Journal of Rural Advancement
[ISSN 2347-2561 (P); 2583-6102 (E)]
Vol. 12, Issue 01, April 2024

Antibiotic and antifungal characteristics of moringa (*Moringa oleifera*)

Tushar Sharma

Department of Biotechnology & Bioinformatics, North-Eastern Hill University, Shillong-793022 (Meghalaya), India

Corresponding author: tusharkisho@gmail.com

Received on: November 15, 2023 Accepted on: December 23 2023

Abstract

To summarize the antibacterial, antifungal, and wound-healing properties of moringa (Moringa oleifera), a review of the literature has been conducted. It has been shown that Moringa oleifera *is a rich source of antioxidants, phenolic compounds, and a variety of other biochemicals e.g. tannins, saponins, flavonoids, and steroids. In the plant, these organic substances have potent antimicrobial, antibacterial, and antifungal properties. The features of* Moringa oleifera*, present in its leaves, flowers, pod, bark, and roots, developed wound-healing properties in a variety of forms, including fresh, powdered, and extracts.*

Keywords: antibacterial, antifungal, antimicrobial, moringa, wound healing.

Introduction

Many of the antibacterials that are currently in use have side effects that include toxicity, hypersensitivity, immunosuppression, and tissue residues that could be dangerous for the public's health. Furthermore, poor farmers cannot afford the more expensive, newer broad-spectrum antibiotics. Due to these drawbacks, the therapeutic efficacy of the antibacterials that are now on the market is compromised, making the search for substitute treatments for bacterial illnesses necessary. The development of contemporary medications from traditional medicinal plants should be prioritized for the treatment of a variety of human and animal diseases, as the global landscape is currently shifting toward the use of non-toxic and environmentally friendly products.

A significant component of traditional medical systems that have endured in developing nations are medicinal plants.

Over 500,000 natural products are produced by the plant kingdom, with between 40 and 80 thousand produced by each species of plant (Bhatt, 1995). There has been a lot of attention lately to the application of plant-based traditional medicine (Han et al., 2002). Regarding resources derived from plants, both national and indigenous rights exist. There has been a rise in fundamental scientific research on medicinal plants and traditional medical practices. According to estimates, just 1–10% of the vast diversity of 250,000–500,000 plant species on Earth have had their medicinal qualities investigated pharmacologically and chemically (Farnsworth, 1991; Verpoorte, 2000). It has been suggested recently that *Moringa oleifera* has a new benefit: the leaves appear to contain something that promotes plant development and raises crop yields.

One such plant with numerous purported therapeutic benefits is *Moringa oleifera*. According to Sharma et al. (2022a), different Indian moringa (*Moringa oleifera*) components have phenolic, antioxidant, and free radical-scavenging qualities. Seasonal variations in *Moringa oleifera* 's antioxidant properties result in higher levels during the winter and lower levels during the summer (Sharma et al 2022b). Indigenous medical systems use various components of this plant, including the leaves, stem bark, root bark, flowers, fruits, and seeds, to cure a range of human diseases (Chopra et al., 1956; Nadkarni, 1976). Although *Moringa oleifera* root bark is said to have a variety of medicinal uses, little research has been done on its antibacterial activity in recent years despite the fact that the plant's leaves and seeds have been the subject of extensive scientific investigation. Consequently, it was thought worthwhile to look into *Moringa oleifera* root bark's antibacterial properties. In Eritrea, the feeding value of *Moringa oleifera* to rabbits has been evaluated (Kishore and Goitom, 2021a). Research has been done on the ethogram of rabbits given *Moringa oleifera* pod meal (Kishore and Goitom, 2022). Research has also examined the impact of temperature on the general and excretory behavior of White New Zealand rabbits raised on *Moringa oleifera* pod meal (Kishore and Goitom, 2021b). Bark has been utilized to treat scurvy, dental caries/toothache, external sores/ulcer, anti-tumor, snakebite, scorpion bite, headache, digestive issues, and antinutritional aspects (Fahey, 2005).

Antimicrobial characteristics of *Moringa oleifera*

The therapeutic efficacy of *Moringa oleifera* Lam is highly substantial. Many plant parts, including the leaves, roots, seeds, bark, fruit, flowers, and immature pods, have the ability to stimulate the heart and circulatory system, have antibacterial and antifungal properties, and are used in the traditional medical system to treat a variety of illnesses (Dhimmar et al., 2015). The chemical N-benzylethyl thioformate, an aglycone of deoxyniazimincin, is present in *Moringa oleifera* ethanolic root extract and is responsible for the plant's antibacterial activity against a wide range of bacteria and fungi (Upadhyay et al., 2015). Urinary tract infections caused by both Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus, Escherichia coli*, and *Staphylococcus saprophyticus*, may be inhibited by methanolic leaf extract from *Moringa oleifera* (Maurya and Singh, 2014). In vitro tests were conducted to examine the antibacterial properties of *Moringa oleifera* leaves, roots, bark, and seeds against human pathogenic bacteria, yeast, dermatophytes, and helminthes. It was shown using the disk-diffusion method that *Pseudomonas aeruginosa* and *Staphylococcus aureus* cannot grow when fresh leaf juice and seed aqueous extract are present, and that this activity is inhibited by extraction temperatures higher than 56°C (Caceres et al., 1991). *Moringa oleifera*'s antimicrobial components have been confirmed to have inhibitory efficacy against a variety of bacteria. *Scenedesmus obliquus* (green algae), *E. coli* ATCC 13706, *P. aeruginosa* ATCC10145, *S. aureus* NAMRU 3 25923, *Bacillus stearothermophilus* (bacterial strains), Herpes Simplex virus type 1 (HSV 1), and Polio virus type 1 (sabin vaccine) were used in another study involving aqueous methanolic extract and fixed oil against microorganisms. The antibacterial action of *Moringa oleifera* seeds is thought to be attributed to their active constituents, 4-(alpha-L-rhamanosyloxy) benzyl isothiocyanates (Padla et al., 2012). Alkaloids, flavonoids, and steroids found in *Moringa oleifera* fruit have an inhibitory effect on *Candida albicans* culture by either denaturing the protein or preventing spore germination due to the steroid ring they contain (Moodley et al., 2018). Studies have shown that the leaves and flowers of *Moringa oleifera* have antihelmintic activity, which means that they can help control parasitic worms (Bhattacharya et al., 1982). Furthermore, ethanolic extracts from *Moringa oleifera* leaves have been shown to suppress the Indian earthworm *Pheritima posthuma* (Rastogi et al., 2009).

Based on the analysis of the aforementioned studies, it can be concluded that different *Moringa oleifera* organs contained particular biochemicals e.g., tannins, saponins, flavonoids, steroids, and phenolic substances etc. that enabled the plant's antibacterial properties.

Antibacterial characteristics of *Moringa oleifera*

The antibacterial properties of *Moringa oleifera* seed extracts, both aqueous and ethanolic, were tested against Salmonella enteritidis, vibrio cholerea, *Staphylococcus aureus*, and *E. coli* (isolated from the organism and the aquatic environment) in volumes 50, 100, 150, and 200 µl. The concentrations of 1.5 and 1.10 units were used. Aqueous and ethanolic extracts of *Moringa oleifera* showed antibacterial efficacy (inhibition halo> 13mm) against *S. aureus, V. cholera, and E. coli* isolated from the white leg shrimp*, Litopenaeous vannmaei. E. Coli* that was obtained from *Oreochrom isniloticus* and tilapia fish showed sensitivity to *Moringa oleifera* 's ethanolic extract. According to Kone et al. (2004), bacteria are the microorganisms that cause opportunistic diseases in the highest-ranking order. Nowadays, bacterial infections are treated with a plethora of antibacterial medicines. However, many virulently pathogenic bacterial species developed drug resistance as a result of the widespread and careless use of antibacterial medicines (Berkowitz, 1995). Because of its many applications and well-known bactericidal potential, the *Moringa oleifera* plant has been the subject of extensive research (Suarez et al., 2003; Ghebremichael et al., 2005). Studies on the antibacterial properties of *Moringa oleifera* plants have been conducted for 40 years; however, since 2012, only nine years have been devoted to the goal of combating antibiotic resistance. Strong proof is the use of Multi-Drug Resistance (MDR) bacteria as test organisms. Both in vitro and in vivo antibacterial testing of *Moringa oleifera* plants against MDR bacteria has been done. Plants known as *Moringa oleifera* have the ability to resist harmful bacterial infections (Novitarini et al., 2022). According to

Mishra et al. (2011), the juice of *Moringa oleifera* leaves has the ability to combat harmful microorganisms that affect humans. The essential oil portion of the plant material contained in the distillate fraction may be the cause of the stem distillate of *Moringa oleifera* 's antibacterial properties (Ravindra et al., 2019). The distillate of *Moringa oleifera* showed a significant decrease in the growth of test microorganisms, indicating an antibacterial action. *E. coli* showed the highest level of inhibition among the studied microorganisms, followed by *S. aureus*, *K. pneumoniae*, *P. aeruginosa*, and *B. subtilis*. Potent suppressive effects of the seed kernel extract of *Moringa oleifera* were noted for Bacillus cereus, *Staphylococcus aureus*, *Aspergillus species*, and *Mucor species*. Nevertheless, its efficacy against *E. coli* and *P. aeruginosa* was reduced. This suggested that *Moringa oleifera* seed kernel extract could be used to treat infections caused by these species, with the exception of *E. coli* and *P. aeruginosa* (Dinesha et al., 2018). Only an apolar extract made from *Moringa oleifera* seeds exhibited antibacterial efficacy against Gram-positive bacteria, according to a recent study (Anzano et al. 2022). Using the disk-diffusion method, Caceres et al. (1992) investigated the antibacterial properties of *Moringa oleifera* leaves, roots, bark, and seeds against dermatophytes, helminths, bacteria, and yeast. *Pseudomonas aeruginosa* and *Staphylococcus aureus* are inhibited from growing by the fresh leaf juice and aqueous extracts from seeds. They deduced that no action was seen against *Candida albicans*, Gram-positive, Gram-negative, or other harmful microorganisms. Mehta et al. (2003) reported that the stem bark juice had antibacterial properties against *S. aureus*. Three fractions of *Moringa oleifera* leaf extract were tested for their antimicrobial activity against *E. Coli*, *Klebsiella aerogenes*, *K. pneumoniae*, *S. aureus*, and *Basillus subtilis* by Dahot (1998). It was found that all three fractions exhibited potent inhibitory activity against *E. Coli*, *S. aureus*, and *B. subtilis*. However, fraction 2 demonstrated a considerable zone of inhibition against *Aspergillus niger*, and a definite zone of inhibition was observed against *K. aerogenes*. Similar claims were made by Amer et al. (2008), Renitta et al. (2009), Peixoto et al. (2011), and Mbikay (2012) on the potential use of ethanol and aqueous *Moringa oleifera* leaf extract as a therapy for specific bacterial infections. Water treated with *Moringa oleifera* powder can eliminate up to 90–99% of the germs present because they are associated to solid particles (Schwarz, 2000; Oloduro and Aderiye, 2007; Amagloh and Benang, 2009; Bukar et al., 2010). Similar to this, Shekhar et al. (2000) investigated the antibacterial activity of crude ethanol extract of *Moringa oleifera* seed against *Salmonella typhii, E. coli, Vibrio cholera, Shigella dysentriae*, and *Pseudomonas aeruginosa* in drinking water. They concluded that the extracts had an effect on E. coli. The antibacterial activity of *Moringa oleifera* seed extract was also evaluated by Arama et al. (2011) against *E. coli* (ATCC 25922), *S. typhii*, and *V. cholerae*. The results showed that *V. cholerae* was the bacteria species most resistant to *Moringa oleifera* extract, compared to *E. coli* and *S. typhii*. Rahman et al. (2009) examined the antibacterial activity of leaf extracts from *Moringa oleifera* against six gram-positive bacteria (*Staphylococcus aureus*, *Bacillus cereus*, *Streptococcus-B-haemolytica*, *Bacillus subtilis*, *Sarcina lutea*, and *Bacillus megaterium*) and four gram-negative bacteria (*Shigella shinga*, *Pseudomonas* *aeruginosa*, *Shigella sonnei*, and *Pseudomonas spp*.) and six gram-positive bacteria (*Staphylococcus aureus, Bacillus cereus, Streptococcus-B-haemolytica, Bacillus megaterium*). The results showed that leaf extracts had an inhibitory effect on all tested bacteria, with the exception of *S. aureus* and *S. haemolytica*. Doughari et al. (2007); Nantachit (2006) and Prashith et al. (2010) noted that *Moringa oleifera* had comparable antibacterial efficacy against certain microorganisms. A recent study by Saadabi and Abu Zaid (2011) discovered that aqueous extracts of *Moringa oleifera* had dose-dependent inhibitory effects against many pathogenic microorganisms, such as *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, and *Pseudomonas aeruginosa*. Additionally, it was discovered that extracts from *Moringa oleifera* were inhibitory to B. subtilis and Mycobacterium phlei (Eilert et al., 1981). Different levels of antimicrobial activity were noted, ranging from *P. aeruginosa* resistance to *B. stearothermophilus* sensitivity (Ali et al., 2004). Pseudocides and *B. subtilis* were the most sensitive strains of bacteria, and cations (Na+, K+, Mg2+, and Ca2+) affected their activity, according to a study comparing the relative antimicrobial activity of seed extracts against bacteria (*Pasturella multocida, E. coli, B. subtilis, and S. aureus*) (Jabeen et al., 2008). Pterygospermin, which was first identified in Moringa pterygosperma, is present in *Moringa oleifera* and possesses potent antibacterial properties (Rao et al., 1946). According to Prashit Kekuda et al. (2010), there was a greater suppression of *E. coli, S. aureus, Klebsiella pneumoniae*, *P. aeruginosa*, and *B. subtilis* in a comparative analysis of the antibacterial activity of *Moringa oleifera* steam distillate. One study using an ethanolic extract of leaves, seeds, and flowers showed the antibacterial activity against *E. coli*, *K. pneumoniae*, *Enterobacter species*, *Proteus mirabilis*, *P. aeruginosa*, *Salmonella typhi A*, *S. aureus*, *Streptococcus*, and *Candida albicans*, in contrast to resistance against *P. aeruginosa* and *Candida albicans* for *Moringa oleifera* in other studies (Nepolean et al., 2009). There have been reports of antibacterial activity for a number of other specific components of *Moringa oleifera*, such as 4-(4'-O-acetyl-a-L-rhamnopyranosyloxy) benzyl isothiocyanate, 4-(a-L-rhamnopyranosyloxy) benzyl isothiocyanate, niazimicin, benzyl isothiocyanate, and 4-(a-L-rhamnopyranosyloxy) benzyl glucosinolate (Fahey). The root contains other bioactive substances that are effective against a variety of germs, including spirochin and anthonine. Strong inhibitory action of anthonine is seen against *Vibrio cholerae* (Nwosu and Okafor, 1995). Against four additional pathogenic gram-positive and gram-negative bacteria as well as *Candida albicans*, no activity was shown. No activity against six pathogenic dermatophytes was shown using a dilution approach (Caceres et al., 1991). Numerous research have demonstrated *Moringa oleifera* 's antibacterial properties. Bukar et al. (2010) assessed the bactericidal activity of *Moringa oleifera* leaf and seed chloroform and ethanol extracts using the Disc agar diffusion technique. Tests were conducted on the antibacterial activities of *Moringa oleifera* against six Gram-negative bacteria (*E. coli, Enterobacter aerogenes, Pseudomonas aeruginosa, Salmonella typhi, Salmonella typhimurium*, and *Shigella spp*.) and one Gram-positive bacteria (*Staphylococcus aureus*). Leaf ethanol (MLE) extracts from *Moringa oleifera* shown efficacy against four bacterial isolates. At all the quantities tested, *Shigella species, S. typhi*, and *S. typhimurium* were not sensitive, but Enterobacter species, *S. aureus*, *P. aeruginosa*, and *E. coli* were. The leaf chloroform (MLC) of *Moringa oleifera* shown efficacy against *S. typhi*, *S. typhimurium*, and *E. coli*. Similarly, three bacterial isolates (*S. aureus*, *E. coli*, and *S. typhi*) were susceptible to the effects of *Moringa oleifera* seed ethanol (MSE) extract. *P. aeruginosa*, *S. typhimurium*, *Shigella spp*., and *Enterobacter spp*. were insensitive to all tested doses. Two bacterial isolates (*S. typhimurium* and *E. coli*) were successfully combatted by *Moringa oleifera* seed chloroform (MSC) extract. *P. aeruginosa, S. typhi, Shigella spp., Enterobacter spp.,* and *S. aureus* were insensitive to all tested doses. Lar et al. (2011) discovered the antibacterial efficacy of ethanol and aqueous extracts of dried *Moringa oleifera* seeds using three gram negative organisms: *E. coli, Shigella flexneri*, and *Salmonella typhi*. They did this by using the agar well diffusion method. At the several quantities tested, the water extract had little effect on the test organisms; however, the ethanolic seed extract showed significant antibacterial action, with *Shigella flexneri* and *E. coli* showing susceptibility. Both extracts did not reveal any susceptibility to *Salmonella typhi*. The studies conducted by Bijal and Bhumika (2015) verified that distinct inhibition patterns were seen in the ethanol, methanol, petroleum ether, and aqueous extracts of *Moringa oleifera* leaves. The outcome shows that *Moringa oleifera* 's leaf, flower, pulp, and seed solvent extracts were effective against *S. aureus* and *E. coli*. According to Dzotam et al. (2016), leaf extracts of *Moringa oleifera* may be used either alone or in conjunction with other antibiotics to treat a variety of infectious disorders. Furthermore, Khanitta and Angelika (2015) used the Bauer-Kirby diffusion technique to ascertain the antibacterial activities of three distinct extracts:

i) a cold water extract of *Moringa oleifera* seed powder;

ii) a cold water extract of *Moringa oleifera* residue following oil extraction by Soxhlet method; and

iii) a cold water extract of *Moringa oleifera* seed oil obtained by Soxhlet method (disk method).

All investigated isolates (*Staphylococcus aureus, Bacillus subtilis, Salmonella typhimurium, Enterobactor aerogenes*, and *Pseudomonas aerogonosa*) are effectively inhibited by *Moringa oleifera* seed oil. Similarly, extracts from the seeds and residue of *Moringa oleifera* are effective against every bacterial isolate mentioned above, with the exception of *Staphylococcus aureus*. The investigations conducted by Patel and Mohan (2018) verified that distinct *Moringa oleifera* tissue extracts exhibited varying patterns of inhibition against several bacterial strains. *Salmonella typhi*, *Salmonella paratyphi*, *Pseudomonas aeruginosa*, *Salmonella coli*, *Escherichia coli*, *Bacillus cereus, Bacillus subtilis, Enterococcus faecalis, Micrococcus luteus, Staphylococcus aureus, Staphylococcus epidermidis*, and *Salmonella typhi* are the organisms that are being examined. Bichi and Shehu (2018) used the Agar well diffusion method in another study. The *Moringa oleifera* seed oil demonstrated a discernible antibacterial effect on E. coli when extracted in hexane. The average zones of inhibition for the 100%, 75%, 50%, and 25% of the seed oil were 17.7 mm, 14.3 mm, 11.3 mm, and 9.0 mm, respectively. The distillate of *Moringa* *oleifera* showed a significant decrease in the growth of test microorganisms, indicating an antibacterial action. According to Biswas et al. (2012), among the bacteria that were examined, *E. coli* showed the greatest suppression. *S. aureus, K. pneumoniae, P. aeruginosa,* and *B. subtilis* also showed significant inhibition. According to Kekuda et al. (2010), the essential oil portion of the plant material included in the distillate fraction may be the cause of the steam distillate of *Moringa oleifera* 's antibacterial activity. According to Ayyanar et al. (2023), ethy-l-acetate and methanolic extracts shown higher levels of inhibition against the investigated bacterial strains, including E. coli (24.0 ± 0.1 mm) and *Pseudomonas aeruginosa* (25.1 ± 0.3 mm). To increase antibacterial qualities, *Moringa oleifera* Ag-NPs and their crude aqueous extract can be used (Ahmed et al., 2023).

After reviewing the previous research, it can be said that because different varieties of *Moringa oleifera* include a variety of natural chemicals e.g. tannins, saponins, flavonoids, steroids, and phenolic substances etc., they have potent antibacterial properties.

Antifungal characteristics of *Moringa oleifera*

Numerous investigations have demonstrated the antifungal properties of various crude extracts from various *Moringa oleifera* tissues against fungus. The antifungal activity of ethanol and chloroform extracts of *Moringa oleifera* leaves and seeds was assessed by Bukar et al. (2010). The study's findings demonstrated that MSC completely prevented the development of Rhizopus and *Mucor spp*. at a concentration of 1000 µg/ml, while MSE only partially prevented the growth of Rhizopus and Mucor spp. at a dose of 1000 µg/ml. At 1000 µg/ml, MLC inhibited the growth of Rhizopus and *Mucor spp*. by 25%, while MLE inhibited the growth of Rhizopus and *Mucor spp*. by 100% and 50%, respectively, at the same concentration. Based on this investigation, it was found that MSC exhibited the highest level of antifungal activity against the test fungus, totally inhibiting the development of both Rhizopus and *Mucor species* at 1000µg/ml. The chemical N-benzylethyl thioformate, an aglycone of deoxyniazimincin, is present in *Moringa oleifera* ethanolic root extract and is responsible for the plant's antifungal action against a wide range of bacteria and fungi (Upadhyay et al., 2015). The antifungal strains Aspergillus flavus, *Aspergillus terreus, Aspergillus niger, Aspergillus oryzae, Fusarium solani, Penicillium sclerotigenum, Cladosporium cladosporioides*, *Trichophyton mentagrophytes, Penicillium species,* and *Pullarium species* have all been shown to be inhibited by extracts from the leaves, seeds, and stems of *Moringa oleifera* (Upadhyay et al., 2015). According to Ahmadua et al. (2020), the methanolic leaf extract exhibits about 99% suppression against the necrotrophic plant fungus *Botrytis cinerea*. The essential oil portion of the plant material contained in the distillate fraction may be the cause of the stem distillate of *Moringa oleifera* 's antifungal properties (Ravindra et al., 2019). A further sign of fungal inhibition was a smaller colony diameter on distillate-poisoned plates when compared to control plates. Using the broth dilution and agar plate procedures, Nwosu and Okafor (1995), Nikkon et al. (2003), Chen et al. (2007), Jamil et al. (2008), and Prashith et al. (2010) reported the antifungal efficacy of *Moringa oleifera* leaf extract against seven pathogenic fungi. It was discovered that *Moringa oleifera* leaf extract was useful in inhibiting the growth of *Basidiobolus haptosporus* and *Basidiobolus ranarums* fungi (Nwosu and Okafor, 1995). In addition, *Moringa oleifera* has the ability to inhibit fungi (Chuang et al., 2007). According to a study evaluating the relative antibacterial activity of seed extracts against two fungi, *Fusarium solani* and *Rhizopus solani*, these strains were the most susceptible, and cations, such as Na+, K+, Mg2+, and Ca2+, affected their activity (Jabeen et al., 2008). Pterygospermin, which was first discovered in *Moringa pterygosperma*, is present in *Moringa oleifera* and possesses potent fungicidal properties (Rao et al., 1946). According to Prashit Kekuda et al. (2010), *Aspergillus niger* exhibited the strongest inhibition, followed by *Aspergillus oryzae, Aspergillus terreus*, and *Aspergillus nidulans*. Pinal et al. (2014) demonstrated the antifungal effectiveness of *Moringa oleifera* leaf extracts against *Saccharomyces cerevisiae*, *Candida albicans*, and *Candida tropicalis* using the Agar well diffusion method. While no action was seen against *Candida albicans*, the ethanol and aqueous leaf extract results demonstrated activity against *Saccharomyces cerevisiae* and *Candida tropicalis*. When applied to *Saccharomyces cerevisiae*, water and ethanol extract of *Moringa oleifera* exhibited the biggest zone of inhibition. Using the agar well diffusion method, researchers examined the antifungal activity of aqueous and ethanol extracts of *Moringa oleifera* Lam. leaf against a range of clinical fungal pathogens, including *Aspergillus niger, Aspergillus flavus, Aspergillus fumigatus*, and *Cryptococcus neoformans* (Isitua et al., 2016). The outcome demonstrated that all fungal strains were susceptible to the ethanol and water extracts in the crude extracts of *Moringa oleifera*. In a recent study, Aondo et al. (2018) discovered that the crude extracts of *Moringa oleifera* (Bark seed and leaf) reduced the growth of *Aspergillus flavus mycelia*. *Certain saprophytic* fungi cannot contaminate culture media due to *Moringa oleifera* 's antifungal properties. The results indicated that the fungi could be effectively inhibited by ethyl acetate, methanolic, ethanolic, and aqueous extract of *Moringa oleifera* leaves, seeds, and bark. The study conducted by Patel and Mohan (2018) revealed that distinct tissue extracts of *Moringa oleifera* exhibited varying patterns of inhibition against distinct strains of fungi. *Aspergillus niger, Aspergillus paracitic, Candida albicans, Aspergillus flavus, Trichoderma harzanium, Alternata burnsi*, and *Fusarium oxysporum* are among the tested fungal isolates. Reduced colony width in distillate-poisoned plates as compared to control plates was another indication of fungal inhibition (Biswas et al., 2012). *A. niger* showed the greatest inhibition, followed by *A. oryzae*, *A. terreus*, and *A. nidulans*. The essential oil fraction of the plant material contained in the distillate fraction may be responsible for the steam distillate of *Moringa oleifera* 's antifungal properties (Kekuda et al., 2010). the existence of tannins, saponins, flavonoids, steroids, and phenolic substances. Against *C. kruzei*, the investigated extracts showed varying degrees of antifungal activity. With a minimal inhibitory concentration of 10 mg/ml, the leaf extract demonstrated efficacy against C. kruzei (Al-Khalasi et al., 2024).

Based on the analysis of the results mentioned above, it can be concluded that *Moringa oleifera* has excellent antifungal properties due to the presence of a variety of natural chemicals like tannins, saponins, flavonoids, steroids, and phenolic substances etc.

Wound healing characteristics of *Moringa oleifera*

Ethyl acetate and a 300 mg/kg dosage of *Moringa oleifera* leaf water extract were shown to have a substantial impact on wound healing following incision or excision (Mishra et al., 2011). According to research, dried pulp extracts, leaves, and seeds have demonstrated effective improvement of wound closure, granuloma rupture strength, and reduction of skin rupture strength in the scar area in preclinical experiments (Muhammad et al., 2016). By enhancing the downregulation of inflammatory markers and raising the level of vascular endothelial growth factor in the wounded tissue, leaf extracts have demonstrated encouraging effects in diabetic rats (Bhattacharya et al., 2018). By lowering the levels of several inflammatory indicators, compounds found in aqueous extract have had a significant impact on diabetic foot ulcers (Muhammad et al., 2016). The most potent standardized extract was chosen by the researcher through an in vitro experiment, and it was subsequently made into a film to aid in wound healing. According to the findings, among the various extracts, the aqueous extract exhibited the highest levels of cell proliferation and migration (Awodele et al., 2012). When compared to oral or topical use of other extracts, the most popular intervention for wound healing was determined to be the aqueous extracts of *Moringa oleifera* leaves. In the meantime, the fastest excision-induced wound healing activity was demonstrated by the n-hexane extract of *Moringa oleifera* seeds (Shafie et al., 2022). Using in vivo models, Ashames et al. (2024) evaluated the effectiveness of amniotic fluid and *Moringa oleifera* -loaded nanoclay films for wound healing. AMF-Me.mo-loaded nanofilms' antimicrobial activity helped to clean the wound site, putting them in a position to be a viable option for rabbit burn wound healing. Abdullah et al. (2022) used an infected excision wound model in rats to study the wound-healing properties of *Moringa oleifera* leaf extract. Methicillin-resistant Staphylococcus aureus (MRSA) or Pseudomonas aeruginosa were used to cause infection. In addition to its antibacterial properties, *Moringa oleifera* demonstrated a considerable improvement in wound contraction, a shorter time to epithelization, higher activity of antioxidant enzymes, and a decrease in capillary density. In contrast to MRSA, the extract had less of an impact on wounds infected with P. aeruginosa. *Moringa oleifera* boosted the expression of the VEGF and TGF-β1 genes.

Conclusion

It has been shown that *Moringa oleifera* is a rich source of antioxidants, phenolic compounds, and a variety of other biochemicals e.g. tannins, saponins, flavonoids, and steroids. In the plant, these organic substances have potent antimicrobial, antibacterial, and antifungal properties. The features of *Moringa oleifera*, present in its leaves, flowers, pod, bark, and roots, developed wound-healing properties in a variety of forms, including fresh, powdered, and extracts.

References

Abdullah A, Al-Ghanayem, Alhussaini M S, Asad M and Joseph B. 2022. Effect of *Moringa oleifera* leaf extract on excision wound infections in rats: antioxidant, antimicrobial, and gene expression analysis. *Molecules*. **27**(14): 4481.

Ahmadua T, Ahmad K, Ismail S I, Rashed O and Asib N. 2020. Omar D. Antifungal efficacy of *Moringa oliefera* leaves and seed extract against *Botrytis cinerea* causing graymold disease of tomato. Braz. J. Biol. **81**:1007–1022.

Ahmed M, Marrez D A, Abdelmoeen N M, Mahmoud E A, Ali M A S, Decsi K and Tóth Z. 2023. Proximate analysis of *Moringa oleifera* leaves and the antimicrobial activities of successive leaf ethanolic and aqueous extracts compared with green chemically synthesized Ag-NPs and crude aqueous extract against some pathogens. *Int. J. Mol. Sci*. **24**(4): 3529.

Ali G H, El-Taweel G E and Ali M A. 2004. The cytotoxicity and antimicrobial efficiency of *Moringa oleifera* seeds extracts. *Int. J. Environ. Stud*. **61**:699-708.

Al-Khalasi S, Al-Ghafri A, Al-Saqri S, Al-Jahdhami H, Al-Hosni S and Elmiligy Y. 2024. Antifungal activity of *Moringa peregrina* plant extracts against *Candida kruzei*. *European Journal of Theoretical and Applied Sciences*. **2**(2): 87-101.

Amagloh F K and Benang A. 2009. Effectiveness of *Moringa oleifera* seed as coagulant for water purification. *Afr J Agric Res*. **4**:119-123.

Amer J, Raheela J, Muhammad S and Muhammad A. 2008. Microscopic evaluation of the antimicrobial activity of seeds extracts of *Moringa oleifera*. *Pak J Bot*. **40**(4):1349-1358.

Anzano A, De Falco B, Ammar M, Ricciardelli A, Grauso L, Sabbah M, Capparelli R and Lanzotti V. 2022. Chemical analysis and antimicrobial activity of *Moringa oleifera* Lam. leaves and seeds. *Molecules*. **27**: 8920.

Aondo T O, Odiaka N I, Akesa T M, and Olaleye O O. 2018. Phytochemical and antifungal efficacy of different parts of *Moringa oleifera* plant extracts. *Asian Journal of Biotechnology and Bioresource Technology*. **3**(2): 1-8.

Arama P F, Wagai S O, Ogur J A, Walter A O, Owido S O and Mahagayu C M. 2011.Harvesting surface rainwater – purification using *Moringa oleifera* seed extracts and aluminum sulfate. *Journal of Agricultural Extension and Rural Development*. **3**(6): 102-112.

Ashames A, Ijaz M, Buabeid M, Yasin H, Yaseen S, Bhandare R R and Murtaza G. 2024. *In Vivo* wound healing potential and molecular pathways of amniotic fluid and *Moringa Olifera*-loaded nanoclay films. *Molecules*. **29**(3): 729.

Awodele O, Oreagba I A, Odoma S, Jaime A, Da Silva T and Osunkalu V.O. 2012. Toxicological evaluation of the aqueous leaf extract of *Moringa oleifera* Lam. (Moringaceae) *J. Ethnopharmacol*. **139**: 330–336.

Ayyanar M, Krupa J, Jenipher C, Amalraj S and Gurav S S. 2023.

Phytochemical composition, in vitro antioxidant and antibacterial activity of *Moringa concanensis* nimmo leaves. *Vegetos* Retrieved from https://link.springer.com/article/10.1007/s42535-023-00663-9.

Berkowitz F E. 1995. Antibiotic resistance in bacteria. *South Med. Journal*. **88**: 797-804.

Bhatt K K S. 1995. *Medicinal Plant Information Databases*. FAO-Food and Organization of the United Nations Italy. **11**: 163.

Bhattacharya A, Tiwari P, Sahu P K, Kumar S A. 2018. Review of the phytochemical and pharmacological characteristics of *Moringa oleifera*. *J. Pharm. Bioallied Sci*. **10**: 181–191.

Bhattacharya S B, Das A K and Banerji N. 1982. Chemical investigations on the gum exudate from sajna (*Moringa oleifera*). *Carbohydr. Res*. **102**: 253-262.

Bichi M H and Shehu U H. 2018. Antimicrobial properties of *Moringa oleifera* seed oil. *International Journal of Research in Earth & Environmental Sciences*. **13**(1).

Bijal A and Bhumika D. 2015. Antibacterial activity and phytochemical screening of different parts of *Moringa oleifera* against selected gram positive and gram negative bacteria. *Journal of Pharmaceutical, Chemical and Biological Sciences*. **3**(3): 421-425.

Biswas S K, Chowdhury A, Das J, Roy A and Hosen S M Z. 2012. Pharmacological potentials of *Moringa oleifera* lam.: a review. *International Journal of Pharmaceutical Sciences and Research*. **3**(2): 305-310.

Bukar, A, Uba, A. and Oyeyi, T I. 2010. Antimicrobial profile of *Moringa oleifera* Lam. extracts against some food – borne microorganisms. *Bayero Journal of Pure and Applied Sciences*, **3**(1): 43 – 48.

Caceres A, Cabrera O, Morales O, Mollinedo P, Mendia P. 1991. Pharmacologic properties of *Moringa oleifera*: preliminary screening for antibacterial activity. *Journal of Ethnopharmacology*. **33**: 213-216.

Caceres A, Saravia A, Zabala L, Leon E. 1992. Pharmacologic properties of *Moringa oleifera*. 2: screening for antispasmodic, anti-inflammatory and diuretic activity. *J Ethnopharmacol*. **36**: 233-237.

Chen H M, Chuang P H, Lee C W, Chou J Y, Murugan M, Shieh B J. 2007. Anti-fungal activity of crude extracts and essential oil of *Moringa oleifera* Lam. *Bioresour Technol*. **98**: 232–236.

Chopra R N, Nayar S L, Chopra I C. 1956. *Glossary of Indian Medicinal Plants*. 1st Edition, CSIR, New Delhi. 2: 66-6.

Chuang P H, Lee C W, Chou C Y, Murugan M, Shieh B J and Chen H M. 2007. Anti-fungal activity of crude extracts and essential oil of *Moringa* *oleifera* Lam. *Bioresour. Technol*. **98**: 232-236.

Dahot M U. 1998. Vitamin contents of flower and seeds of *Moringa oleifera* Lam. *J Islamic Academy Sci*. **11**(1): 27-32.

Dhimmar N D, Patel N M, Gajera V and Lambole V. 2015. Pharmacological activities of *Moringa oleifera*: an overview. *Research Journal of Pharmacy and Technology*. **8**(4): 476-480.

Dinesha B L, Nidoni U, Ramachandra. C T, Naik N, Sankalpa K B. 2018. Effect of extraction methods on physicochemical, nutritional, antinutritional, antioxidant and antimicrobial activity of moringa (*Moringa oleifera* Lam.) seed kernel oil. *J. Appl. Nat. Sci*. **10**: 287–295.

Doughari J H, Pukuma M S and De N. 2007. Antibacterial effects of *Balanites aegyptiaca* L. Drel. and *Moringa oleifera* Lam. on *Salmonella typhi*. *Afr J Biotechnol*. **6**(19): 2212-2215.

Dzotam J K, Touani F K, and Kuete V. 2016. Antibacterial and antibiotic-modifying activities of three food plants (*Xanthosoma mafaffa* Lam, *Moringa oleifera* (L.) Schott and *Passiflora edulis* Sims) against multidrug-resistant (MDR) Gram-negative bacteria. *BMC complementary and alternative medicine*. **16**(1).

Eilert U, Wolters B, Nahrstedt A. 1981. The antibiotic principle of seeds of *Moringa oleifera* and *Moringa stenopetala*. *Planta Med*. **42**: 55-61.

Fahey J W, Zalcmann A T, Talalay P. 2001. The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. *Phytochemistry*, **56**(1): 5-51.

Fahey J W. 2005. *Moringa oleifera*: a review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Part 1. *Trees Life J*. **1**: 5.

Farnsworth N R. 1991. Biological and phytochemical screening of plants. *J. Pharmacol. Sci*. **55**: 225-276.

Ghebremichael K A, Gunaratna K R, Henriksson H, Brumer H. and Dalhammar G. 2005. A simple purification and activity assay of the coagulant protein from *Moringa oleifera* seed. *Water Re.s* 39: 2338–2344.

Han S S, Keum Y S, Seo H J and Surh Y J. 2002. Curcumin suppresses activation of NF-B and AP-1 induced by phorbol ester in cultured human promyelocytic leukemia cells. *J. Biochem. Mol. Biol*. **35**: 337- 342.

Isitua C C, Ibeh I and Olayinka J N. 2016. *In Vitro* antifungal activity of *Moringa oleifera* Lam leaf on some selected clinical fungal strains. *Indian Journal of Applied Research*. **6**(8).

Jabeen R, Shahid M, Jamil A and Ashraf M. 2008. Microscopic evaluation of the antimicrobial activity of seed extracts of *Moringa oleifera*. *Pak. J. Bot*. **40**:1349.

Jamil A, Raheela J, Muhammad S and Muhammad A. 2008. Microscopic evaluation of the antimicrobial activity of seed extracts of *Moringa oleifera*. *Pak J Bot*. **40**(4):1349-1358.

Kekuda T R P, Mallikarjun N, Swathi D, Nayana K V, Aiyar M B and Rohini T R. 2010, Antibacterial and Antifungal efficacy of steam distillate of *Moringa oleifera* Lam. *J Pharm Sci and Res*. **2**(1): 34-37.

Khanitta R and Angelika P. 2015. Antimicrobial activities of *Moringa oleifera* seed and seed oil residue and oxidative stability of its cold pressed oil compared with extra virgin olive oil**.** *Songklanakarin Journal of Science and Technology*. **37**(5): 587-594.

Kishore A and Goitom K. 2021a. Nutritional evaluation of *Moringa oleifera* pod meal for white New Zealand rabbits. *The Journal of Rural Advancement*. **9**(2): 43–50. Retrieved from http://jra.idtra.co.in/index.php/jra/article/view/29

Kishore A and Goitom K. 2021b. Thermal effect on general and excretion behaviour of White New Zealand rabbit kept on moringa (*Moringa oleifera*) pod meal. *The Journal of Rural Advancement*. **9**(1): 1–6. Retrieved from http://jra.idtra.co.in/index.php/jra/article/view/23.

Kishore A and Goitom K. 2022. Ethogram of rabbits on concentrate feed with and without moringa pods. *Indian Journal of Small Ruminants*. **28**(2): 315-319.

Kone W M, Atindeou K K, Terreaux C, Hostettmann K, Traore D and Dosso M. 2004. Screening of 50 medicinal plants for antibacterial activity. *Journal of Ethnopharmacol*. **93**: 43-49

Lar P M, Lojile E E, Dashe E and Oluoma J N. 2011. Antibacterial activity of *Moringa oleifera* seed extracts on some gram negative bacterial isolates. *African Journal of Natural Sciences*. **14**: 57 – 62.

Maurya S K and Singh A K. 2014. *Clinical Efficacy of Moringa oleifera Lam. Stems Bark in Urinary Tract Infections*. Int. Sch. Res. Not. 906843.

Mbikay M. 2012. Therapeutic potential of *Moringa oleifera* leaves in chronichyperglycemia and dyslipidemia: A review. *Front Pharmacol*. **3**: 1-12.

Mehta L K, Balaraman R, Amin A H, Bafna P A and Gulati O D. 2003. Effect of fruits of *Moringa oleifera* on the lipid profile of normal and hypercholesterolaemic rabbits. *J Ethnopharmacol*. **86**: 191–195.

Mishra G, Singh P, Verma R, Kumar S, Srivastav S, Jha K K and Khosa R L. 2011. Traditional uses, phytochemistry and pharmacological properties of *Moringa oleifera* plant: An overview. *Der Pharmacia Lett*. **3**: 141–164.

Moodley J S, Krishna S B N and Pillay K. 2018. Green synthesis of silver nanoparticles from *Moringa oleifera* leaf extracts and its antimicrobial potential. *Adv. Nat. Sci. Nanosci. Nanotechnol*. **9**: 1–10.

Muhammad A A, Arulselvan P, Cheah P S, Abas F and Fakurazi S. 2016. Evaluation of wound healing properties of bioactive aqueous fraction from *Moringa oleifera* Lam on experimentally induced diabetic animal model. *Drug Des. Devel. Ther*. **10**:1715–1730.

Nadkarni K M and Nadkarni A K. 1976. *The Indian Materia Medica with Ayurvedic, Unani-Tibbi, Siddha, Allopathic, Homeopathic, Naturopathic and Home remedies*. Popular Prakashan Pvt. Ltd, Bombay, pp. 810.

Nantachit K. 2006. Antibacterial activity of the capsules of *Moringa oleifera* Lamk. Moringaceae. *CMU J*. **5**(3): 365-368.

Nepolean P, Anitha J and Emilin R R. 2009. Isolation, analysis and identification of phytochemicals of antimicrobial activity of *Moringa oleifera* Lam. *Curr. Biotica*. **3**: 33-39.

Nikkon F, Saud A, Rahman M H and Haque M E. 2003. In vitro antimicrobial activity of the compound isolated from chloroform extract of *Moringa oleifera* Lam. *Pak J Biol Sci*. **6**(22): 1888–1890.

Novitarini, Jason Merari P and Marlina D. 2022. Antibacterial Activity of Moringa Plants (*Moringa oleifera* Lam.) to Overcome Antibiotic Resistance: A Systematic Review. *Bioscientia Medicina*. **6**(10): 2259-2273.

Nwosu M O and Okafor J I. 1995. Preliminary studies on the antifungal activities of some medicinal plants against basidiobolus and some other pathogenic fungi. *Mycoses*. **38**(5-6): 191-195.

Oloduro A O and Aderiye B I. 2007. Efficacy of *Moringa oleifera* seed extract on the microflora of surface and underground water. *J. Plant Sci*. **2**: 453-458.

Padla E P, Solis L T, Levida R M, Shen C C, Ragasa C Y. 2012. Antimicrobial isothiocyanates from the seeds of *Moringa oleifera* Lam. *Z. Für Nat*. C. **67**: 557–564.

Patel N and Mohan J S S. 2018. Antimicrobial activity and phytochemical analysis of *Moringa oleifera* Lam. crude extracts against selected bacterial and fungal strains. *Int. J. Pharmacogn. Phytochem. Res.* **10**, 68–79.

Peixoto J R, Silva G C, Costa R A. 2011. *In vitro* antibacterial effect of aqueous and ethanolic moringa leaf extracts. *Asian Pac. J Trop Med*. **4**: 201-204.

Pinal P, Nivedita P, Dhara P, Sharav D, and Dhananjay, M. 2014. Phytochemical analysis and antifungal activity of *Moringa oleifera*. *International Journal of*

Pharmacy and Pharmaceutical Sciences. **6**(5).

Prashith K T R, Mallikarjun N, Swathi D, Nayana K V, Aiyar M B, Rohini T R. 2010. Antibacterial and antifungal efficacy of steam distillate of *Moringa oleifera* Lam. *Pharm Sci Res*. **2**(1): 34-37.

Rahman M M, Sheikh M M I, Sharmin S A, Islam M S, Rahman M A, Rahman M M, Alam M. 2009. Antibacterial activity of leaf juice and extracts of *Moringa oleifera* Lam against some human pathogenic bacteria. CMU J Nat Sci. **8**(2):219.

Rao R R, George M and Pandalai K M. 1946. Pterygospermin: the Antibacterial Principle of *Moringa pterygosperma*, Gaertn. *Nature*. **158**: 745-746.

Rastogi T, Bhutda V, Moon K, Aswar K B and Khadabadi S S. 2009. Comparative studies on anthelmintic activity of *Moringa oleifera* and *Vitex negundo*. *Asian J. Res. Chem*. **2**:181-182.

Ravindra A V, Rao P S and Siddheshwar S S. 2019. A pharmacological review on *Moringa oleifera*. *World Journal of Pharmaceutical Research*. **8**(8): 910-920.

Renitta R E, Nepolean P and Anitha J. 2009. Isolation, analysis and identification of phytochemicals of antimicrobial activity of *Moringa oleifera* Lam. *Current Biotica*. **3**(1):33-39.

Saadabi A M and Abu Z A I. 2011. An in vitro antimicrobial activity of *Moringa oleifera* L. seed extracts against different groups of microorganisms. *Asian J. Basic Appl. Sci*. **5**:129-134.

Schwarz D. 2000. *Water clarification using Moringa oleifera*. Technical Information W1e, Gate Information Service, Eschborn, Germany.

Shafie N M, Shah R N I R S, Krishnan P, Haleem N A and Tan T Y C. 2022. Scoping Review: Evaluation of *Moringa oleifera* (Lam.) for potential wound healing in *in vivo* studies. *Molecules*. **27**(17): 5541.

Sharma T, Kishore A and Singh P. 2022a. Phenolic, antioxidant and free radical-scavenging properties of various parts of Indian moringa (*Moringa oleifera*) during the winter season. *The Journal of Rural Advancement*, **10**(01): 1–7. Retrieved from https://jra.idtra.co.in/index.php/jra/article/view/30.

Sharma T, Kumar A and Kishore A. 2022b. Seasonal variation in antioxidant properties of various parts of the Moringa oleifera plant collected from different Indian locations. The Journal of Rural Advancement. **10**(01): 13–18. Retrieved from https://jra.idtra.co.in/index.php/jra/article/view/32.

Shekhar C, Shukla R, Kumar Aand Dubey N K. 2000. Laboratory of Herbal Pesticides, Centre of advance study on botany, Banaras Hindu University, Varanasi, India. *Eur J Clin Microbiol Infectious Dis*. **6**:23-28.

Suarez M, Entenza J M, Doerries C, Meyer E, Bourquin L, Sutherland J, Marison I, Moreillon, P. et al. 2003. Expression of a plant-derived peptide harboring watercleaning and antimicrobial activities. *Biotechnol Bioeng*. **81**: 13–20.

Upadhyay P, Yadav M K, Mishra S, Sharma P, Purohit S. 2015. *Moringa oleifera*: A review of the medical evidence for its nutritional and pharmacological properties. *Int. J. Res. Pharm. Sci*. **5**:12–16.

Verpoorte R. 2000. Pharmacognosy in the new millennium: lead finding and biotechnology. *J. Pharm. Pharmacol*, **52**: 253- 262.