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Research Paper

Moringa oleifera seed oil: A review

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ABSTRACT: *Moringa oleifera seed oil is receiving global attention due to several commercial interests, namely the nutritional, physical, chemical and pharmacological properties. As well as large applies as food, lubricant, perfumes, drugs, skincare and biodiesel raw material. The oil detaches mainly by the great concentration of omega-9 and small quantities of polyunsaturated fatty acids that promote great oxidative resistance and lower susceptibility to rancification. Furthermore, it also synthetize tocopherol, bioactive compounds, sterols, vitamin E and minerals. Several research confirm antioxidant, anti-inflammatory and antimicrobial activities detected from the oil, representing quite important to health. However, it is still necessary more research to elucidate its compounds and action types in an organism.*
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I. INTRODUCTION

Moringa oleifera seed oil naturally rich in monounsaturated fatty acids, mostly oleic acid, has been receiving worldwide attention for its great stability, good nutritional characteristics and medicinal attributes [1,2,3].

Great behenic acid content is the reason why the oil is commercially known as "oil Ben" or "oil Behen". The oil is more than 70% is composed by monounsaturated fatty acids, mostly oleic acid, also known as omega-9. It has saturated fatty acids and small amounts of polyunsaturated fatty acids, which promote a great significant resistance to oxidative degradation [4]. The oil is an excellent source of tocopherols, sterols, vitamin E, some minerals and bioactive compounds. It can also be applied for edible purposes, rheumatism, foot drop, blood purification and to improve cardiac function [5,6]. Numerous properties are reported in the literature as nutritional [4], antimicrobial [6], antioxidant [7], and anti-inflammatory [8], which makes it suitable for both human consumption and commercial purposes. Despite the *Moringa oleifera* seed oil importance and necessity to explore the properties from plant specific parts and its derivatives, there is still few information on current literature about the main characteristics of this seed oil.

For this reason, the present study makes a specific review of *Moringa oleifera* seed oil about the main characteristics of nutritional, physicochemical, antimicrobial, anti-inflammatory and antioxidant activities.

II. NUTRICIONAL CHARACTERIZATION

From *Moringa oleifera* seed are extracted the oil that yields 38 to 40% [2]. The oil has great amount of fatty acids (44.93%), hydrocarbons (32.95%), aldehydes (12.76%), esters (3.55%) and oxygenated hydrocarbons (2.62%) [9]. Furthermore, it contains unsaturated fatty acids, mostly oleic acid, also known as omega-9. Lipid profile has an oleic acid content greater than 70% and small amounts of polyunsaturated fatty acids (PUFA), which promote a great oxidative degradation resistance [4]. For saturated fatty acids composition, the oil contains from 12.80 to 23.68% (Table 1), namely dominant palmitic acid, followed by behenic, stearic and arachidic acids. Fatty acid composition can be well observed in Table 1.

Table 1. Fatty acid composition from Moringa seed oil.

	References			
Fatty acids	[10]	[11]	[12]	[13]
Palmitic acid (16:0)	7.80	6.68	6.45	5.8
Palmitoleic acid (16:1)	3.50	1.73	0.32	1.2
Stearic acid (18:00)	7.50	5.58	2.85	3.9

Oleic acid (18:1)	70.2	71.07	75.32	79.5
Linoleic acid (18:2)	2.10	0.15	10.24	2.2
Alfa-linolenic acid (18:3)	-	-	-	-
Arachídic acid (20:00)	2.00	3.47	3.00	2.2
Eicosanoic acid (20:1)	2.30	2.07	-	-
Behenic acid (22:00)	1.40	6.74	0.50	5.1
SFA	18.8	23.68	12.80	17.2
MUFA	76.0	74.93	75.64	80.7
PUFA	5.20	0.86	10.44	2.2
USFA	81.2	-	86.08	-

Note: - Not reported/determined, mesure unit (%).

Considering data (table 1), some differences are observed about composition of oil fatty acids, among results presented. These results may possibly be justified regarding the edaphoclimatic conditions of the cultivated area, *M. oleifera* variety [14] and extraction methods applied [15]. Another interesting fact observed in Table 1 is the great oleic acid content in *M. oleifera* seed oil (> 70%), which is required in terms of nutrition, producing benefic effects for human health. According to [16], oils with great monounsaturated fatty acid content are becoming the "new standard" of oil in the entire food industry, therefore it is likely that the ingestion will diffuse. By the behenic acid content, the oil is also known as "Ben oil" or "Behen oil". The refined oil is odorless, clear and rancid resistant, which demands commercial interest regarding the physical, chemical and pharmacological properties [17,18]. It is also applied as food, lubricant, perfume, medicines, skin care and biodiesel raw material [19,20,21,22]. Moringa seed oil also has levels of α, β, γ and δ-tocopherol, as can be observed in table 2.

Table 2. Tocopherol content from *Moringa oleifera* seed oil.

	References		
Tocopherois	[18]	[11]	[10]
Total tocopherol	160	301	-
α- tocopherol	150	211.7	92.22
β- tocopherol	70.80	75.4	4.87
δ- tocopherol	-	8.60	47.63
γ- tocopherol	55.50	5.2	91.59

Note: [18]: measure unit (μg/g), [11]: measure unit (mg/kg), [10]: measure unit (mg kg−1 of oil). - Not reported/determined.

These results (Table 2) are interesting because great levels of tocopherols contribute to great oxidative stability and protection of *M. oleifera* oil during storage and processing [23,14]. Among the tocopherols, α-tocopherol is detached, for being the most important, for promoting several biochemical functions in the body, modeling the expression proteins involved on cholesterol metabolism, as well as cell proliferation and inhibition [24,25]. However, tocopherol contents observed in Table 2 is greater than other oils, and even seed oils from other species but same family [26,27,14]. In addition, due to the great amount of tocopherols and considerable amounts of phenolic compounds similarly observed in olive oil, Moringa oil can be used for diet as a source of vegetable oil for human consumption [18].

Besides tocopherols, the oil also has other biologically active substances already identified, namely sterols, carotenoids and polyphenolic compounds, which can eliminate free radicals [28,29].

According to [10] the total unsaponifiables matter present in Moringa seed oil are composed by 80% sterols, 5% phytol and other plant polyenoic alcohols, 1.5% hydrocarbon and Vitamin E. According to Dinesha, et al., 2018, Moringa seed oil (extracted by the SC-CO2 method) has 44.71 (mg GAE/g) total phenols, 18.25 (mg RE/g) total flavonoids and 17.06 (ppm) total carotenoids. Also was observed in this study some antinutritional factors such as tannins (6.13%), saponins (0.26%) and phytate (3.09%).

In addition, Moringa oil has significant concentrations of 36.67% potassium and 5.86% magnesium [30] essential elements for body, once potassium acts along sodium in order to control blood pressure, maintain the fluid, electrolyte balance and cellular integrity. Magnesium is necessary for energy metabolism [31, 30].

Already the sterolic oil fraction (Table 3), is composed mainly of β-sitosterol, stigmasterol, campesterol and Δ^5-avenasterol together with small amounts of Δ^7-campestanol, Δ^7-avenasterol, stigmastanol, clerosterol and brassicasterol.

Table 3. Sterolic fraction composition from *Moringa oleifera* seed oil.

	References		
Sterolic fraction	[18]	[11]	[10]
β-sitosterol	45.11	48.25	47.17
Stigmasterol	19.20	20.01	19.26
Campesterol	16.90	10.97	17.84
Δ^5-avenasterol	10.00	13.66	8.04
Clerosterol	1.20	0.75	1.23
24-methylene cholesterol	0.90	0.75	0.61
Δ^7-campestanol	0.66	-	-
Δ^7-avenasterol	0.53	1.68	0.64
Stigmastanol	0.49	-	0.89
28-isoavenasterol	0.30	-	-
Brassicasterol	0.07	0.03	0.06

Note: - Not reported/determined, measure unit (%).

This fraction is important by the participation on cholesterol metabolism, which reduces the circulating LDL on cholesterol [32, 33, 14]. According to studies, the substance β-sitosterol has greater level in the sterolic fraction as observed on Table 3 and is identified as the main phytosterol of numerous vegetable oils [34]. Two sterols types were also observed, stigmasterol and campesterol, and are synthetized for several plants [35]. The substance β-sitosterol has a great nutritional value, biological activity and medicinal properties, which can be widely applied for medical purposes, and food and cosmetic industries. It also provides effects on serum cholesterol reduction by confronting carcinoma cells and inflammation [36]. Due to the great phytosterol content, *M. oleifera* seed oil can be used as dietary nutraceuticals, supplements or functional food ingredients [10]. Among the identified sterol fractions (Table 3), the Δ^5-avenasterol has a good proportion in the oil and is the most important sterols by acting as antioxidant and anti-polymerization in heated oils [37].

III. PHYSICAL-CHEMICAL CHARACTERIZATION

Regarding the physicochemical characteristics of *Moringa oleifera* seed crude oil, parameters are reported by literature as iodine, saponification, and peroxide value, as well as viscosity, density at 25º C, gravity, refractive index, yield, acid value, induction period (TABLE 4).

Table 4. Physical-chemical composition of *Moringa oleifera* seed oil.

	References			
	[11]	[9]	[18]	[13]
Iodine value ($gI^2/100g^{-1}$)	65.3	68.65	69.01	68.5
Saponification value	167.0	180.92	183.00	191.2
Peroxide index	1.03	2.6	0.83	-
Gravity	-	0.9050	-	0.90
Refractive index	1.4713	1.4559	-	1.47
Yield (%)	-	38	-	-
Acid value ($ng/KOHg^{-1}$)	1.01*	-	0.60*	-
Induction period (h)	56.6	-	10.5	-
Viscosity	-	-	-	43.6
Density at 25°C	0.92	-	-	0.92

Note:* determined (%), - Not reported/determined.

The parameters observed in Table 4 are important to determine the quality and stability of *M. oleifera* seed crude oil. Among these parameters, iodine value represents the degree of oil unsaturation [9]. This

indicates that as greater the iodine value as greater the degree of fats and oils unsaturation. Iodine results in table 4 (65.3, 68.65, 69.01 and 68.5 $gI^2/100\ g^{-1}$) are according to ranges (80-106 $gI^2/100g^{-1}$) proposed by [38] for edible oils. Regarding oil saponification, the contents (167.00, 180.92, 183.00 and 191.2) are within of the international standard recommendation [38] for edible oils that is 181 ± 2.60. According to Table 4, it is observed that the peroxide results reported in the studies (0.83 to 2.6) are also within the limit allowed by the international standard, [38], which determines the maximum 10m/mol/kg for edible oils. These results are excellent, once the desirable peroxide index for edible oils is the lowest possible value, because ensures greater oil quality. This indicates that the oil has great oxidative stability and can be stored for long periods due to the low level of oxidative and lipolytic activities [9], incresing oxidation resistance.

Other parameters for determining oil quality are also reported and are extensively studied in research using oil as a biodiesel source, such as gravity, viscosity, density, yield and refractive index. Regarding these parameters, it is observed in Table 4 that the results had similar values between the studies. The induction period (Rancimat: 20L/h, 100 °C ± 2 °C), which is an important feature that describes the oils and fats oxidative stability [39] was also analyzed (Table 4). Divergences were observed between the analyzed values, although the literature emphasizes the great oxidative stability as one of the main oil characteristics [4]. These analyzed physicochemical characteristics of *Moringa oleifera* seed oil infers how promising the oil is for food.

IV. ANTIOXIDANT ACTIVITY

M. oleifera seed oil provides a pronounced antioxidant activity with wide applications for food, lubricants and cosmetics, important for diverse industries [7]. Prominent presence of monounsaturated fatty acid reduces risk of cholesterol and heart disease. Scientific evidences indicate Moringa seed oil provides abundant natural antioxidants, and that this oil consumption can develop benefits to health regarding the hypocholesterolemia effects, because the presence of phytosterols and free radicals elimination from body, and presence of tocopherols, phenolics and carotenoids [40].

Due to its antioxidant potential, Moringa seed oil is less prone to oxidative damage than other edible oils containing oleic acid (sunflower, safflower and almond oil) [39]. In addition, the oil can be mixed in order to increase oxidative stability of commercial oils or margarines. [41] reported that adequate mixture of moringa oil with traditional edible oils (palm, soy and sunflower oil) improves the physical-chemical characteristics and oxidative stability of oils. Moreover, mixing of oil with 50% butter results in a greater stability, lower cholesterol contente and 35.5º C melting temperature [42]. If largely cultivated, Moringa seed oil can be considered a replaceable source of vegetable oil for several purposes [43] and can replace olive oil [44].

According to [13], *Moringa oleifera* seed oil is potentially effective as therapy treatment for xenobiotic-induced liver disorders. Furthermore, this oil hepatoprotective action is mediated by natural antioxidant compounds, namely tocopherols, phenolics and carotenoids.

In study reported by [45] the Moringa seed oil can attenuate the nefrotoxity for gentamicin, via antioxidant, anti-inflammatory, and antiapoptotic mechanisms in rats. This action is due to the bioactive compounds present in this oil.

Assays concluded together, the MTX injection induced oxidative stress of rat neurotoxicity. Interestingly, supplementation of virgin coconut (VCO) and Moringa seed oils (MSO) attenuates MTX-induced brain neurotoxicity through the antioxidant mechanism that inhibits oxidative stress, inflammation and acetylcholinesterase activity of rat brain. This study suggests that virgin coconut and Moringa seed oils are potential adjuvants to neurotoxic modulation for patients with cancer submitted to MTX chemotherapy [46].

V. ANTI-INFLAMATORY AND ANTIMICROBIAN ACTIVITY

Moringa oil pharmacological studies reported numerous biological activities as antibacterial, antifungal, antioxidant, antifertility and anticancer effects [47]. The oil has also been applied to treat arthritis, rheumatism and hypertension (Mahmood and Haq, 2010). According to [6] Moringa seed oil extracted by SC-CO^2 method promotes great antibacterial and antifungal activities against Gram-positive (*Bacillus cereus*, *Staphylococcus aureus*), Gram-negative bacteria (*Escherichia coli, Pseudomonas aeruginosa*) and some fungi (*Mucor* and *Aspergillus* species). Another research related that *Moringa oleifera* oil had greater antimicrobial activity for Gram-positive and Gram-negative bacteria than fungi and yeast. In addition, *Moringa oleifera* oil-fortified labneh analyzed in this trial was considered as a new product with great functional properties, acceptability, nutritional value, prolonging its shelf life [48].

According to [49] mixing bionanocompounds such as *Moringa oleifera* oil film/AgNPs-enriched with silver nanoparticles PVC within food packaging products can restrict the pathogenic microorganisms growth, and increase food quality and shelf life. Although nanoencapsulation may be effective in controlling pathogenic microorganisms, there are still points that need to be investigated, such as the regulations effects of nanoparticle use on microorganism control [50]. According to [51] *M. oleifera* seed oil promotes acaricidal activity on *T.*

urticae. Storage time can positively influence its mite toxicity. The oil stored for 120 days is most suitable for mite control.

Regarding anti-inflammatory activity, the study concluded the extracted oil and balanced cream of *M. oleifera* antagonized the early and late stages of inflammation caused by carrageenan. The formulated cream was more effective than oil. Results support the traditional application of this plant under inflammatory conditions and suggest presence of active biological compounds that were supported by analytical data such as the gas chromatography associated with mass spectrometry (GCMS), exploiting the exact active compounds for anti-inflammatory activity, which may result in the development of a super low-toxicity and great therapeutic index anti-inflammatory agent [8].

M. oleifera seed oil and extracts had prominent free radical scavenging activities. However, there was not proteinase inhibition and low stabilization membrane responses for oil and extracts, the anti-inflammatory activity of *Moringa oleifera* seed may be occur via other anti-inflammatory mechanisms. These results would be largely applied to nutraceutical scientists and nutritionists who formulate antioxidant-based therapeutic diets [52].

VI. CONCLUSION

Given the characteristics and health properties about Moringa seed oil, the oil application promises for food field, once the oil is abundant in monounsaturated fatty acids, which consists a natural antioxidant less prone to oxidants damage than other edible oils, as well as having mineral properties similar to olive oil. Moreover, several research confirm antioxidant, anti-inflammatory and antimicrobial activities promoted by oil, which is important to health. However, more research still is necessary to elucidate these compounds and action ways in the organism.

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