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# Nutritional, microbiological and pharmacological properties of *Moringa oleifera*

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**ABSTRACT**
*Moringa oleifera* is a multipurpose herbal tropical plant, an alternative with therapeutic purposes and with great impact as a sustainable strategy within the UN Agenda 2030, within its second sustainable development goal (SDG) Zero Hunger. The objective of the present literature review was to know the nutritional, microbiological and pharmacological properties of *M. oleifera*. *M. oleifera* is a promising tree in solving food safety problems used in the preparation of food for human consumption. *M. oleifera* contains phytochemicals in leaves, seeds and pods, glycosides, polyphenols, tannins, flavonoids and derivatives, components such as essential amino acids, carotenoids and anthocyanidins that provide the plant with nutritional, functional, and pharmacological properties with antimicrobial, hypotensive, and antioxidant activities. hypoglycemic, immunomodulatory, and anti-inflammatory. Moringa leaves contain fiber, ash, carbohydrates, total proteins, lipids, minerals such as sodium, potassium, magnesium, phosphorus, iron, zinc, copper, calcium, and manganese. *M. oleifera* brings with it the solution to problems of the general population such as malnutrition, environmental pollution, and diseases that affect humanity.

**Keywords:** Zero hunger, Sustainable Development Goals, Backyard agriculture, Food.

## 1 INTRODUCTION

*Moringa oleifera* (*M. oleifera*) is an important and well-known plant in the field of Ayurveda, as it has traditionally been used for a variety of purposes. It is known to have infinite potential as a complementary food and nutraceutical due to the presence of abundant phytochemical components. In addition to being a good source of a variety of useful bioactive chemicals, *M. oleifera* is also an anticipated plant in nutritional research, as it has only a minimal need for crop growth requirements, allowing for wide distribution in many countries. The pharmacological potential of plants, as well as their safety and toxicity, has been critically studied in both in vitro and in vivo studies, and many studies have found convincing activities of *M. oleifera* as a potent agent with minimal toxicity (Azlan et al., 2022).

It is also documented that the plant *M. oleifera* has a wide range of pharmacological properties, including activities such as antimicrobial, hypotensive, hypoglycemic, immunomodulatory, and anti-inflammatory (Fernandes et al., 2020). *M. oleifera* L., known for its nutritional and medicinal value, has strong antiproliferative effects on several types of cancer (Wang et al., 2020). The use of medicinal plants has increased in recent years due to the presence of numerous biologically active secondary metabolites. Among these metabolites are polyphenols, such as flavonoids, phenolic acids, lignans, and stilbenes. Phenols, carotenoids, and anthocyanidins are plant-derived antioxidants that are effective in controlling excessive free radical activity. Primary free radicals such as superoxide and hydroxyl radicals are generally associated with cell damage and apoptosis. In addition to antioxidants, the presence of antimicrobial agents in medicinal plants has been documented. Therefore, the objective of this literature review was to know the nutritional, microbiological and pharmacological properties of *Moringa oleifera*.

## 2 ORIGIN

*M. oleifera* is a tropical plant native to India (Cheng *et al*., 2019; Merugu *et al*., 2020). The plant can grow well in the humid tropics or warm, dry lands, can survive in less fertile soils, and is also little affected by drought (Sultana 2020). Grown in several areas of Mexico, it belongs to the Moringaceae family, which ranges from 5 to 10 m in height. The flowers, seeds, pods, and leaves of the *Moringa* tree have several medicinal benefits used for therapeutic purposes (Ogundipe *et al*., 2022).

*M. oleifera* is considered a versatile plant due to its multiple uses. The leaves, green pods, and seeds are edible and used as food as part of the traditional diet in many countries in the tropics and subtropics (Nova *et al*., 2020). Also, globally, *Moringa* is known by different names, i.e., benzolive tree, drumstick tree, horseradish tree, mulangay, moonga, saijhan, morango, sajna, mlonge or Ben oil tree (Zainab et al., 2020), thigh tree or miracle tree (Merugu et al., 2020*), tree of life (Pagano et al* 2020 ).

## 3 PHYTOCHEMICAL PROFILE OF THE LEAVES

*Moringa* provides adequate nutrition due to a variety of vital phytochemicals found in the leaves, seeds, and pods (Arora & Arora, 2021). Phytochemical evaluation of M. oleifera dried leaf methanolic extract *suggested that it is rich in broad classes of phytoconstituents, including flavonoids, phenolics, glycosides, and tannins (Suresh* et al., 2020), the total phenolics in the extract were calculated from a standard gallic acid curve, finding a total phenolic concentration of *9.8* mg/mL gallic acid equivalent; the flavonoid content in the extract was obtained of the standard catechinin curve, the total flavonoids in the extract were 0.46 mg/ml.

Components of *M. oleifera* include 9-octadecenoic acid (z), heptadecanoic acid, and phytol acetate (Syeda *et al*., 2020).

The phenolic acids extracted from the leaves of *M. oleifera* are mainly gallic, chlorogenic, ellagic and ferulic acid, while the flavonoid contents are mainly quercetin and kaempferol. On top of that, other parts of *M. oleifera* also contain bioactive compounds that are attributable to each of the potential pharmacological properties and benefits (Azlan *et al*., 2022). In the same way, phenolic compounds have been identified from the hydroethanolic extracts of *M. oleifera*, 24 phenolic compounds were found, 19 of which were glycosylated derivatives of flavonol, 3 phenolic acids and 2 flavan-3-ols. These being (+)-catechin, (-)-epicatechin, quercetin-3-O-rutinoside, apigenin-6-C-glucoside, quercetin-3-O glycoside, kaempferol-3-O-rutinoside, isorhamnetin-3-O-rutinoside, kampferol-3-O-glucoside, and isorhamnetin-3-O-glucoside, respectively, comparing their retention time, UV-Vis with spectra and patterns of mass fragmentation with those of available commercial standards. Only three phenolic acids, peaks 1/2 ([M-H]- to m/z 337) and 4 ([M-H]- to m/z 367), were tentatively identified as cis/trans 3-O-p-coumaroylquinic acid and 3-O-feruloyquinic acid, respectively. Peak 1 had a base peak at m/z 191 (quinic acid) along with a peak at m/z 163 (corresponding to the p-coumaryl acid remainder); peak 2 presented the same chromatographic behavior, which leads to the respective identification of the cis and trans isomers of coumaroylquinic acid (Fernandes et al., 2020), quercetin-O-dihexoside, quercetin-O-acetylhexoside, quercetin-malonylexoside, and quercetin-acetylglycoside-synapic acid were identified.

The second major group of flavonoids identified was that of C-glycosylated apigenin derivatives, identified as apigenin-6,8-C-diglucoside, apigenin-O-hexoside-C-hexoside, and apigenin-C-hexoside. Derivatives of kaempferol, provisionally identified as kaempferol-O-malonylhexoside, were also found. A pseudomolecular ion provisionally identified as kaempferol-O-malonyldihexoside was presented (Fernandes *et al*., 2020).

Moringa *leaves also contain high levels of* fiber (11.23 g/100 g), ash (4.56 g/100 g), carbohydrates (56.33 g/100 g), total protein (9.38 g/100 g ), and lipids (7.76 g/100 g). The plant is an excellent source of essential minerals, such as sodium, potassium, magnesium, phosphorus, iron, zinc, copper, calcium, and manganese (Hodas et al., 2021).*,*

These phytochemicals contribute significantly in the prevention of various health disorders such as cancer, diabetes, cardiovascular disease, age-related functional disorders, arthritis, and inflammation (Zainab *et al*., 2020). It is important to know the phytochemical profile, since there is in *vitro* evidence of the inhibitory activity of plant extracts and/or pure phytoconstituents isolated against enzymes that metabolize carbohydrates, which represents a preliminary step in antidiabetic activity detection programs (Elwekeel *et al*., 2022).

M. *oleifera* seeds contain 19–47% oil, 10–52% protein, and 2.5–20% glucosinolates. *Moringa* glucosinolates are a group of glucosinolates comprising a benzene ring with two rhamnose moiets attached. There are four types of glucosinolates *in M. oleifera that are unique and important functional components of* M. oleifera, the main glucosinolate in M. oleifera *seeds* is GLC (4-αrhamnopyranosyloxy-benzyl *glucosinolate* ). The extracts were simply separated into oil, proteins, and GLCs (Chen *et al*., 2019).

Likewise, in Shanghai, China, using ultra-performance liquid chromatography coupled with mass spectrometry (UPLC-Q-TOF-MS), bioactive components were isolated from the leaves of *M. oleifera*, such as glycosides, phenolics and derivatives and flavonoids and derivatives, components that provide the plant with nutritional, phytochemical, antioxidant, α-amylase, and α-glucosidase inhibitory properties (Gu *et al*., 2020). The amino acid composition is essential for the evaluation of protein quality, the seed had 23.77% essential amino acids, 17 amino acids were isolated (7 non-essential and 10 essential amino acids), expressed in g of amino acid per 100 g of protein, with high content of Glu (22.71 g/100 g of protein) followed by Arg (15.78 g/100 g of protein).

Essential amino acid values ranged from 30.7 to 136.3. Sulfur (Cys and Met) and aromatic amino acids (Phe and Tyr) had the first and second highest values, at 136.3 and 104.3, respectively. In contrast, the lis with the minimum amino acid score of 30.7 being the first limiting amino acid of the M. *oleifera seed protein*.

Seed oil contained 78.44% unsaturated fatty acids, with oleic acid (C18:1) exceeding 70% and 20.60% saturated fatty acids, In addition, palmitic acid (C16:0) and behenic acid (C22:0) had the second and third highest content of 6.99% and 5.02%, respectively (Gu *et al*., 2020). In this regard, Fernandes et al. (2020) identified 21 fatty acids in the lipid fractions of fruits and flowers, while only 14 were detected in seeds. The lipid fraction of the flowers was mainly composed of unsaturated fatty acids (SFA; ~41%, due to the contribution of C16:0, C22:0 and C18:0), followed by polyunsaturated fatty acids (PUFA; 32.4±0.2-37.9±0.1%), α-linolenic acid (C18:3n3) and linoleic acids (C18:2n6). The fruits of *M. oleifera* were abundant in monounsaturated fatty acids (MUFA; 49.0±0.1-55.0±0.6%), particularly those collected in home orchards in Quinhamel, Portugal, due to the high contents of oleic acid (C18:1n9), followed by SFA (31.3±0.2-33.4±0.5%), which predominated in the fruit samples from Bissau, given the high levels of palmitic (C16:0), behenic acid (C22:0) and stearic acid (C18:0). MUFAs also predominated in seed samples (73.1±0.5 – 75.1±0.2%), mainly C18:1n9, but also lower levels of eicosenoic acid (C20:1) and palmitoleic acids (C16:1). SFAs C16:0 and C22:0 were also detected in this part of the plant

Seeds are rich in mineral elements, being especially a good source of Ca in the human diet , S was most concentrated in seeds, exceeding 2000 mg/100 g, followed by K, P, Mg and Ca. In addition, total saponins (146.92 to 169.82 mg GEs/g), total phenolics (37.07 to 40.75 mg GAE/g), total flavonoids (6.85 to 8.43 mg ERs/g) and condensed tannin contents (2.74 to 5.28 mg ECs/g) were identified in different M. *oleifera* seed extracts. Seed extracts exhibited good antioxidant activities as evaluated by different *in vitro* assays, including 2,2-azino-bis-3-ethylbenzothiazloin-6-sulfonic acid (ABTS), 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging capacity, and ferric reducing antioxidant power assays (Gu *et al*., 2020).

## 4 PHARMACOLOGICAL PROPERTIES

The pharmacological properties of *M. oleifera* have been studied for several potential biological properties, such as cardioprotective, antioxidant, antiviral, antibacterial, antidiabetic, and anticancer effects (Azlan *et al*., 2022). However, one of the most studied and published aspects of the applicability of *Moringa* in the diet is its nutritional benefits, especially in populations with a diet low in essential nutrients (Hodas et al., 2021). This is because it has a high growth speed, ease of cultivation and can develop in soils affected by drought. This plant shows a wide range of benefits and is considered to be one of the most useful trees (Rivero et al., 2018).

Each part of *M. oleifera* has its own benefits, and the most studied parts are the leaves and seeds. It has been suggested that the high polyphenol content in *M. oleifera* is one of the factors that contribute significantly to its beneficial health effects. The bioactive compounds of *M. oleifera* have exhibited many remarkable medicinal properties with various potential biological activities (Azlan et al., 2022).

Diabetes control is also achieved through the use of some anti-diabetic compounds that lower blood glucose levels (Al-Ishaq et al., 2019). Most people, especially in developing countries, turn to traditional medicine for the treatment of diabetes using medicinal plants (Feunaing *et al*., 2022).

M. oleifera *extracts* have been studied for their potential hypoglycemic, hypolipidemic, antioxidant, and anti-inflammatory effects. In addition, several animal studies have evaluated the mechanism of action and function *of M. oleifera in models of chronic diseases such as diabetes mellitus, since each part* of the M. oleifera tree provides a mixture of *nutrients and substances capable of producing a diverse range of effects on the body (Vargas-Sánchez* et al., 2019). A study by Watanabe *et al*., (2021) mentions that elevated blood glucose levels of rodents with induced diabetes are significantly reduced by daily oral administration of *M. oleifera extracts*.

*M. oleifera* contains several substances associated with functional and medicinal benefits. These compounds can regulate osmotic control, enzymatic and hormonal activities. Despite the interest, the development of *Moringa* products focused on health applications has a key impediment: the lack of data and clear evidence of its efficacy and safety, mainly in chronic diseases. However, there is preclinical evidence that may stimulate more rigorous studies. Currently, the therapeutic use of *Moringa* is carried out in South Asian medicine (Hodas *et al*., 2021).

M. oleifera *leaf methanolic extract* has beneficial effects against bronchoconstriction, airway inflammation, and asthma. Further exploratory studies may lead to the identification and isolation of potential anti-asthmatic molecules from the plant (Suresh *et al*., 2020),

M. oleifera *leaf* produced benefits against inflammation, bronchospasm, mast cell degranulation, immune reactions, and anaphylactic reactions, the extract inhibits the inflammatory mediator, histamine.

Similarly, at the University of Malta, Cuschieri et al. (2023) demonstrated *that M. oleifera extracts have cerebroprotective effects against ischemic cerebrovascular event because* M. oleifera derivatives *have an effect on the nervous system and can act as neuroprotective agents reducing oxidative stress, although it is still unknown that phytochemical derivatives of* Moringa extract They have that potentially brain-protective effect.

## 4.1 ANTIBACTERIAL EFFECT

Bacterial infections are the most common cause of bovine mastitis, especially *Escherichia coli* (*E. coli*). Clinical mastitis can be diagnosed through visible symptoms such as red, swollen udder or fever in dairy cattle. Therefore, the development of new control and prevention strategies is needed. Severe cases can lead to the death of cows. Acute inflammation responses induced by *E. coli* are usually due to the endotoxin known as lipopolysaccharide (LPS) present in the outer membrane of bacteria. The LPS is recognized by the toll-like receptor 4 (TLR4) which then activates a series of signaling pathways. Therefore, Cheng et al. (2019) examined whether *Moringa* leaf extract could have potential preventive effects on LPS-induced inflammatory responses, due to its potential anti-inflammatory and antioxidant effect using bovine mammary epithelial cells. These studies demonstrated that methanolic extract of *M. oleifera* leaves has beneficial effects on bovine mammary epithelial cells through its anti-inflammatory, antioxidant and casein production properties. The data suggest that *Moringa* extract could be a good food supplement to protect the udder of cows from inflammatory responses due to mastitis.

In Andhra Pradesh, India, Syeda et al. (2020) observed good antibacterial action against three different organisms*: E. coli, Bacillus subtilis (*B. subtilis*) and* Staphylococcus *aureus (S. aureus*) in aqueous infusion of *M. oleifera.* The extraction and isolation of the crude extract of the plant was Soxhlet, by gas chromatography/mass spectroscopy (GC-MS) analysis; for the antibacterial analysis, E. coli Gram negative (MTCC 443) and two Gram positive B. *subtilis* (MTCC 441), *S. aureus* were used as reference strains (ATCC 259323), bacterial strains were cultured overnight at 37°C in Luria-Bertani medium (LB) and the antibacterial activity of *M. oleifera* extract was determined using the well diffusion method.

Similarly, Fernandes et al. (2020) investigated the antimicrobial activity of *M. oleifera* extracts against Gram-positive bacteria Bacillus *cereus (B. cereus), S. aureus* and *Listeria monocytogenes (L. monocytogenes*), *Gram-negative* E. coli bacteria, *Enterobacter cloacae (E. cloacae*) and *Salmonella typhimurium* (*S. typhimurium*), comparing the antibacterial activity of the extract with streptomycin and ampicillin, antibiotics used as positive controls.

In another research conducted in India by Merugu et al. (2020), the antibacterial activity of *M. oleifera fruit extract* synthesized with silver and copper nanoparticles was measured at a concentration of 20 mg against *Pseudomonas putida (*P. putida*),* B. subtilis*, S. aureus*, E. coli , and *Klebsiella* pneumoniae *(*K. pneumoniae); Measuring the halo of the inhibition zone found 77% (*B. subtilis), 82% (*S. aureus*), 76% (E. coli*), 84% (K. *pneumoniae), 80% (*P. putida*) compared to the antibiotic ampicillin at a concentration of 10 mg.*

However, in Perugia, Italy, Pagano et al. (2020) conducted antibacterial assays with hydroalcoholic extract of *powdered leaf of M. oleifera* observing susceptibility against Gram-positive bacteria: *S. aureus, Staphylococcus epidermidis* (S. epidermidis*), Enterococcus faecalis* (E. faecalis*), and* Streptococcus *pyogenes (S. pyogenes*), while no activity was observed against Gram-negative bacteria or yeast. At the concentration of 100 mg/ml, S. *aureus* is the most sensitive showing the highest inhibition halo (30 mm) and also S. *epidermidis and* S. pyogenes showed significant sensitivity (26 and 24 mm, respectively). Decreasing the concentration to 25 mg/mL with *S. epidermidis* was sensitive, while no sensitivity was observed at 12.5 mg/mL and 6.25 mg/mL, respectively.

Also, in the city of Tanta, El-Gharbia Governorate, Egypt, the antimicrobial effect of the aqueous extract of *M. oleifera* leaves on foodborne enterobacteriaceae in ground meat was tested, which were *E. coli* O157:H7, *Salmonella enterica* serovar *typhimurium*, and *S. aureus* (Abdallah *et al*., 2023). The culture of each pathogen strain was cultured in soybean tryptone broth and incubated for 24 h at 37°C. Total plate aerobic count and enterobacteriaceae count could be used as good indicators to determine the quality and safety of meat and meat products.

## 4.2 ANTIFUNGAL ACTIVITY

Fernandes et al. (2020) investigated the antifungal activity of *M. oleifera* extracts against *Aspergillus fumigatus, Aspergillus ochraceus, Aspergillus niger, Penicillium funicolosum, Penicillium achrochloron, and Penicillium* aurantiogriseum*, comparing the antifungal activity of the extract with ketoconazole and bifonazole, antifungals used as positive controls.*

## 4.3 ANTIOXIDANT EFFECTS OF *MORINGA OLEIFERA*

In particular, *Moringa* leaf is an effective source of natural antioxidants. It contains several antioxidant compounds, including phenolic acids, flavonoids, vitamin C, tannin, saponin, phytate, oxalate, alkaloid, cardenolides, and cardiac glycosides (Cheng *et al*., 2019).

The high antioxidant activity of *M. oleifera* is often attributed to the concentration of polyphenolic compounds such as flavonoids (myricetin, quercetin, and kaempferol) and phenolic acids (chlorogenic acid, caffeic acid, and most abundantly, gallic acid) (Nova *et al*., 2020). Antioxidant activities can be beneficial in many applications, and much evidence has shown that dietary polyphenols help alleviate complications of many critical diseases, such as cancer, heart disease, and chronic inflammation that are commonly linked to oxidative stress (Azlan *et al*., 2022).

In vitro *antioxidant assays of M. oleifera methanolic extract with the 2,2-diphenyl-1-picrylhydracyl (DPPH) free radical method, ferric reducing potential (FRAP), super oxide radical (NO) removal, hydrogen peroxide (H2O2) removal time, and the order of antioxidant activity of* M. oleifera methanolic *extract were performed in Andhra Pradesh, India* was FRAP>DPPH>NO>H2O2, the H2O2 with the lowest antioxidant activity (51.4% at 200 mg/ml) (Syeda *et al*., 2020).

The antioxidant activity observed for *M. oleifera* is very important in promoting the wound healing process by protecting the tissue from oxidative damage (Pagano *et al*., 2020).

## 4.4 HYPOGLYCEMIC EFFECT

The hypoglycemic effect of *M. oleifera* leaves has also been associated with their fiber content and the presence of flavonoids and phenolic acids through different mechanisms (Nova *et al*., 2020).

*Moringa* can be used to treat both type 1 diabetes (the condition arises due to a lack of insulin production) and type 2 diabetes (the development of insulin resistance in the body commonly occurs through the malfunctioning of β cells) (Arora & Arora, 2021).

However, Taweerutchana et al. (2017) concluded in their research that M. oleifera leaf had no *effect on glycemic control in type 2 diabetes mellitus; what could be shown is that the use of* M. oleifera had no adverse effects. Interestingly, that study showed that *M. oleifera* leaf had a tendency to lower blood pressure in patients with diabetes.

## 4.5 ANTI-INFLAMMATORY EFFECT

The presence of flavonoids such as quercetin makes M. oleifera leaf extracts *a suitable anti-inflammatory agent due to the inhibition activity of nuclear* factor-kappa B (NF-B*); in addition, the hydroalcoholic extract* of M. oleiferaκ leaf was shown to be able to inhibit the secretion of nitric oxide and pro-inflammatory markers such as prostaglandin E2. tumor necrosis *factor-alpha* (TNF-) and interleukin-6 (IL-6) (Pagano αet al.*, 2020).*

## 5 NUTRITIONAL PROPERTIES

*Moringa* oleifera is a tree that, due to its nutritional properties, has a great impact as a sustainable strategy within the UN's 2030 Agenda, within its second sustainable development goal (SDG) Zero Hunger, M. *oleifera* is a promising tree in the solution of food security problems, since it is currently used in the preparation of food for human consumption. Food sustainability meets the nutritional needs and social well-being of people worldwide for present and future generations.

The leaves and seeds of *M. oleifera* are eaten fresh, powdered, or cooked and contain a varied profile of nutrients and health-promoting compounds, such as fatty acids, tocopherolsβ, -carotene, and phenolic compounds. The fruits are fibrous and are traditionally used to treat digestive problems and to prevent colon cancer (Fernandes *et al*., 2020). The leaves, seeds and pods of M. *oleifera* ensure food because its productivity can be guaranteed on a small and large scale, it is a sustainable and resilient agricultural practice. Backyard agriculture can be generated in each house-room by growing flowers, aromatic herbs, vegetables, fruit trees and from it we obtain organic, nutritional and quality food products. In each family garden, the generational culture of "sowing life" would be fostered, thus ensuring the availability of food.

Fernandes et al. (2020) presented the proximal composition of M. *oleifera* seeds, flowers and fruits collected in Quinhamel and Bissau, Portugal, finding that carbohydrates were the main components in all samples studied; The highest levels were detected in the fruit 71.91±0.04 and 79.6±0.1 g/100 g ps and the lowest in seeds 38.85±0.03 and 41.2±0.3 g/100 g ps. Proteins come in second and seeds show the highest levels (30.0 ± 0.6-31.88±0.08 g/100 g ps), followed by flower and fruit. These last two parts of the plant also had an interesting ash content (total minerals), ranging from 19.83±0.01 to 21.3±0.4 g/100 g dry weight. As expected, the seeds had a higher fat content (~26.3 g/100 g dry weight) than the other edible parts of *M. oleifera.* In addition, the fruits harvested in Quinhamel stood out with a significantly higher fat content (4.3±0.1 g/100 g dry weight) than those harvested in Bissau (2.67±0.06 g/100 g dry weight).

The vitamin C content of fresh *Sajna* leaves was determined by a titrimetric method. The content varied widely between M. *oleifera crops*, *with Chaitali* Myn containing the highest vitamin C content (278 mg/100 g), and the vitamin C content of other cultures ranging from 187.96 to 212.50 mg/100 g. The mineral content of *Sajna* leaves also varied between crops. The calcium content was determined by a titrimetric method. The highest Ca content was found in *Baromashi Myn (2,645 g/100 g), followed by* Chaitali *Mym (2,164 g/100 g*). The phosphorus content was determined by a spectrophotometric method, *Barsali* Joy contained the highest P concentration (0.304 g/100 g DM). K contents were determined by a flame photometric method, *Barsali* Joy also contained the highest K content (2,025 g/100 g DM) (Sultana 2020).

Chromatographic analysis made it possible to detect and quantify sugars such as fructose, glucose, sucrose and trehalose. Only glucose and fructose were found in the seeds. The highest levels were quantified in fruits (16.7±0.1 – 18.8±0.2 g/100 g bw), followed by flowers (11.1±0.1-12.0 ± 0.2 g/100 g fw) and, finally, by seeds with significantly lower levels (1.32 ± 0.09 – 1.86 ± 0.06 g/100 g fw) (Fernandes *et al*., 2020).

Regarding organic acids, the analysis allowed the identification of oxalic, malic, ascorbic, citric and fumaric acids in samples of flowers and fruits of *M. oleifera.* Citric and malic acids were the main compounds, while only traces of fumaric acid were detected. The fruit harvested in Bissau, Portugal contained a higher level of ascorbic acid (0.65 ± 0.02 g/100 g fw) than those from Quinhamel, Portugal, the total organic acid content ranged from 4.71 ± 0.02-5.75±0.02 g/100 g pf in fruits to 5.85±0.01 – 6.42±0.01 g/100 g pf in flowers. In the seeds of *M. oleifera*, ~10.5 g/100 g fw of oxalic acid was quantified, approximately twice the total organic acid content found in the other two parts of the plant. Traces of fumaric acid were also detected (Fernandes *et al*., 2020).

Recently, in Brazil, with a multidisciplinary approach, Rodrigues et al. (2023) developed a commercial beverage with a multifaceted approach with a multifaceted approach with a multifaceted approach with a multidisciplinary approach, with a multidisciplinary approach, with a multidisciplinary approach, with a multidisciplinary approach.Analyses performed with the analytical technique of high-resolution liquid chromatography with diode array detector (HPLC-DAD), this technique allows the separation, identification (by comparison with standards) and quantification of the different chemical species of a mixture in solution. The analyses revealed a significant chemovariation in phenolic compositions between commercial Moringa beverages *and a soluble Moringa powdered beverage* , the latter showing the highest concentration of phenolic and flavonoid compounds, with potent antioxidant capacity. However, this sample was the least preferred by consumers because it had high levels of Cd, exceeding the WHO acceptable values of 0.3 mg/kg. In the sensory evaluation, the sweet and floral taste was pleasant, on the contrary, with the herbaceous flavors, the presence of acid, bitter taste and precipitate formation were considered unfavorable sensory attributes. Consumers reported a sense of health, well-being, relaxation and leisure with Moringa drinks.

## 5.1 BIOACTIVE PROPERTIES OF *M. OLEIFERA*

In Portugal, in order to evaluate the bioactive properties of the different edible parts of *M. oleifera*, pre-cooked extracts, hydroethanolic extracts and infusions were prepared. The fruit was traditionally prepared as a culinary vegetable, stewed in curries and soups. On the other hand, the seeds and flowers, the ripe seeds are fried and eaten like peanuts and added to sauces for their bitter taste.

The flowers are cooked and eaten mixed with other foods or fried in butter or oil (Fernandes *et al*., 2020).

In India, *M. oleifera* has been a major component of the diet for a long time, the leaves of the plant and fruit are used in traditional medicine and as vegetables (Merugu *et al*., 2020).

Recently, Nelwamondo et al. (2023) performed the biosynthesis of magnesium oxide (MgO) and calcium carbonate ($CaCO_3$) nanoparticles using *M. oleifera* extract and its effectiveness on the growth, yield, and photosynthetic performance of peanut (*Arachis hypogaea)* genotypes L.) tested at different concentrations of 50, 100 and 200 mg/L. The findings demonstrated that foliar application of MgO and CaCO3 nanoparticles positively affected peanut biomass production. The Results

revealed that the concentration of 50 mg/L of MgO and 100 mg/L of $CaCO_3$ significantly improved the growth, yield and productivity of peanut plants. Therefore, foliar application of nanoparticles of 50 mg/L MgO and 100 mg/L $CaCO_3$ could be recommended as a nanofertilizer application rate for peanut production.

## 6 FUNCTIONAL PROPERTIES

The crude protein content varied significantly between the different M. *oleifera* cultures, ranging from 22.99 to 29.36%. The highest protein content was found in *Barsali* Joy, while the lowest was found in *Chaitali* Myn. *Chaitali* Joy contained the highest crude fat content, while *Baromashi* Myn had the lowest content. The fiber content was highest in *Chaitali* Joy, while the lowest was found in *Baromashi* Myn. In terms of carbohydrate content between crops, there was no significant variation (Sultana 2020).

In Guangxi, China, Tang et al. (2021) evaluated the effect of ultrasonic power on the structure and functional properties of water-soluble protein extracted from defatted M. *oleifera* seeds. The behaviors indicated that ultrasound had a significant effect on the tertiary structure of the water-soluble protein of *M. oleifera* seed. Its solubility, foaming properties, and emulsifying properties first increased and then decreased as ultrasonic power increased. The ultrasonic treatment altered its functional properties, which could be

attributed to exposure of the hydrophilic group and change of secondary and tertiary structure. Therefore, ultrasonic treatment could effectively improve the thermal stability of *M. oleifera* seeds, results that provide a useful theoretical basis for understanding the mechanism of ultrasonic treatment and thus its potential application in food processing.

Aqueous and ethanolic extracts of *M. oleifera* leaves were evaluated *in vitro* to determine their main active components and to determine their immunostimulant, cytotoxic, antitumor, bactericidal and antioxidant activities. The phytochemical analysis of the extracts showed higher amounts of phenolic and cyanogenic glycosides in the aqueous extracts than in the ethanolic extracts, characterized by several flavonoids, condensed tannins and saponins. In addition, the aqueous extract showed marked cytotoxic effect on SAF-1 fibroblast cell lines (at doses greater than 0.01 mg mL-1) and PLHC-1 high-performance liquid chromatography (at doses greater than 0.25 mg mL-1). The ethanolic extract improved the viability of SAF-1 cells and decreased the viability of PLHC-1 cells when used at higher concentrations. Both ethanolic and aqueous extracts showed significant bactericidal activity on pathogenic strains of *Vibrio anguillarum* and *Photobacterium damselae*. The joint results on the cytotoxic, bactericidal and antioxidant activities of *M. oleifera* leaf extracts point to their possible use as additives in functional diets for farmed fish (García-Beltrán *et al*., 2020).

Kotsou et al. (2023) conducted research on feeding the larva or mealworm (*Tenebrio molitor*), certified by the European Food Safety Agency (EFSA) for human consumption and has become the most sustainable food than traditional protein sources. In order to increase their nutritional value and make them a valuable component of the human diet, *M. oleifera* leaves were used in different proportions (up to 50%) as a substitute for wheat bran (the commonly used feed), to evaluate their effect on the growth and development of larvae, as well as their crude protein composition. fats and fatty acids, ashes, vitamins, and antioxidants. It was found that the addition of *M. oleifera* leaves to the feed had no negative impact on the development and survival of the insects, registering an increase in their nutritional value in crude protein of up to 22.61% and vitamin C and A content of up to 40.74% and 491.63%, respectively. Therefore, the use of *M. oleifera* leaves as a food additive are highly recommended for raising larvae to improve the nutritional value of insects.

## 6.1 COMPOSITION AND COAGULATING EFFECT OF *M. OLEIFERA SEEDS*

The seeds of *M. oleifera* were dried, crushed and sifted to remove particles larger than 0.85 mm (mesh 20), and the powder obtained was called M1. The oil extracted from the seeds was M2, the extraction of the oil was carried out by means of a Soxhlet extractor and n-hexane as solvent at 70°C to constant mass. The results revealed that the content of aromatic and phenolic compound fatty acids of the M1 and M2 samples decreased after oil extraction by 69.94±1.40% and 48.38±4.19%, respectively, values that were consistent with the typical profile of oilseeds and, therefore, allowed to classify *M. oleifera* seeds as oilseed material (Magalhães *et al*., 2021). The proteins with coagulating and flocculant properties were retained in the oil extracted from the seeds. Water treatment by coagulation followed by dissolved air flotation was not significantly different between the two samples, and its mean oil and grease removal efficiency was approximately 82.43±0.70%. These results confirm the promising use of *M. oleifera* seed residues for the removal of oils and fats from wastewater as a more affordable, sustainable, and natural alternative (Magalhães *et al*., 2021).

In this regard, at a University in Ethiopia, water purification has been improved using *M. oleifera seeds and extract pastes for coagulation after wastewater filtration (Dandesa* et al., *2023),* *seeds were removed from the seed husk or coat,* M. oleifera seeds were crushed using mortar to obtain a fine powder and sifting the powder through a small mesh. The powdered seed powder was mixed with a small amount of deionized water to form a paste and then stirred for 1 min to activate the coagulant, the solution is filtered with cloth/mesh to remove the insoluble part/residue of the paste. Different doses of coagulant paste were added to the wastewater, tested in synthetic turbidity solution, $PO_{4}$–3, F− and Fe+3, and stirred at 120 rpm for 1 min. It was left to settle for 24 h to separate the flocs. When the particles have settled to the bottom, clean water can be obtained, this is transferred to a VSco® filtration tank for final filtration and thus have completely safe water to drink.

## 6.2 INDUSTRIAL APPLICATION OF *M. OLEIFERA*

In Southern Africa, Ngom et al. (2020) worked on the biosynthesis of zinc oxide nanoparticles (ZnO-NP) using natural flower, seed, and leaf extracts of *M. oleifera* as chelating and/or oxidizing/reducing agents of zinc nitrate hexahydrate. The structural and optical properties of the ZnO-NP obtained by the leaves are slightly different from those obtained

with the other excerpts. The average size of ZnO-NP crystals calculated by X-ray diffraction analysis are 13.2, 13.9, and 10.8 nm for ZnO-NP synthesized by flowers, seeds, and leaves, respectively.

Currently, in Zaragoza, Spain, innovative food packaging systems have been developed to prolong shelf life made with waste from the food industry and ethanolic extract and acetone from *M. oleifera* leaves for its antioxidant power, a property that characterizes it by its high phenolic content (Barzan *et al*., 2024), extracts were incorporated into the packaging as coatings or interlayers, both systems showed significant protection against free radicals in *vitro* (50% antioxidant power) and more than 50% prevention of lipid peroxidation of ground beef for 16 days by, analyzed with direct measurements of high-resolution photonic technique in situ Raman microspectroscopy.

The *M. oleifera* tree offers multiple benefits, so more research is required to understand and apply its chemical constituents, functional properties, and to be able to develop pharmacological products. It is a good option for the search and application of nutritional, chemical, medicinal, industrial, agricultural, among others, for the benefit of the living being. In the food industry, *M. oleifera* can be a natural food preservative, it is a promising product for using natural food additives.

## 7 CONCLUSION

The scientific evidence of the nutritional, microbiological and pharmacological properties of *Moringa oleifera* offers therapeutic alternatives such as antitumor and above all food, it is a promising tree in the solution of food safety problems for human beings. *M. oleifera* brings with it the solution to problems of the general population such as malnutrition, environmental pollution, diseases that affect humanity.

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