ISSN 1998 – 409X

REVIEW ARTICLE

Moringa oleifera Seed Oil – Phytochemistry and Pharmaceutical Potential

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Abstract

Moringa oleifera seed oil, commonly known as ben oil or behen oil, has emerged as a promising natural lipid with significant pharmaceutical potential due to its rich phytochemical composition and favorable physicochemical properties. Extraction methods, including cold press, solvent extraction, aqueous enzymatic extraction, and supercritical CO_2 extraction, influence oil quality and yield. Ben oil is predominantly composed of oleic acid, along with behenic, palmitic, and stearic acids, and contains bioactive compounds such as tocopherols, phytosterols, phenolics, and flavonoids. The oil exhibits notable antioxidant, antimicrobial, wound-healing, emollient, and skin-protective activities. Its high oxidative stability and lipid composition support its application as a pharmaceutical excipient and carrier in lipid-based drug delivery systems, including liposomes and nanoemulsions. Overall, *M. oleifera* seed oil is an important bioactive ingredient with potential for use in pharmaceutical and cosmeceutical formulations. This review discusses the extraction methods, chemical composition, biological activities, and formulation applications of the oil.

Key words: Extraction, lipid profile, moringa seed oil, pharmaceutical applications, phytochemistry

INTRODUCTION

Moringa oleifera Lam., a member of the Moringaceae family, is a fast-growing and drought-tolerant tree widely recognized as the miracle tree. It is indigenous to the sub-Himalayan regions of the Indian subcontinent, including India, Pakistan, Bangladesh, and Afghanistan. It is now extensively cultivated throughout the tropical and subtropical regions of Africa, Asia, Latin America, and the Middle East.[1] The plant has earned remarkable global recognition owing to the broad spectrum of medicinal, nutritional, and industrial applications associated with virtually all of its parts, including the leaves, seeds, pods, flowers, bark, and roots.[2] *M. oleifera* was recognized as the "Botanical of the Year" by the U.S. National Institutes of Health in 2008, reflecting increasing scientific interest in its nutritional and therapeutic potential.[3]

Among the various parts of *M. oleifera*, the seeds have attracted considerable scientific attention due to their high oil content, which can constitute up to 40% of the seed kernel dry weight.[4,5] The seed oil, commonly known as ben oil or behen oil, is characterized by a distinctive fatty acid profile dominated by oleic acid (70%), a monounsaturated omega-9 fatty acid that confers excellent oxidative stability and functional versatility. In addition, the presence of behenic acid (5–6%) contributes natural structuring properties that enhance its suitability for semi-solid pharmaceutical and cosmetic formulations.[6,7] This composition, often compared to olive oil, positions *M. oleifera* seed oil as a promising candidate for application in food, cosmetic, and pharmaceutical industries.[8]

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Received: 15-07-2026
Revised: 21-08-2026
Accepted: 01-09-2026

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From a pharmaceutical perspective, there is growing interest in the use of natural plant-derived lipids as pharmaceutical excipients and bioactive carriers in drug delivery systems. Natural oils offer several advantages over synthetic lipid excipients, including biocompatibility, biodegradability, structural diversity, and intrinsic biological activities.[9] *M. oleifera* seed oil, with its high oleic acid content, minor bioactive constituents, including tocopherols, phytosterols, and phenolic compounds, as well as its favorable physicochemical properties, has emerged as a multifunctional lipid excipient with strong potential in lipid-based drug delivery, topical formulations, and nutraceutical applications.[10,11]

In view of the potential applications of *Moringa oleifera* seed oil in pharmaceutical formulations, the present review provides a comprehensive and updated overview of its chemical composition, biological activities and formulation potential, with specific emphasis on: extraction methods and their influence on oil quality; phytochemical composition, including fatty acids, minor bioactive compounds, and gas chromatography–mass spectrometry (GC-MS) characterization; physicochemical properties and their pharmaceutical significance; biological activities, including antioxidant, antimicrobial, anti-inflammatory, wound healing and dermatological effects; and formulation potential in lipid-based and conventional pharmaceutical dosage forms. Collectively, the information presented in this review highlights the potential of *M. oleifera* seed oil as a promising natural excipient and bioactive ingredient for pharmaceutical applications.

EXTRACTION METHODS OF SEED OIL

Ben oil is extracted from the dried kernel of moringa seeds using various extraction methods, namely, cold pressing, solvent extraction, enzymatic, and supercritical CO_2 extraction. The extraction techniques significantly influence the yield, physicochemical properties, and functional characteristics of moringa seed oil. Conventional solvent extraction methods generally provide higher oil recovery. In contrast, cold pressing minimizes thermal exposure and avoids the use of organic solvents, thereby preserving heat-sensitive bioactive compounds, maintaining the natural quality of the oil, and reducing solvent residues that may be undesirable in pharmaceutical applications. Advanced extraction methods, such as aqueous enzymatic extraction and supercritical CO_2 extraction, are considered promising because they reduce or eliminate the use of organic solvents while preserving bioactive constituents under controlled extraction conditions.[5,7,12-14]

Consequently, the extraction method plays a critical role in determining the yield, chemical composition, oxidative stability, and pharmaceutical suitability of *M. oleifera* seed oil. Among the reported extraction methods, cold pressing and n-hexane Soxhlet extraction produced the highest oil yields (approximately 41–42%), whereas petroleum ether and aqueous enzymatic extraction resulted in comparatively lower yields (22–31%).[5,7,12,13] Although solvent extraction generally provides higher oil recovery, cold pressing and advanced solvent-free techniques better preserve thermolabile bioactive compounds, minimize residual solvent contamination, and produce oil with superior quality for pharmaceutical and cosmeceutical formulations.[10] The extraction methods and their implications for pharmaceutical applications are presented in Table 1.

PHYTOCHEMICAL COMPOSITION OF SEED OIL

Fatty acid

M. oleifera seed oil is characterized by a high proportion of monounsaturated fatty acids, particularly oleic acid, along with notable amounts of saturated fatty acids such as behenic, palmitic, and stearic acids. The high oleic acid content enhances the oil's pharmaceutical suitability, as it serves as a functional lipid that can improve drug solubility and influence precipitation behavior in lipid-based formulations. Palmitic acid acts as a solid, waxy component that contributes to the physical structure of lipid-based drug delivery systems. Stearic acid is a primary waxy building block that provides structural stability and a solid form for lipid formulations.[15] Behenic acid, a long-chain saturated fatty acid present in *M. oleifera* seed oil, contributes to the hydrophobicity and structural integrity of lipid matrices. Its long carbon chain may support sustained drug release characteristics, enhance formulation stability, and provide lubrication in formulations.[9]

Minor bioactive compounds

Tocopherols, which belong to the Vitamin E family, are important minor bioactive constituents present in *M. oleifera* seed oil.[5] These compounds act as natural antioxidants and may contribute to the oxidative stability of pharmaceutical formulations by protecting lipid components from oxidative degradation. Among the tocopherol isomers, α-tocopherol is considered the most biologically active form and has been associated with antioxidant and anti-inflammatory activities.[16] In addition to tocopherols, sterols have also been reported as minor constituents of *M. oleifera* seed oil.[5] The study reported that esterification with fatty acids may modify the physical properties of phytosterols, thereby improving their dispersion and solubilization properties in formulations.[17] Phenolic compounds, particularly ferulic, gallic, caffeic, and vanillic acids, together with flavonoids such as apigenin and naringenin, present in *M. oleifera* seed oil are recognized for their antioxidant potential. These compounds may help protect against oxidative stress by

Table 1: The extraction methods and their implications for pharmaceutical applications

Extraction method	Oil characteristics	Oil recovery percent (%)	Pharmaceutical implications	References
Cold pressing	Produced oil with acceptable physicochemical characteristics	41.7±3.71	Suitable for formulations requiring minimal thermal processing.	[7]
Soxhlet extraction using n-hexane	Showed high extraction efficiency and oil recovery	41.47	Useful for obtaining higher oil yield for analytical and formulation studies.	[12]
Soxhlet extraction using petroleum ether	Efficient lipid extraction with measurable oil yield	30.8±2.19	Applicable for the physicochemical characterization of seed oil.	[5,13]
Aqueous enzymatic extraction	Produced oil under mild extraction conditions	22.6±1.17	May support environmentally friendly processing approaches.	[5]
Supercritical CO_2 extraction	Produced solvent-free oil with optimized extraction yield and antioxidant potential	38.54	May support applications requiring controlled extraction conditions and reduced solvent residues.	[14]

neutralizing reactive oxygen and nitrogen species, thereby contributing to the antioxidant potential of pharmaceutical formulations.[7,18]

GC-MS profile

GC-MS is widely used to characterize the chemical composition of plant-derived oils and phytoconstituents. GC-MS analysis of *M. oleifera* seed oil identified a diverse range of compounds belonging to different chemical classes, providing insight into its phytochemical composition. The identified compounds and their relative percentage composition are presented in Table 2.[19]

Among the identified compounds, oleic acid was detected as the predominant fatty acid, followed by 9-octadecenol and palmitic acid. The presence of fatty acids, alcohols, hydrocarbons, and terpenoid constituents indicates the diverse chemical profile of *M. oleifera* seed oil. Such constituents may collectively contribute to the stability and functional characteristics of the oil.[19]

PHYSICOCHEMICAL PROFILE OF *M. OLEIFERA* SEED OIL AND ITS PHARMACEUTICAL IMPORTANCE [TABLE 3]

The physicochemical profile of *M. oleifera* seed oil in Table 3 highlights its suitability for pharmaceutical applications. Low acid and peroxide values indicate good oxidative stability and resistance to hydrolytic degradation, supporting long-term storage stability. In addition, the reported refractive index, density, viscosity, and saponification characteristics reflect favorable quality, purity, and formulation attributes. Collectively, these properties support the potential use of *M. oleifera* seed oil as a natural lipid-based excipient and carrier in pharmaceutical, cosmetic, and topical formulations.

PHARMACEUTICAL ACTIVITIES OF MORINGA SEED OIL

Antioxidant activity

The antioxidant activity of *M. oleifera* seed oil has been widely investigated using multiple *in vitro* assay systems, including 2,2-diphenyl-1-picrylhydrazyl, 2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), and hydrogen peroxide radical scavenging assays. The use of multiple assay systems is considered essential since no single method provides a comprehensive estimation of the antioxidant efficacy of plant-derived samples. Atolani *et al.*[24] reported that *M. oleifera* seed oil possesses significant free radical scavenging potential. The study reported that the seed oil exhibited high DPPH scavenging activity (74.98%), high ABTS scavenging activity (83.41%), and moderate hydrogen peroxide scavenging activity (59.58%) at 20 µg/mL, with activities comparable to the standard antioxidant, ascorbic acid. The strong free radical scavenging activity observed in the seed oil has been attributed to its fatty acid constituents, particularly oleic acid, which can quench free radicals in both lipid and aqueous environments and chelate pro-oxidant metals.[24] The study further confirmed the antioxidant capacity of cold-pressed *M. oleifera* seed oil, reporting an ABTS antioxidant capacity of 365 µM trolox equivalent antioxidant capacity, attributing this activity to the richness of the oil in bioactive antioxidant compounds, including polyphenols, sterols, and tocopherols.[24] Similarly, *M. oleifera* seed oil demonstrated superior DPPH radical scavenging activity compared to commercial peanut and tea seed oils, along with the lowest peroxide value among the tested oils, indicating its

Table 2: GC-MS identified compounds of *Moringa oleifera* seed oil with relative percentage composition

Chemical class	Compound	Molecular formula	Molecular weight	Relative abundance (%)
Fatty acids and derivatives	Myristic acid	$C_{14}H_{28}O_2$	228	0.49
	Palmitic acid	$C_{16}H_{32}O_2$	256	10.64
	Stearic acid	$C_{18}H_{36}O_2$	284	6.07
	Oleic acid	$C_{18}H_{34}O_2$	282	22.51
	Arachidic acid	$C_{20}H_{40}O_2$	312	2.21
	Docosanoic acid	$C_{22}H_{44}O_2$	340	1.03
	Erucic acid	$C_{22}H_{42}O_2$	338	1.98
	Methyl-11-octadecenoate	$C_{19}H_{36}O_2$	296	1.90
	α-Monopalmitin	$C_{19}H_{38}O_4$	330	1.65
Alcohols	9-octadecenol	$C_{18}H_{34}O$	266	12.76
Aliphatic hydrocarbons	n-undecane	$C_{11}H_{24}$	156	3.81
	n-tridecane	$C_{13}H_{28}$	184	0.67
Aromatic hydrocarbons	o-Ethyl toluene	C_9H_{12}	120	4.69
	1,2,3-trimethylbenzene	C_9H_{12}	120	2.83
	o-Cymene	$C_{10}H_{14}$	134	1.78
	Cumene-p-ethyl	$C_{11}H_{16}$	148	0.67
	4-phenylbut-3-ene-1-yne	$C_{10}H_8$	128	5.79
	m-Propyltoluene	$C_{10}H_{14}$	134	3.56
Terpenoids	2,3-Epoxycarane	$C_{10}H_{16}O$	152	2.26
	p-mentha-1,3,8-triene	$C_{10}H_{14}$	134	2.36
	4-methylindan	$C_{10}H_{12}$	132	2.35
	2-phenyl-2-pentene	$C_{11}H_{14}$	146	2.47
	1-ethylindane	$C_{11}H_{14}$	146	1.07
	1,6-Methano [10]annulene	$C_{11}H_{10}$	142	0.90

GC-MS: Gas chromatography–mass spectrometry

outstanding oxidative stability.[7,25]

The antioxidant activity of the oil is closely associated with its minor bioactive constituents. The Algerian *M. oleifera* seed oil contained notable amounts of tocopherols (287–327 mg/kg), with α-tocopherol as the predominant form (195.8–263.2 mg/kg), followed by γ-tocopherol (51.2–77.8 mg/kg). Boukandoul *et al.*[26] γ-tocopherol may exhibit stronger antioxidant activity in food systems, whereas α-tocopherol possesses greater biological activity and nutritional significance. Total phytosterol content ranged from 4 to 5 g/kg, with β-sitosterol as the dominant sterol (45.3–49.3%), while total phenolic compounds ranged from 11 to 17 mg/kg. Furthermore, DPPH analysis indicated that the antioxidant activity was predominantly associated with lipophilic constituents, particularly tocopherols and sterols.[26]

From a pharmaceutical perspective, the antioxidant constituents of *M. oleifera* seed oil hold significant relevance. Excessive generation of reactive oxygen species has been associated with oxidative stress, cell death, lipid membrane degradation, and various pathological conditions.[24] The ability of the oil to scavenge these reactive species suggests its potential utility as a natural antioxidant ingredient in pharmaceutical formulations, nutraceuticals, and lipid-based drug delivery systems where the oxidative stability of the lipid excipient is of critical importance.

Anti-inflammatory activity

M. oleifera seed oil has demonstrated significant anti-inflammatory activity in both topical and systemic experimental models. Topical application of the oil significantly inhibited ear edema in mouse models of irritative contact dermatitis induced by phenol and 12-O-tetradecanoylphorbol-13-acetate, while also reducing epidermal hypertrophy and psoriasis-like skin lesions, indicating its effectiveness in controlling cutaneous inflammation and keratinocyte hyperproliferation.[27] Beyond dermatological applications, *M. oleifera* seed oil formulated into suppositories exhibited significant anti-hemorrhoidal activity by reducing the recto-anal coefficient and promoting tissue repair in rat models of croton oil-induced hemorrhoids.[28] Furthermore, systemic administration of *M. oleifera* seed oil extract in Ehrlich ascites carcinoma models normalized inflammatory cytokine levels by reducing interleukin (IL)-2, (IL-6), and tumor

Table 3: Physicochemical properties and pharmaceutical importance of *Moringa oleifera* seed oil

Parameter	Reported value	Pharmaceutic importance
Color	Golden yellow	Functions as a visual indicator of lipid quality and stability, where variations reflect pigment concentration and the extent of oxidative degradation.[20] The characteristic golden-yellow color enhances visual acceptability in topical formulations such as creams and emulsions.
Odor	Nutty smell	Functions as a definitive organoleptic indicator of identity and stability, where this characteristic scent ensures oil authenticity and confirms the absence of oxidative or microbial degradation.[20]
Density (g/cm^3)	0.896 g/mL	Acts as a critical purity indicator for detecting contaminants and classifying oil weight, where variations reflect the degree of unsaturation and oxidative stability.[21] Needed for dosing, emulsion design, and comparison with pharmacopeial limits for oils.
Refractive index	1.447	Serves as a specific identity and purity marker influenced by fatty acid chain length and degree of unsaturation; it acts as a diagnostic tool for monitoring contaminants, oxidative aging, or thermal degradation.[20,22]
Viscosity (mPa.s)	49.80±0.30	Represents the oil's resistance to flow and directly affects spreadability, skin feel, and formulation performance in pharmaceutical and cosmetic formulations such as creams and lotions.[21]
Acid value (mg KOH/g)	0.46±0.001 mg KOH/g oil	The primary indicator of stability is measuring triglyceride degradation into free fatty acids; the low reported value indicates minimal hydrolytic degradation and good storage stability, ensuring the formulation remains free from rancidity and sensory defects.[11]
Saponification value (mg KOH/g)	253.5±1.460 mg KOH/g oil	Reflects the mean molecular weight of triacylglycerols, establishing the oil's industrial utility for soap production, and its suitability as a carrier for lipophilic pharmaceutical actives.[11]
Iodine value (g I_2/100 g)	67.68±1.34	Quantifies the degree of unsaturation and classifies the oil as a non-drying fatty substance; lower values indicate reduced susceptibility to oxidative rancidity and polymerization, ensuring superior storage stability.[21,23]
Peroxide value (meq O_2/kg)	4.89±0.42	Functions as a primary indicator for monitoring the initial stages of oxidative rancidity and the presence of primary oxidation products, where low values ensure long-term chemical stability and extended shelf life for lipid-based pharmaceutical formulations.[23]
Ester value (SV−AV)	186.65 (Derived)	Indicates total glyceride content and chemical purity by confirming the predominance of intact ester moieties within the glycerol scaffold, establishing the oil's high stability for use as a bioactive raw material in pharmaceutical formulations.[21]

necrosis factor-alpha (TNF-α) concentrations.[29]

The anti-inflammatory activity of *M. oleifera* seed oil appears to involve multiple complementary mechanisms. Topical anti-inflammatory effects have been shown to depend on the activation of glucocorticoid (GC) receptors, as these effects were reversed by the GC receptor antagonist mifepristone.[27] The high oleic acid (9-octadecenoic acid) content, which constitutes approximately 73% of the oil, has been reported to suppress the production of nitric oxide and pro-inflammatory cytokines, including TNF-α and IL-6.[27,28] In addition, n-hexadecanoic acid inhibits phospholipase A_2, a key enzyme involved in initiating the inflammatory cascade.[28] *M. oleifera* seed oil inhibits neutrophil migration and reduces the activities of myeloperoxidase and N-acetyl-β-D-glucosaminidase, which are important markers of leukocyte infiltration. Collectively, these bioactive constituents modulate inflammatory signaling pathways, including nuclear factor kappa B, cyclooxygenase, and lipoxygenase, thereby suppressing inflammation and promoting tissue repair.[25,27,30]

From a pharmaceutical perspective, the anti-inflammatory properties of *M. oleifera* seed oil are particularly noteworthy because of its favorable safety profile. Unlike dexamethasone, which has been associated with skin atrophy and systemic reduction in the weight of lymphoid organs such as the spleen and adrenal glands, *M. oleifera* seed oil did not induce skin thinning or significant systemic toxicity in experimental studies.[27] The successful incorporation of *M. oleifera* seed oil into herbal creams and suppositories further demonstrates its versatility as a pharmaceutical excipient and therapeutic agent for topical and rectal drug delivery.[27,30] Collectively, these findings suggest that *M. oleifera* seed oil represents a promising plant-derived anti-inflammatory agent for the management of acute and chronic inflammatory disorders. Nevertheless, most of the available evidence is derived from *in vitro* and animal studies, and further clinical investigations are required to establish its therapeutic efficacy and long-term safety in humans.

Antimicrobial activity

M. oleifera seed oil has demonstrated antimicrobial activity against a variety of bacterial and fungal pathogens, although the extent of activity appears to depend on the extraction method and chemical composition. Hexane-extracted seed oil rich in oleic and other fatty acids produced strong antibacterial effects against *Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa,* and *Enterobacter* spp. pathogens, with a large inhibition zone and a very low minimum inhibitory concentration (MIC) of 0.032 mg/mL against *P. aeruginosa*.[31] Petroleum-ether seed oil also inhibited foodborne pathogens, giving inhibition zones up to 18.5 mm against *S. aureus* and MICs of 64–256 µL/mL, supporting its use as a natural antibacterial agent in product preservation or topical preparations.[32] In contrast, chemically characterized fixed seed oil with 74% oleic acid showed no direct antibacterial effect (MIC ≥ 1024 µg/mL) but markedly potentiated gentamicin, ofloxacin, and penicillin against multidrug-resistant strains, indicating value as an adjuvant excipient rather than a standalone drug.[33] Crude *M. oleifera* seed oil also demonstrated broad-spectrum antimicrobial activity against *Bacillus subtilis*, *S. aureus*, *Escherichia coli*, *K. pneumoniae*, and fungal pathogens, including *Candida albicans* and *Rhizopus stolonifera*, supporting topical antimicrobial and antifungal product development.[34] Seed oil similarly showed strong activity against *Streptococcus pyogenes* with clear zones of 11–15 mm, supporting the direct antibacterial potential of the oil.[35] Overall, the available evidence indicates that *M. oleifera* seed oil possesses antimicrobial potential, although its activity appears to be influenced by extraction method, chemical composition, and the target microorganism.

Dermatological and topical applications

Wound healing activity

Topical application of *M. oleifera* seed oil demonstrates significant potential in accelerating the repair of both acute physiological and chronic skin wounds. Ventura *et al*.[36] demonstrated that *M. oleifera* seed oil reduces healing time in healthy, diabetic, and immunosuppressed wound models by enhancing collagen deposition and restoring myofibroblast populations during the proliferative phase of healing. In healthy wounds, closure time was reduced from 14 to 11 days, with similar improvements observed in diabetic and immunosuppressed conditions, including a reduction in diabetic wound healing time from 15 to 13 days. These effects have been largely attributed to the oil's high oleic acid content (~72.27%), which may support the transition from inflammation to repair by modulating macrophage activity.[36] Collectively, these findings suggest that *M. oleifera* seed oil may serve as a functional agent for restoring the skin barrier and managing complex, non-healing lesions.

Emollient and skin-protective effects

Athikomkulchai *et al*.[10] reported that *M. oleifera* seed oil serves as a natural emollient by forming a hydrophobic barrier on the skin surface, thereby enhancing moisture retention and supporting skin hydration. The high concentration of oleic acid (~71.57%) is fundamental to this effect. Oleic acid has been reported to increase skin permeability by disordering stratum corneum lipids, thereby enhancing the penetration of bioactive constituents into the epidermis. Clinical evaluations have demonstrated that topical application of a 25% *M. oleifera* seed oil cream can increase skin hydration by up to 85% over 4 weeks while significantly reducing skin erythema. Beyond its moisturizing effects, the oil provides skin-protective benefits through the presence of α-tocopherol (Vitamin E) and plant sterols. These compounds help scavenge free radicals produced by ultraviolet radiation and environmental pollutants, thereby minimizing oxidative stress and protecting against photoaging. Overall, the emollient, moisturizing, and antioxidant properties of *M. oleifera* seed oil support its potential use in dermatological and topical formulations intended to improve skin hydration and barrier function.[10]

FORMULATION POTENTIAL OF *M. OLEIFERA* SEED OIL

Lipid-based drug delivery potential

M. oleifera seed oil shows considerable potential for application in lipid-based drug delivery systems, primarily due to its high oleic acid content and favorable oxidative stability, which may help protect encapsulated bioactive compounds from degradation.[11] As a multifunctional lipid excipient, *M. oleifera* seed oil has been successfully incorporated into liposomal formulations prepared by thin-film hydration, producing small unilamellar vesicles with a particle size of 83.98 nm and an entrapment efficiency of 96.8%.[37] In addition, optimized nanoemulsion systems containing Tween 80 and polyethylene glycol 400 demonstrated excellent physical stability, characterized by a zeta potential of −20.89 mV and high optical clarity of 97.7% transmittance, highlighting their suitability as carriers for lipophilic compounds.[11] The oil also exhibits penetration-enhancing properties that may facilitate the dermal delivery and bioavailability of topically applied bioactive compounds.[10] Furthermore, the presence of behenic acid (5–6%) provides natural structuring and solidifying capabilities, making *M. oleifera* seed oil a promising naturally derived alternative for stabilizing complex pharmaceutical formulations without the need for partial hydrogenation.[6]

Pharmaceutical dosage forms

Beyond its role as a lipid excipient in advanced drug delivery systems, *M. oleifera* seed oil has also been incorporated into conventional topical pharmaceutical formulations. An

oil-in-water herbal cream containing 15% *M. oleifera* seed kernel oil was reported to be physically stable and non-greasy, exhibiting significant *in vitro* anti-inflammatory activity (IC_{50} = 124.5 µg/mL) compared with acetylsalicylic acid and antibacterial activity against *S. aureus* and *E. coli* when compared with gentamicin.[30] In addition, *M. oleifera* seed oil has been formulated into anti-hemorrhoidal suppositories using both fatty (dika fat) and water-soluble (macrogol) bases. The formulations exhibited acceptable physicochemical properties, and the optimized dika fat-based suppository demonstrated significant anti-hemorrhoidal activity in an experimental rat model, highlighting the potential of moringa seed oil for the management of anorectal inflammatory conditions and its versatility in pharmaceutical dosage form development.[28]

Future perspectives and challenges

M. oleifera seed oil shows strong promise as a natural lipid excipient, but several challenges must be addressed before broad pharmaceutical adoption. Although its high oleic acid content, oxidative stability, and skin benefits support its use in creams, nanoemulsions, and lipid carriers, most formulation work remains at laboratory or early cosmetic scale, with limited translation into standardized medicinal products.[10,11] There is also variability in composition due to cultivation and extraction methods and processing techniques, highlighting the need for standardization of oil quality, including fatty acid, tocopherol, and phytosterol profiles, if it is to be accepted as a reproducible excipient.[4] Future work should therefore focus on good manufacturing practice-grade production, scalable green extraction, systematic preclinical and clinical evaluation, and integration into well-characterized lipid-based delivery systems for poorly soluble drugs.[38]

CONCLUSION

M. oleifera seed oil is a promising natural lipid with considerable pharmaceutical potential owing to its favorable physicochemical properties, rich phytochemical composition, and diverse biological activities. Available evidence supports its antioxidant, antimicrobial, anti-inflammatory, wound-healing, and skin-protective effects, while its high oleic acid content and oxidative stability make it a suitable candidate for lipid-based drug delivery systems and conventional pharmaceutical formulations. Although further standardization, safety evaluation, and clinical validation are required, current findings highlight *M. oleifera* seed oil as a multifunctional bioactive ingredient and excipient with significant potential for future pharmaceutical applications.

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Source of Support: Nil. **Conflicts of Interest:** None declared.