to promoting growth and health²⁷.

CONCLUSION

M. oleifera, a phyto-antimicrobial agent possesses active compounds which delays microbial growth of pathogens and spoilage organisms. These plant antimicrobials satisfy the needs of today's consumers looking for safe and healthy products without chemical preservatives. *Moringa oleifera* is considered one of the most useful antimicrobial plants that can be easily found in Asia. Thru researches, it was found out that its various plant parts are specific to microbial inhibitions of Gram-positive and Gram-negative bacteria. The use of this plant can be applied in various manners in food industry as additives, medicine as replacement for synthetic antibiotics and as water clarification agent for environmental concerns.

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