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A comprehensive review of *Moringa oleifera* Lam.: A valuable plant in food and medicine

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Abstract *Moringa oleifera* Lam. (Moringacase) is a fast-growing, woody plant found in African countries, regions bordering the Himalayas, India, and Pakistan. Reports indicate that *M. oleifera* is a potential food source to address hunger crises and combat human malnutrition. Additionally, *M. oleifera* seeds serve as a source of vegetable oil, known as Moringa oil, providing various health benefits. Moringa seed oil is highly nutritious, containing a high level of oleic acid (>75%) and higher amounts of vitamins B and C than other nutritious vegetables, such as spinach. Moreover, *M. oleifera* contains various bioactive compounds including flavonoids, carotenoids, steroids, terpenes, linoleic acid, behenic acid, etc. Different parts of the plant contain bioactive compounds exhibiting anti-inflammatory, antibacterial, antioxidant, anti-hypertensive, and blood sugar-stabilizing properties. Furthermore, *M. oleifera* is known in traditional medicine for treating various ailments, such as skin wounds, inflammation, disinfection, fever reduction, constipation, and asthma, and stimulating milk production in breastfeeding women. However, despite its potential applications in industries, agriculture, wastewater treatment, and medicine, *M. oleifera* still needs to be explored. This article provides an overview of the chemical composition, nutritional content, biological activities, and applications of *M. oleifera* based on scientific literature and research studies.

Keywords: Food, Health, Nutrition, Oil, Phytochemicals

Introduction

Moringa oleifera Lam. is the most common woody plant species in the *Moringa* genus. They can thrive and survive in harsh climatic conditions, hot and arid regions, and humid tropical climates. The plant is widely distributed from South Asia through the Arabian Peninsula, Madagascar, and Africa (Pandey *et al*., 2012). Northwestern India is known as one of the primary regions for the cultivation of this plant (Meireles *et al*., 2020).

Moringa oleifera is a medium-sized woody plant with many sprawling branches. Its leaves are approximately 30–50 cm long, dark green, and grow in

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clusters of three. The small leaves are symmetrical and elliptical. Its flowers are white, forming large clusters with a sweet fragrance. The pods are straight and can grow up to 50 cm long. When fresh, the pods are bright green, while when dried, they turn dark green or black with either soft or hard shells. When removed, the seeds are white with various undefined shapes, such as round or flat, with three angular wings (Patil *et al*., 2022). The plant has various health benefits, and each part, including roots, stems, leaves, pods, and seeds, can be utilized. *M. oleifera* is considered a source of fiber-rich food and medicinal properties (Pandey *et al*., 2012; Patil *et al*., 2022). Additionally, *M. oleifera* is known by many other names, such as drumstick tree or horseradish tree (Figure 1).

In Vietnam, *Moringa oleifera* grows naturally in the Ninh Thuan, Binh Thuan, Dong Nai, Ba Ria - Vung Tau, and Kien Giang provinces (Chau and Sam, 2021). This plant favors tropical regions, making Vietnam an ideal place for growth and development.

Figure 1. *Moringa oleifera* tree

Moringa oleifera contains various plant components such as alkaloids, saponins, tannins, steroids, phenolic acids, glucosinolates, flavonoids, and terpenes. The diversity of these phytochemical compounds contributes to numerous pharmacological applications. It can help reduce fever, lower blood cholesterol, fight inflammation, alleviate pain, and combat cancer. Additionally, *M. oleifera* contains antioxidant and antibacterial compounds (Abd Rani *et al*., 2018).

In traditional medicine, almost all parts of *M. oleifera*, including leaves, pods, bark, flowers, roots, seeds, and seed oil, have been used to treat various human ailments, as they have liver protection, fever reduction, and anti-convulsant effects (Hamza and Azmach, 2017).

Despite its superior properties, this plant's exploitation is quite limited, especially in Vietnam. Exploiting *M. oleifera*'s full potential in food and medicine will contribute to expanding its cultivation, improving farmers' income, and opening up many new research directions for human health.

Chemical components of *Moringa oleifera*

Moringa oleifera has high nutritional content, serving as a source of vitamins, especially vitamins A and C, and various minerals, including Ca, P, K, Fe, Cu, S, and Mg. (Mohlala *et al*., 2023). Each part of *M. oleifera* has different medicinal properties and effects, such as cardiovascular protection (Biswas *et al*., 2012), fever reduction (Dubey *et al*., 2013), anti-cancer (Jung *et al*., 2015), anticonvulsant (Rajasree *et al*., 2012), anti-inflammatory (Bhattacharya *et al*., 2014), gastric ulcer and colitis treatment and prevention (Devaraj *et al*., 2007), antispasmodic (Anwar *et al*., 2007), diuretic and laxative (Islam *et al*., 2020), cholesterol reduction (Reddy *et al*., 2017), antioxidant (Sreelatha and Padma, 2009), diabetes treatment (Mohamed *et al*., 2019), liver protection (Muzumbukilwa *et al*., 2019), and antibacterial and antifungal activity (Rahman *et al*., 2008). The chemical components of *M. oleifera* are contained in various parts of the plant, including leaves, seeds, roots, flowers, resin, bark, and fruit peel. These compounds have been extensively studied and classified into the following groups: flavonoids, carbamates, glucosinolates, phenols, steroids, and carotenoids (Table 1).

Bark and roots: The bark and roots can be utilized for antibacterial purposes. Extracts from bark and roots, in combination with ethanol, methanol, and distilled water, are effective against fungi, such as *Neurospora crassa* and *Aspergillus niger*, with higher concentrations leading to increased mycelial inhibition, lasting up to 96 hours (Meireles *et al*., 2020). Additionally, the roots of *M. oleifera* are used clinically for anti-inflammatory therapy (Ezeamuzie *et al*., 1996). Choudhary *et al*. (2013) demonstrated that root bark extract at a dosage of 500 mg/kg acted as an anti-peptic ulcer agent in rats. Furthermore, it also contains an abundant source of alkaloids such as morphine and moriginine, and minerals such as Ca, Mg, and Na (Dhakad *et al*., 2019).

Flowers: The flowers of *M. oleifera* contain a variety of antioxidant compounds, such as ascorbic acid and carotenoids, as well as tannins, flavonoids, alkaloids, and glycosides (Meireles *et al*., 2020). Moreover, the flowers of this plant are also used to produce honey because they are a good source of nectar. Additionally, the methanol extract of *M. oleifera* flowers exhibits anti-cancer properties, inhibiting 50% of PC3 cell growth at doses of 22.61 and 6.25 µg/mL between 24 and 48 hours (Ju *et al*., 2018).

Table 1. Some of the chemical compounds present in the parts of *Moringa oleifera* Lam

No.	Compound name	Part	References
	Flavonoid		
1	Quercetin-3-O -(6"-malonylglucoside)	Leaves	Bennett *et al*. (2003)
2	kaempferol-3-O -(6"-malonylglucoside)		
3	Isoquercitrin		Sahakitpichan *et al*. (2011)
	Carbamates		
4	Lasiodiplodin	Trunk	Chen *et al*. (2014)
5	p-Hydroxybenzoic acid		
6	Methylparaben	Root bark	
	Phenol		
7	Cryptochlorogen acid	Leaves	Vongsak *et al*. (2014)
8	p-hydroxybenzaldehyde	Stem, root bark	Chen *et al*. (2014)
	Glucosinolates		
9	Niazirin	Seed	Cheenpracha *et al*. (2010)
10	Methyl-1-aminopentasulfide-5-sulfinate	Shell	Faizi *et al*. (1997)
	Steroid		
11	β-Sitosterone	Root	Paikra and Gidwani (2017)
	Carotenoid		
12	β-Carotene	Leaves	Saini *et al*. (2014)
13	Lutein		
	Other compounds		
14	Glycerol-1-(9-octadecanoate)	Seed	Guevara *et al*. (1999)
15	D-mannose	Flower	Paikra and Gidwani (2017)
16	α-Phellandren	Root	

Leaves: The leaves of *M. oleifera* contain numerous minerals (Ca, Zn, K, Fe, and Cu) and vitamins (beta-carotene of vitamins A, folic acid, pyridoxine, and nicotinic acid, vitamins B, C, D, and E) that can be utilized to treat malnutrition (Moyo *et al*., 2011). Moringa leaves are also used as a substitute for iron tablets because they help treat anemia in humans (Meireles *et al*., 2020). *M. oleifera* leaves have a low calorific value and can be incorporated into the diets of obese individuals. In particular, the leaves of this plant provide

25.5–31.03 mg of Zn/kg, enough to meet the daily Zn requirement in the diet, essential for proper sperm cell development and DNA and RNA synthesis (Barminas *et al*., 1998).

Pericarp: The pods of *M. oleifera* are known to contain a high amount of fiber (46.78%), amino acids such as palmitic acid, linoleic acid, and oleic acid, and two important compounds, β-carotene and sterols, which are considered strong inhibitors of reactive oxygen species (ROS), helping prevent colorectal cancer and digestive issues (Gupta *et al*., 2010; Kim *et al*., 2019).

Seed: Moringa seeds are a significant source of minerals (Ca, P, and Fe) and vitamins (A, B, and C) and are rich in protein but contain very little fat or carbohydrates (Figure 2). However, the protein, fat, and mineral content (especially Mg) in Moringa seeds has been reported to be significantly higher than in Moringa leaves (Gopalakrishnan *et al*., 2016; Bolarinwa *et al*., 2019). Oral intake of *M. oleifera* seed extract at 1 g/kg daily has been shown to improve cirrhosis in rats, reducing liver damage and cirrhosis symptoms (Hamza, 2010).

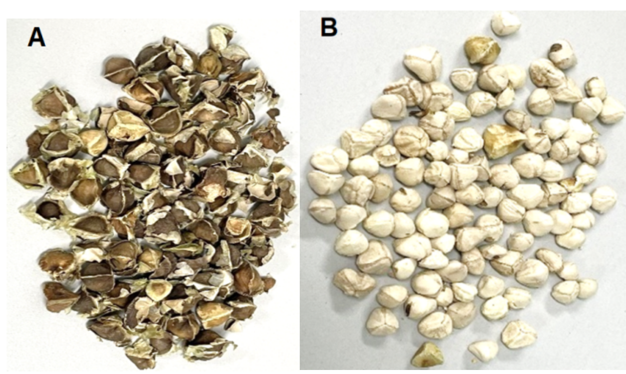

Figure 2. *Moringa oleifera* Lam. seeds before (A) and after (B) husking

Ingredients and oil extraction methods from moringa seeds

Compared to other oil-producing plants, Moringa seed oil is less common due to its higher market value. Among a range of common vegetable oils such as soybean, peanut, sunflower, and olive oils, Moringa seed oil is priced 2–3 times higher based on the same volume of oil. However, Moringa seed oil has become popular in the cosmetics industry as it is believed to have the ability to support, improve, and treat skin and hair issues (Nadeem and Imran, 2016). The use of Moringa seed oil for cooking is limited, as it is scarce in commercial markets, supermarkets, and grocery stores. Therefore, consumer access to commercial cooking oil markets for Moringa seed oil is restricted, but it has the potential to become a promising source of cooking oil in the future.

Additionally, Moringa seed oil has seen significant growth in the pharmaceutical and cosmetics industries. Therefore, overlooking these shortcomings, Moringa seed oil is comparable to other vegetable oils in terms of quantity and quality.

The seeds are protected by an outer husk layer, and the inner fruit flesh is extracted after removing the husk layer. The pressing process takes place at temperatures above 170 °C. The amount of oil obtained depends on various factors such as the variety, temperature, and equipment used. (Figure 3). Sensory evaluation of the oil after pressing reveals a shiny golden color, a fragrant aroma similar to peanuts, and a slightly bitter taste but with a sweet aftertaste. These characteristics are considered unique for identifying oil. The shelf life of the oil depends on its stability before the oxidation process. When compared to olive oil, Moringa seed oil is of higher value. Therefore, Moringa seed oil is seen as a potential substitute for olive oil in terms of quality (Fu *et al*., 2021).

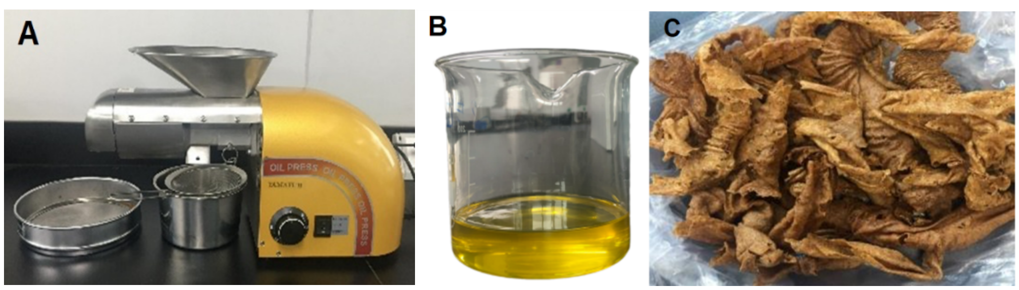

Figure 3. Oil press machine (A), Moringa oil (B), and Moringa seed oil residue (C)

The process of extracting triglycerides from oil-bearing seeds is called extraction. Over the decades, conventional extraction processes have been mechanical and chemical. For mechanical pressing, seeds are placed between shields, where the volume available for seeds is reduced due to compression, thus squeezing the oil out of the seeds. Mechanical oil extraction includes hydraulic pressing (cold pressing) or screw pressing (hot pressing), controlled by an engine. Although mechanical pressing is effective, it often results in very low oil yields. According to research by Cheikhyoussef *et al*. (2020), the cold pressing process takes place under the following conditions: Seeds are dried at 35–40 °C before oil extraction, and then the seeds are ground into fine powder with added water (1 seed: 2 water) or simply ground into fine particles when extracted using an oil press. The oil yield after mechanical pressing is 11–62%. The crude oil undergoes a degumming process. Up to 98.7% of the oil is recovered after the degumming process of cold-pressed Moringa seed oil.

Additionally, the use of chemicals for oil extraction is common, and Moringa seed oil is no exception. The prescribed conditions include a Soxhlet system and n-hexane solvent. With kernel sizes of 500 µm, the extraction time is 8–10 hours, and the temperature is 65–75 °C. The highest oil yield obtained from Moringa oil has been 43.01% by weight (Abdulkareem *et al*., 2011; Efeovbokhan *et al*., 2015).

In the oil processing industry, significant solvent losses in the atmosphere occur, along with prolonged extraction times, so it is essential to introduce environmentally friendly methods. Advanced extraction techniques, such as Supercritical Fluid Extraction (SPE), are scientific alternatives. Optimized CO_2 extraction of Moringa seed oil maximizes oil yield. The optimal process conditions for CO_2 supercritical fluid extraction of Moringa seed oil are an extraction temperature of 45 °C, extraction time of 2.5 hours, extraction pressure of 50 MPa, and CO_2 flow rate of 240 L/h, resulting in a maximum yield of 38.54% (Chen *et al*., 2022).

Nutritional value of Moringa oil

The importance of fats has been affirmed in nutritional diets. Fats play a crucial role in generating and storing energy for the body. Choosing and using fat sources has health benefits and is always a concern for consumers. Understanding the health protection issue when incorporating lipids into the body requires selective use, and the emergence of various vegetable oils brings innovation along with improving human health benefits. Among a range of familiar vegetable oils, such as soybean, olive, and coconut oil, one not widely known but still relevant is Moringa oil. The oil source from the *M. oleifera* tree is ranked second only to palm oil (Table 2) (Ghazali and Mohammed, 2011).

Table 2. The oil content in *Moringa oleifera* seeds and some other oil-bearing seeds

Oils	Content (%)
Moringa oil (MOO)	38–42
Sunflower oil (SFO)	37–40
Mango kernel oil (MKO)	13–15
Cottonseed oil (CSO)	18–20
Palm oil (PO)	46–50
Chia seed oil (CHO)	35–40
Soybean oil (SBO)	18–20
Watermelon seed oil (WSO)	35–40
Linseed oil (LSO)	40–42

According to the data in Table 2, the potential oil source in *M. oleifera* has significant economic value to the vegetable oil industry. With its high oil content (up to 42%), ranking second only to palm oil (50%), Moringa oil presents itself as a promising factor for future development, offering excellent nutritional benefits for health. Therefore, Moringa oil is considered capable of meeting the criteria of nutrition and health; although this is relatively less known, it can be realized through proper utilization.

Table 3. Composition, saturation, and unsaturation of fatty acids of Moringa oil (Gharsallah *et al*., 2021)

Fatty acids	Percent (%)
Palmitic acid (C16:0)	6.11±0
Palmitoleic acid (C16:1)	1.4±0.09
Stearic acid (C18:0)	5.37±0.45
Oleic acid (C18:1)	73.36±0.22
Linoleic acid (C18:2)	1.01±0.06
Linolenic acid (C18:3)	0.44±0.22
Arachidic acid (C20:0)	3.26±0.04
Gadoleic acid (C20:1)	2.21±0.25
Behenic acid (C22:0)	7.71±0.2
Lignoceric acid (C24:0)	0.66±0.27
SAFA - Saturated fatty acid	21.11±0.65
MUFA - Monounsaturated fatty acid	76.97±0.19
PUFAs - Polyunsaturated fatty acids	1.45±0.16

Based on the data in Table 3, there are several good sources of fatty acids, such as oleic acid (73.36%), monounsaturated fatty acids (76.97%), polyunsaturated fatty acids (21%), and behenic acid (7.71%) in Moringa oil. Among them, the ratio of saturated fatty acids (SAFA) to unsaturated fatty acids (MUFA) is 1:3, meaning that one unit of SAFA is replaced by three units of MUFA. The threefold higher content of MUFA than SAFA allows Moringa oil to be utilized for various purposes ranging from pharmaceuticals and cosmetics to becoming the best cooking oil source. One study showed that was found that a diet supplemented with high levels of unsaturated fats reduced the very low-density lipoprotein density in serum by 22%, cholesterol by 22%, and neutral fat by 19% in diabetic patients. Another study claimed that feeding mice a diet rich in monounsaturated fatty acids significantly reduced inflammation (Alagawany *et al*., 2022). Additionally, with a high content of unsaturated fatty acids, it is suitable for industries such as paint, soap, and perfume. Moreover, it is considered suitable for medicinal products, with oleic acid accounting for over 70%, and functional foods due to its cholesterol-lowering effects (Reddy *et al*., 2017). It has preventive effects against cardiovascular diseases and cancer (Biswas *et al*., 2012; Jung *et al*., 2015). This indicates that it is a good source of healthy fats for human consumption (Oyeleye *et al*., 2019; Alhassan *et al*., 2019). In addition to containing a high amount of oleic acid, a remarkable characteristic of Moringa oil is its high antioxidant capacity under stringent conditions, such as deep frying at high temperatures and for extended periods. This makes Moringa oil a nutritious and stable option without altering its nutritional essence during long-term use (Abdulkarim *et al*., 2007).

Not only does Moringa oil possess an extremely high antioxidant capacity compared to other vegetable oils, such as soybean, sunflower, and rapeseed, but its good fatty acid composition and other neutral fat components also make it suitable for various purposes, including edible and non-edible uses. Numerous studies have indicated that Moringa oil has a glossy yellow color and a pleasant odor, reminiscent of peanut oil. Based on its color and appealing aroma, Moringa oil is attractive for direct consumption without requiring any mandatory processing steps, such as refining, bleaching, or deodorizing, which are used for other commercial oils. For instance, soybean oil has a dark red color and a strong characteristic odor, requiring additional processing steps to produce a safe and usable product (Nadeem and Imran, 2016).

Table 4. Levels of fatty acid components in Moringa oil compared to some other seed oils (Gharsallah *et al*., 2021)

Fatty acids	MOO (%)	SBO (%)	CO (%)	SFO (%)	PO (%)
C12:0	0.5	-	-	-	0.10
C14:0	-	0.1	0.2	-	1.24
C16:0	6.65	11	3.9	6.8	37.9
C18:0	2.28	4.0	1.9	4.7	4.11
C18:1	78.04	23.4	64.1	18.6	43.9
C18:2	4.16	53.2	18.7	68.2	13.4
C18:3	-	7.8	9.2	0.5	0.45
C20:0	2.46	0.3	0.6	0.2	0.38
C20:0	5.84	0.1	0.2	-	-

Note: MOO (Moringa oil); SBO (Soybean oil), CO (Canola oil), SFO (Sunflower oil), PO (Palm oil)

As shown in Table 4, when compared to other oils, such as soybean, sunflower, rapeseed, and cottonseed oils, Moringa oil exhibits prominent advantages. First, the oleic acid content of Moringa oil reaches 78.04%, which is higher than that of the other oils. Studies have shown that oleic acid acts as a precursor to omega-9 fatty acids, which have anti-inflammatory and anticancer effects (Nadeem and Imran, 2016). A range of anti-inflammatory activities include eye inflammation, skin inflammation, liver inflammation, lung inflammation, and ulcerative colitis inflammation. The anticancer effect is noted in the prevention of breast cancer with a diet rich in olive oil (Farag and Gad, 2022). Additionally, a rare fatty acid component, behenic acid, accounted for a significant proportion (5.8–6.2%). This is considered a structural and thickening agent, offering the potential for replacing vegetable butter (Warra, 2012). A study revealed that blending sunflower oil, soybean oil, and rapeseed oil with Moringa oil alters the characteristic properties of these oils. Through storage, the blending of sunflower, soybean, and rapeseed oils with Moringa oil results in lower concentrations of primary and secondary oxidation products during long-term storage. These findings demonstrate that Moringa oil can be used to enhance the oxidative stability of oils (Nadeem and Imran, 2016).

Furthermore, *M. oleifera* seeds can yield 30–40% high-quality oil, containing a substantial amount of oleic acid suitable for participating in biodiesel production. Scientific evidence indicates that biodiesel made from *M. oleifera* oil surpasses biodiesel made from other substances. Moreover, biodiesel derived from Moringa oil has a higher iodine value than conventional diesel fuel. This demonstrates that biodiesel based on *M. oleifera* offers stability and sustainability (Nadeem and Imran, 2016).

Functions of bioactive compounds contained in *Moringa oleifera* for human health

According to a study by Gupta *et al*. (2018), the diversity of *M. oleifera* as a plant is astonishingly acknowledged as the “miracle tree” due to its versatility across numerous applications in medicine, cosmetics, food technology, and biofuels and providing immense nutritional value; hence it was honored with the title of “Plant of the Year 2007” by the US National Institute of Health. Additionally, *M. oleifera* is a promising candidate to become a food source if cultivated widely and extensively due to the treasure trove of proteins, lipids, vitamins, and minerals it contains. Apart from macronutrients, *M. oleifera* is favored as a food source because it provides a plethora of non-nutrient compounds or phytochemicals (biologically active compounds), making it highly beneficial for both human and animal health (Arora *et al*., 2013).

Due to its inherent nutrient content, derivatives from various parts of the plant yield a wide range of biologically active compounds with multifunctional effects, including carotenoids, polyphenols (represented by myrecytin, quercetin, and kaempferol), alkaloids, glucosinolates, isothiocyanates, tannins, and saponins. Table 5 presents a list of some bioactive components that have biological activity against or treat specific diseases and the corresponding references.

Table 5. Bioactive activities in *M. oleifera* and their positive effects on chronic diseases

Ingredient	Effects	Subjects	References
Flavonoid (Quercitin)	Blood sugar lowering properties. Aid in treating diabetes	Zucker mouse	Rivera *et al*. (2008)
	Lowering blood fat. Preventing atherosclerosis	Rabbit	Juzwiak *et al*. (2005); Kamada *et al*. (2005)
	Reducing DGAT (diacylglycerol acyltransferase) expression. Improving fatty liver condition	Guinea fowl	Das *et al*. (2012)
	Inhibiting cholesterol esterase and α-glucosidase. Treating cardiovascular disease and diabetes	Rat intestinal and porcine pancreas	Adisakwattana and Chanathong (2011)
	Inhibiting NF-kB activation. Helping to improve heart health	Mouse	Siddhuraju and Becker (2003)
Alkanol	Cardio protection	Mouse	Panda *et al*. (2013)
Tannins	Anti-inflammatory	Mouse	Richter *et al*. (2003)
Isothiocyanate	Reducing signs of inflammation. Improving cardiovascular disease status	Raw macrophages	Kooltheat *et al*. (2014)
	Inhibiting NF-kB signaling. Preventing cancer development Intestinal epithelial cells	Breast Cancer Cells	Khalafalla *et al*. (2010)
	Reducing insulin resistance. Supporting diabetes treatment	Rat	Fernandez (2017)
B-Sitosterol	Reducing cholesterol absorption. Preventing cardiovascular disease High-fat diet-fed mice	Rat	Halaby *et al*. (2013)

Applications of Moringa oil for human health

Cholesterol-lowering and blood pressure control: High blood pressure is a leading cause of cardiovascular diseases and premature death worldwide. The global prevalence of hypertension doubled from 1990 to 2019 (Nugroho *et al*., 2022). In 2019, a study revealed that the seeds and leaves of *M. oleifera* regulate the activities of enzymes related to hypertension and lipid metabolism in mice fed a high-fat diet (Oyeleye *et al*., 2019). According to the research, supplementation with Moringa oil at a dose of 200 mg/kg/day in daily meals for 120 days showed the potential to reduce serum cholesterol, phospholipids, triglycerides, and fat in the liver, heart, and major arteries compared to not using supplemental oil. Furthermore, supplementing the above dose could effectively replace the use of lovastatin (a cholesterol-lowering and low-density lipoprotein, triglyceride-lowering drug) without the need for drug abuse (Mehta *et al*., 2003).

Anti-cancer properties: Cancer is one of the leading causes of death worldwide. In 2015, an estimated 17.5 million cancer cases were reported, followed by 8.7 million deaths (Azamjah *et al*., 2019). Niazimicin lacks inhibitory activity, while niaziminin and 4-[(4′-O-acetyl-α-lrhamno syloxy)benzyl]isothicyanate found in *M. oleifera* are potent inhibitors of the Epstein–Barr virus, a cancer-causing virus (Murakami *et al*., 1998). Another *in vitro* study showed that alcohol extracts from the leaves and bark of *M. oleifera* at 500 µg/mL have cytotoxic effects on cancer cells (Al-Asmari *et al*., 2015).

Skin nourishment: Moringa oil is believed to provide moisture to the skin, creating a biological barrier to nourish and regenerate skin due to the powerful antioxidant compounds from vitamin E and C in Moringa oil. This helps prevent the formation of wrinkles on the skin and reduces the development of free radicals, thereby promoting improved and healthier skin (Nadeem and Imran, 2016).

Toxicity: The use of Moringa products to date or the use of any products indiscriminately can cause unintended side effects, including life-threatening consequences. Data on the chemical composition of *M. oleifera* vary depending on factors such as environmental conditions and extraction methods. The toxicity of *M. oleifera* varies depending on the extraction method, concentration, animal model, and other factors (de Barros *et al*., 2022). According to Nadeem and Imran (2016), *M. oleifera* oil is relatively safe for humans. Moringa oil has many benefits in medicine. However, verifying and conducting research on the human body still faces many difficulties, as research requires a lot of human and financial resources and time. Nevertheless, the benefits of the Moringa tree begin with traditional medicine and have been shown to support the treatment of many diseases. The scientific foundation is increasingly developing based on basic research on the mechanical properties of the Moringa tree. Therefore, it is hoped that in the near future, there will be many studies proving the efficacy of Moringa seed oil for human health.

Industrial applications of *Moringa oleifera*

Moringa oil is known as a versatile food with many uses in the medical field, and it is excellent in other parts that bring many benefits and industrial applications not only in the seed and oil parts of this plant. *Moringa oleifera* has many developed industrial applications, such as for raw materials in formulas for body lotions, lotions, soap formulations, and lip balms, because *M. oleifera* has a high content of oleic acid and vitamins A and E, which have high value in industrial applications (Nadeem and Imran, 2016), and the oil is also used to produce biodiesel because methyl esters of biodiesel made from *M. oleifera* are at their highest levels compared to oils made from other substrates such as soybeans and sunflower seeds. (Rashid *et al*., 2008), while the quality of *M. oleifera* diesel is optimally higher in ignition efficiency than the quality of diesel oils from other plant sources due to the highest recovery of glycerin by-products, providing efficiency not only in quality but also achieving economic efficiency, turning waste into valuable products, such as fertilizers, increasing soil fertility and reducing environmental pollution (Parawira, 2010). According to Torres-Castillo *et al*. (2013), alcohol extracts of Moringa leaves contain high levels of polyphenolic compounds and flavonoids with important natural antioxidant properties that play a role in the antioxidant properties of plant materials, have antibacterial activities, and act as preservatives in food. Some studies by Suarez *et al*. (2003) have shown that *M. oleifera* seeds contain polypeptides that can act as water purifiers, agglomerate particles, suspend bacteria in a state of suspension, and have antibiotic activities to inhibit growth and destroy Gram-negative and Gram-positive bacteria, improving water quality and purifying water.

Conclusion

Moringa oleifera is a plant with high economic potential in various parts, bringing many benefits to humans. Its nutritional components, chemical compositions, and diverse compounds, including carbohydrates, lipids, proteins, vitamins, minerals, phenolic compounds, saponins, tannins, and steroids, are involved in biological activities, such as anti-inflammatory, antibacterial, and antioxidant activities, blood pressure control, blood sugar stabilization, and cancer prevention, have been summarized. However, in addition to the development of medicine, medical research needs to study more about the exploitation of *M. oleifera* applications with the different benefits of each part, such as stems and leaves, in the potential development of agriculture, livestock development, improving digestion, milk yield, wastewater treatment, and reducing water pollution. Because *M. oleifera* has many benefits, humans need to actively exploit this plant for development in the future, not only in the daily food sector but also in medicine.

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