Review Article

Moringa oleifera: Promising Gut Microbiome Promotor, Immun-modulator and Natural Antimicrobial

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Abstract

Moringa oleifera, is a rich source of variant bioactive compounds, which exert remarkable immune-modulatory impacts by regulating immune cell activity and cytokine output. Interestingly, Moringa-derived water-soluble polysaccharides activate the gut-associated immune system through beneficial modulation of gut microbiota composition, increasing genera such as Muribaculaceae and Lactobacillus. Furthermore, *M. oleifera* exhibits potent antimicrobial capabilities by enhancing endogenous defenses, reactive oxygen species. In conclusion, underscore *M. oleifera* is potential to promote illness competing and immune function.

Key words: *Moringa oleifera* – antimicrobial - anticancer – immunomodulation- microbiome.

Introduction

A trend plant, *Moringa oleifera* (*M. oleifera* MO), holds remarkable promise because of richness in nutrient component, and high protein biological value (Chen *et al*., 2020). It comprises flavonoid and phenolic components that have been accompanied with promoted health, feed conversion efficiency get better (Rizwan *et al*., 2022). Studies have exposed the advantageous impacts of M. OLEIFERA on the human health (Kou *et al*., 2018). Flavonoids are considered the prime phenolic compounds as secondary metabolites in M. OLEIFERA leaves (Oldoni *et al*., 2019). Flavonoids' compounds exert beneficial action versus a broad scope of clinical illnesses and microbiological activity, potent antioxidant (Mukhopadhyay and Prajapati, 2015). Abundant uses have been recognized for *M. oleifera*, antimicrobial, anti-bacterial, anti-fungal and anti-tumor activity (Barahuie *et al*., 2023).

Gut health

Recently, abundant researches have displayed the significant role of gut microbiota in human health (Gonz´alez Olmo *et al*., 2021 and Loo *et al*., 2020). It is known that the majority of plants' oligo and polysaccharides not be digested in the upper gastrointestinal tract, so be digested or processed by intestinal bacteria (Shang *et al*., 2018). This process has prompted the growth of bacterial microbiota that produce beneficial metabolites as short chain fatty acids, which are useful to host metabolism, particularly gastrointestinal health (Shi *et al*., 2015).

Several reports demonstrated the beneficial impacts of *M. oleifera* extracts on gut health and maintenance of intestinal homeostasis (Dou *et al*., 2019 and Jaja-Chimedza *et al*., 2018). *Moringa* polysaccharides have improved intestinal integrity, increased mucosal thickness and villus height in the duodenum, ileum and colon in addition to crypt depth ratio in the ileum and jejunum (Wang *et al*., 2019 and Tian *et al*., 2021). Also, moringa polysaccharides enhance the activity of digestive enzymes, amylase, alkaline phosphatase, lipase and trypsin enzymes (Kaur *et al*., 2015). so consequently reflect the digestive function (Adorian *et al*., 2019). Furthermore, moringa polysaccharide improves the diversity of the gut microbiota and the flora structure by elevating the number of beneficial bacteria and reducing the number of harmful bacteria (Dou *et al*., 2019 and Jaja-Chimedza *et al*., 2018). Administration of moringa polysaccharides greatly diminished the serum diamine oxidase, D-lactate and tumor necrosis factor-α (TNF- α), agents which induce intestinal damage (Wang *et al*., 2019). These biological activities of moringa polysaccharides facilitate new approaches for metabolic illnesses therapy and the conservation of human health. A study reported that oral supply of ethanolic root-bark extract of *M. oleifera* has valuable antiulcer and antisecretory effects and is potentially used as a source for antiulcer therapy (Choudhary *et al*., 2013).

A study investigated the impacts of *M. oleifera* polysaccharide (MOP) on immune organ indicators and colonic microbiomics in 21 newborn calves for 8 weeks. Calves were humanely electroshocked on the last day of the trial and slaughtered afterwards. Thymus, spleen, blood and colonic contents were collected for further testing. The results displayed that MOP significantly elevated IgA, IgG, and IgM levels at serum immunity level (Zhao *et al*., 2023).

Gut microbiota modulation

Immunomodulation comprises the targeted manipulation of the immune system to, primarily resulting in improved illness resistance and overall health (Byrne *et al*., 2023). Dietary immunomodulation includes the integration of particular nutrients and bioactive components into animal feed to optimize immune performance (Bobeck *et al*., 2020).

Gut-associated immune system activation

The gut, being the biggest immunological organ, employs a substantial role both in nutrient absorption and digestion (Mohai *et al*., 2025). The intestine of mammals encompasses a plenty and complex population of microorganisms, involving billions of bacteria (Min *et al*., 2020). These microbes play a pivotal role in digestion and nutrient absorption, contributing significantly in the body's immune job (Lu *et al*., 2020). Any alterations in intestinal flora can cause pathological alterations within the intestinal tissue. Furthermore, such disruption can lead to the output of carcinogenic compounds and chronic inflammation, thereby inducing a remarkable risk to health (Singh *et al*., 2023).

Polysaccharides present in *M. oleifera* have been associated with various biological activities, comprising immune-modulatory impacts, and possible antimicrobials effect (Mohamed Husien *et al*., 2022).

Liu *et al*. (2018) demonstrated immune-modulatory activity of MOP-2 extracted from *M. oleifera* leaves in vitro.The immune-modulatory activity of *M. oleifera* leaf polysaccharides has been reported in abundant studies. For instance, Mohamed Husien *et al*. (2022) has displayed that high doses of MOP improve intestinal health in UC mice by promoting gut microbiome compositions.

As lactobacilli do a beneficial role in immunomodulation (Elabd *et al*., 2018). The study demonstrated that treatment with MOLP-H lead to elevated Lactobacillus levels (Husien *et al*., 2024). Treatment with MOLP initiates alterations in the gut microbiota constitution, particularly elevating the abundance of beneficial families which have been recognized to support greater activity of natural killer (NK) cells (Wen *et al*., 2022). The innate immune system depends on NK cells to perform identification and removal of abnormal infected cells (Cooper *et al*., 2009). On the other side, studies employing mice demonstrated that MOP administration reduced the growth levels of pathogenic bacterium Helicobacter which implemented in different gastric abnormalities (Husien *et al*., 2024 and Wen *et al*., 2022).

Immunomodulatory effect

Some studies have pointed to the immunomodulatory prospect of moringa polysaccharides. A study used polysaccharide obtained by *M. oleifera* leaves hot water extract and displayed significant proliferative activity in macrophages. Also, moringa polysaccharide enhanced the pinocytic capacity of RAW 264.7 cells and boosted the formation of reactive oxygen radicals, nitric oxide and interleukin-6 molecules in a dose-dependent manner (Dong *et al*., 2018). Ultimately, moringa polysaccharide can be achieved as a potent immuno-modulator, and when taken, it can improve the host's humoral and cell-mediated immunity (Li *et al*., 2020).

Anticancer effect

M. OLEIFERA includes the source of naturally important bioactive compounds that act synergistically in their therapeutic action (Tiloke *et al*., 2018). Exposure to chemical or environmental stresses causes accumulation of free radicals and increased production of inflammatory mediators involved in cancer genesis (Mehta *et al*., 2003). It has been mentioned in the studies that the M. OLEIFERA extract has high anti-cancer activity (Al-Asmari *et al*., 2015, Anwar *et al*., 2007 and Bharali *et al*., 2003), and can target some proteins and molecules to prohibit the progression of the cancer cell (Tiloke *et al*., 2018 and Karim *et* *al*., 2016). M. OLEIFERA has the prospect in the development of a novel alternate and complementary therapeutic agent to fight cancer (Karim *et al*., 2016). Al-Asmari *et al*., (2015) mentioned that M. OLEIFERA extracts can be used as a valuable agent for the treatment of aggressive breast and colorectal carcinoma (Rock *et al*., 1996). A study reported that there is evidence that Dallose (present in leaves of *Moringa*) inhibits the growth of cancer cells at G1 phase without exerting appreciable effects on normal cells (Yamaguchi *et al*., 2008). The GC-MS analyses demonstrated abundant anti-cancer compounds present in the extracts of leaves and bark of M. OLEIFERA. In instance, hexadecanoic acid found in the leaves, seeds and shell of M. OLEIFERA exhibits selective cytotoxicity versus human leukemic cells. Eugenol present in the M. OLEIFERA shell has a potent anticancer effect versus leukemia, melanoma, osteosarcoma, stomach cancer, skin tumor, mast cells and prostate cancer (Al-Asmari *et al*., 2015). M. OLEIFERA seed extracts have been reported to be efficient on hepatic carcinogen metabolizing enzymes and skin papillomagenesis (Anwar *et al*., 2007 and Bharali *et al*., 2003). Furthermore, M. OLEIFERA leaves combat pancreatic cancer cells (Tiloke *et al*., 2018). Flavonoids have anticancer activity by either stopping the cell cycle as breast cancer or stimulating apoptosis to the cancer cells, downregulation of heat shock protein 90 expression in prostate cancer cells (Hertzog *et al*., 2012). The regulation of mitogen and prime signaling pathways linked to the cancer growth. Certain flavonoid compounds have a highly differentiating effect, acting on malignant cells and not affect normal cells [125, 126] (Luo *et al*., 2011 and Chen *et al*., 2013).

Antimicrobial activity of *Moringa*

Antiviral

M.O. exhibits suppressive activity versus early antigen activation of Epstein-Barr virus (Lim *et al*., 2012). It is reported that M. OLEIFERA dry leaf dust support the immune system against infections and thus elevates the well-being of HIV+ people (Burger *et al*., 2002). Furthermore, M. OLEIFERA extracts have beneficial impacts versus SARS-CoV-2 (Mathpal *et al*., 2021) and influenza (Xiong *et al*., 2021), also reduced the expression of hepatitis B virus cccDNA by 80% (Waiyaput *et al*., 2012). It was shown that ethanol extract of M. OLEIFERA exhibited potent inhibitory impacts versus viral growth *in vitro* studies (Aljofan *et al*., 2014).

Antibacterial

The aqueous, chloroform, ethyl acetate and methanol extracts of M. OLEIFERA have been found to affect the bacteria of *Escherichia coli, Salmonella typhi, Pseudomonas aeruginosa, Enterobacter cloacae, Proteus vulgaris, Klebsiella aerogenes, Shigella, Bacillus cereus, Bacillus subtilis, Klebsiella pneumoniae, Streptococcus pyogenes, Vibrio cholera, Salmonella enterica, Staphylococcus aureus, Citrobacter freundii,* and *Pseudomonas fluorescens* and acid –fast bacteria (Gupta *et al*., 2018, Pal *et al*., 2014, Planta *et al*., 2015, Singh *et al*., 2014, Zaffer *et al*., 2014). It can be assumed that M. OLEIFERA may be a prospect source for the treatment of numerous infections caused by resistant microbes (Planta *et al*., 2015 and Zaffer *et al*., 2014). Furthermore, tannins (which are abundant in dried M. OLEIFERA leaves) have significant anti-bacterial action via either privation of the substrates needed for microbial growth or direct effect on microbial metabolism (Ekambaram *et al*., 2016).

Antifungal

The extracts of M. OLEIFERA prohibit the growth of pathogens of subcutaneous phycomycosis in humans and animals. The antifungal performances of various ingredients of the plant involving leaves and seeds have been reported versus fungi such as *Trichophyton interdigitale*, *Aspergillus flavus*, *Penicillium sp.*, *Aspergillus niger*, *Aspergillus oryzae*, *Aspergillus terreus*, *Aspergillus nidulans*, *Fusarium solani*, *Rhizoctonia solani*, *Cladosporium cladosporioides*, *Penicillium sclerotigenum*, *Trichophyton rubrum*, *Microsporum canis* (Asgarpanah *et al*., 2017). The ethanolic extract of leaves revealed antifungal activity against a number of dermatophytes (Jaiswal *et al*., 2009). Moreover, it was found that supplementation of *M. oleifera* leaf powder to aflatoxic contaminated feed, can improved serum liver enzymes and hepatic antioxidant status in broilers, so it has been considered a potential combating to aflatoxin exposure (Umaya *et al*., 2012).

Conclusion

M. oleifera is greatly identified as a promising solution for sustainable health conditions because of its rich nutritional composition and therapeutic merits. Its immune-modulatory impacts via regulation of gut immunity and minimize oxidative stress, improving illness resistance. MOP could regulate the intestinal flora, increasing the relative abundance of beneficial bacteria and decreasing the relative abundance of undesirable bacteria, exposing a positive impact on the intestine. Furthermore, antimicrobial activities of *M. oleifera* have been established rendering their usage as alternative to classical antibiotics facilitating the overcoming on global antibiotic resistance concern.

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