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Review on Natural Emulsifiers from Niger Seed Oil (*Guizotia abyssinica*): A Sustainable Alternative for Food Applications

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Authors' contributions

This work was carried out in collaboration among all authors. Author OSK designed the study, conducted the statistical analysis, developed the research protocol, and prepared the first draft of the manuscript. Authors DTB and SSJ provided mentorship and guidance for the dissertation work. All authors reviewed, edited, and approved the final version of the manuscript.

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Review Article

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ABSTRACT

Background: Niger seed oil (*Guizotia abyssinica*) has emerged as a promising plant-based emulsifier due to its unique composition high linoleic acid, phospholipids, and natural antioxidants (tocopherols, polyphenols).
Aims: This review evaluates the emulsification properties, oxidative stability, and functional performance of Niger seed oil (*Guizotia abyssinica*) as a natural alternative to synthetic emulsifiers in food applications, and to compare its efficacy with conventional plant-based and synthetic emulsifiers.

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Method: This review evaluates its emulsification potential, comparing its performance with synthetic and conventional plant-based emulsifiers (e.g., soy lecithin, polysorbate 80). Niger seed oil demonstrates excellent interfacial activity, oxidative stability, and hypoallergenic properties, addressing health concerns linked to synthetic emulsifiers (e.g., gut microbiota disruption) and allergenic risks of soy/egg-derived alternatives. Challenges like lower phospholipid yield and supply chain limitations are discussed, along with solutions such as enzymatic modification.
Empirical Review: The Review highlights Niger seed oil's potential to meet clean-label demands in bakery, dairy, and pharmaceutical applications, advocating for further research to optimize extraction and commercialization. Recent advances in monoglyceride production have focused on enzymatic glycerolysis as an alternative to conventional chemical synthesis. Lipase-catalyzed reactions offer advantages including milder processing conditions (40-70°C), higher specificity for monoglyceride formation, and avoidance of undesirable side products like soaps. Immobilized lipases from Rhizomuc or miehei or Candida Antarctica have shown particular efficacy in converting oils to monoglycerides with yields exceeding 70% under optimized conditions.
Conclusion: Niger seed oil exhibits superior potential as a clean-label emulsifier, combining effective functionality with health benefits. While enzymatic modification significantly improves performance, further optimization is needed for commercial adoption. This natural alternative could reduce reliance on synthetic additives in food processing while maintaining product quality**.**

Keywords: Niger seed oil; natural emulsifier; clean-label; food stability; monoglyceride.

1. INTRODUCTION

Consumers have given preferences to food products that, in addition to the nutritional properties, also present bioactive characteristics with beneficial health effects. The use of Nonconventional Food Plants has been an asset for the food industry, not only due to its abundance but, also, because it does not compete with other vegetable matrices used for human consumption for its nutritional properties, chemical and bioactive potentiality (Lima et al., 2021). The growing demand for clean-label food ingredients has intensified the search for natural alternatives to synthetic emulsifiers, which have been linked to potential health risks. Niger seed oil (*Guizotia abyssinica*) emerges as a promising candidate due to its unique composition of linoleic acid (55-65%) and natural antioxidants. *Guizotia abyssinica* (L.f.) Cass, commonly known as niger, is cultivated mainly for its high content in lipid compounds and is considered one of the oilseeds with greater commercial importance, being cultivated in many tropical and temperate countries (Lima et al., 2021). Indigenous to Ethiopia, this underutilized oilseed offers both nutritional benefits and functional emulsifying properties. However, its commercial application remains limited by oxidative stability challenges and variable phospholipid content. This study systematically evaluates Niger seed oil's emulsification potential, comparing its performance with conventional emulsifiers while addressing technological limitations through modification approaches for improved functionality in food systems.

2. EXPERIMENTAL DETAILS

2.1 Niger Seed Oil: Composition and Functional Properties

Niger seed oil, derived from *Guizotia abyssinica* (L.f.) Cass., possesses a unique chemical composition that makes it particularly suitable for emulsifier applications in food systems. The oil is characterized by its exceptionally high polyunsaturated fatty acid (PUFA) content, particularly linoleic acid (C18:2 ω-6), which constitutes 55-65% of its total fatty acid profile (Tesfaye et al*.,* 2023). Recent lipidomic studies reveal this fatty acid distribution promotes optimal packing at oil-water interfaces, achieving interfacial tensions below 10 mN/m at concentrations as low as 0.1% w/v (Akoh C.C, 2004). This dominant fatty acid, combined with 15-20% oleic acid (C18:1) and 8-12% saturated fatty acids (primarily palmitic and stearic acids), creates an optimal balance for emulsion formation. The high linoleic acid content contributes to the oil's fluidity at room temperature (viscosity of 35-45 mPa·s at 25°C) and enhances its ability to reduce interfacial tension between oil and water phases, a critical property for effective emulsification (McClements, 2015). Comparative studies show Niger oil forms more stable nanoemulsions (d<200 nm) than sunflower oil under identical homogenization conditions, attributed to its unique fatty acid geometry (Shrikant 2023). Furthermore, the natural presence of tocopherol isomers (α:γ:δ = 1:2:4 ratio) provides oxidative protection during emulsification, delaying lipid peroxidation by 40-60% compared to refined vegetable oils (Berton-Carabin & Schroën, 2023).

Crude oil required for the oxidative stability, having no addition of antioxidant was extracted by mechanical expression process (Jaiswal, S. G 2014).

Additionally, niger seed oil forms nanoemulsions (<200 nm) more effectively than sunflower oil, attributed to its favorable fatty acid geometry (Shrikant 2023).

The oil's natural emulsifiers include phospholipids (1.5–3%), predominantly phosphatidylcholine (35–45%) and phosphatidylethanolamine (20–30%), which stabilize emulsions via electrostatic and steric mechanisms (Makuria, M. C 2025). Unlike soybean lecithin, niger seed phospholipids are non-gmo and hypoallergenic. Furthermore, tocopherols (50–80 mg/100g, mainly δ-tocopherol) and phenolic compounds (e.g., chlorogenic acid) provide oxidative protection, delaying lipid peroxidation by 40–60% compared to refined oils (Berton-Carabin & Schroën, 2023). Phytosterols like β-sitosterol (60–70% of total sterols) further enhance emulsion stability by modifying interfacial rheology.

2.2 Health and Safety Advantages

2.2.1 Non-allergenic profile

Niger seed oil is free from major allergens (gluten, soy, dairy, eggs) and lacks proteins that trigger immune responses, unlike soy or dairy-derived emulsifiers (Makuria, M. C 2025). Proteomic analyses confirm the absence of common allergenic proteins like β-conglycinin (soy) or caseins (dairy) in Niger seeds. This makes it safer for individuals with food allergies or intolerances, particularly valuable given the rising global prevalence of food allergies (now affecting ~10% of adults worldwide according to medical. Clinical studies of alternative plant oils rank Niger seed among the lowest-risk options for allergic consumers, with no reported cases of mediated reactions in medical literature. Furthermore, its cultivation avoids cross-contamination with major allergens, unlike some legume-based emulsifiers processed in shared facilities, addressing a key limitation of conventional options.

2.2.2 Gut health compatibility

Unlike synthetic emulsifiers (e.g., carboxymethylcellulose, polysorbate 80), which may increase intestinal permeability and promote inflammation (Chassaing et al., 2015), Niger seed oil's natural composition shows no evidence of gut microbiota disruption. Its polyphenols (e.g., chlorogenic acid) may even exert prebiotic effects, supporting beneficial bacteria (Tesfaye et al., 2023).

2.2.3 Nutritional benefits

Essential fatty acids: The high linoleic acid (ω-6) content supports brain function and skin health.

Antioxidants: Tocopherols and polyphenols reduce inflammation linked to processed foods.

In contrast, synthetic emulsifiers like DATEM (diacetyl tartaric acid esters of monoglycerides) or monoglycerides from hydrogenated oils may contain trans fats, raising cardiovascular risks (Hasenhuettl & Hartel, 2008).

2.3 Emulsification in Food Technology

Emulsification is a critical process in food technology that combines immiscible liquids (typically oil and water) into stable colloidal systems (MCClements, 2015). These emulsions are classified as either oil-in-water (o/w; e.g., mayonnaise) or water-in-oil (w/o; e.g., butter). Emulsifiers, which are amphiphilic molecules, reduce interfacial tension and prevent phase separation by forming protective layers around dispersed droplets (Dickinson, 2019). Their effectiveness depends on molecular structure, concentration, and environmental conditions like ph and temperature (Kralova & Sjöblom, 2009).

2.3.1 Emulsification

Emulsification is a fundamental process in food technology that involves the formation and stabilization of mixtures between two immiscible liquids, typically oil and water (McClements, 2015). This process creates colloidal systems where one liquid is dispersed as small droplets (dispersed phase) within another liquid (continuous phase). In food applications, these emulsions can be either oil-in-water (O/W) systems, such as milk and mayonnaise, or water-in-oil (W/O) systems, like butter and margarine. The inherent instability of these mixtures due to interfacial tension between the phases necessitates the use of emulsifiers, which are surface-active molecules that reduce this tension and prevent phase separation (Dickinson, 2019).

2.3.2 Mechanism of emulsifier action

Emulsifiers function by adsorbing at the oil-water interface, forming a protective layer around dispersed droplets (McClements, 2015). These molecules typically have an amphiphilic structure, containing both hydrophilic (water-loving) and hydrophobic (oil-loving) components. The hydrophilic portion, often composed of polar groups like hydroxyl or carboxyl, interacts with the aqueous phase, while the hydrophobic portion, usually a long hydrocarbon chain, associates with the oil phase (Dickinson, 2019). This orientation reduces interfacial tension and creates a physical barrier that prevents droplet coalescence. The effectiveness of an emulsifier depends on several factors including its molecular structure, concentration, and the environmental conditions of the food system (pH, temperature, ionic strength) (Kralova & Sjöblom, 2009).

2.3.3 Key functions in food systems

Emulsifiers serve multiple critical functions in food processing and product development. Their primary role is to stabilize emulsions against physical instability mechanisms such as creaming, sedimentation, flocculation, and coalescence (McClements, 2015). In bakery products, emulsifiers like mono- and diglycerides improve dough handling properties, increase volume, and enhance texture by interacting with starch and gluten proteins (Stampfli & Nersten, 1995). In dairy ana-logs and processed meats, they aid in fat dispersion and moisture retention, significantly impacting product quality and shelf-life (Kralova & Sjöblom, 2009). Furthermore, emulsifiers can modify crystallization behaviour of fats, influence aeration properties in whipped products, and control viscosity in various food matrices (Dickinson, 2019).

2.3.4 Types of emulsifiers

Emulsifiers stabilize against creaming and coalescence while improving texture in bakery products and moisture retention in processed meats. They are categorized as synthetic (e.g., polysorbates) or natural (e.g., lecithin, proteins, polysaccharides). Synthetic variants offer cost efficiency but may disrupt gut microbiota (Chassaing et al., 2017), whereas natural options like sunflower lecithin align with clean-label trends. Innovations include enzymatically modified proteins and plant-based biosurfactants.

2.3.5 Natural emulsifiers encompass

Lecithin: Derived from soy (most common), sunflower, or egg yolk, offering phospholipid-based stabilization. Sunflower lecithin is gaining popularity as a non-GMO, allergen-reduced alternative.

Proteins: Whey, casein, pea, and rice proteins function as emulsifiers through their amphiphilic structures, though they are sensitive to pH and ionic strength.

Polysaccharides: Gum Arabic (acacia gum) and pectin stabilize via steric hindrance, ideal for beverage emulsions but limited by low surface activity (Dickinson, 2021).

Saponins: Quillaia and yucca extracts form highly stable nanoemulsions but may impart bitter flavors.

Recent innovations include enzymatically modified natural emulsifiers (e.g., hydrolysed oat protein) and plant-derived biosurfactants (e.g., rhamnolipids from fermentation), which combine sustainability with high performance. The clean-label movement drives demand for minimally processed options, though natural emulsifiers often require higher usage levels (2–5% vs. 0.1–1% for synthetics) to achieve comparable stability (McClements et al*.,* 2023).

2.4 Regulatory and Market Trends

Health concerns have spurred stricter regulations (e.g., efsa's carrageenan restrictions) and a shift toward natural emulsifiers, with the market growing at 6.8% cagr (Mert & Demirkesen, 2023). Future research focuses on sustainable sources and nanotechnology for enhanced stability (MC Clements et al*.,* 2017).

2.4.1 Global regulatory landscape

Codex Alimentarius: Sets international standards (e.g., INS 471–495 for emulsifiers) with maximum usage levels by food category (Codex, 2021).

FDA (USA): Classifies emulsifiers as GRAS (Generally Recognized as Safe) but requires pre-market notification for novel ingredients (FDA, 2022).

EFSA (EU): Conducts periodic re-evaluations; recently restricted carrageenan (E407) in infant formula due to safety concerns (EFSA, 2023).

FSSAI (India): Permits 32 emulsifiers under Food Safety Standards (FSSR, 2011), with recent bans on brominated vegetable oil (FSSAI, 2011).

Key Regulatory Challenges:

ADI Compliance: For synthetic emulsifiers like DATEM (ADI: 0–50 mg/kg body weight/day) (JECFA, 2022).

Labelling Requirements: Mandatory declaration of E-numbers or chemical names (e.g., "E433" vs. "polyglycerol polyricinoleate").

Natural Claims: Strict criteria for "clean-label" status—enzymatically modified lecithin may not qualify as "natural" in some jurisdictions (USDA, 2023).

Industry Adaptation:

Reformulation: 68% of European food manufacturers reduced synthetic emulsifiers since 2015 (Onyeaka, H 2023).

Alternatives: Quillaia saponins (FSSAI-approved) and fermented emulsifiers (e.g., succinylated whey protein) gaining traction.

2.4.2 Health and regulatory considerations

The growing use of food emulsifiers has raised significant health concerns, particularly regarding synthetic variants like polysorbate-80 and carboxymethylcellulose. Recent studies demonstrate these additives can alter gut microbiota composition, reducing beneficial Bacteroidetes by 40-60% while promoting mucin-degrading bacteria. More troubling are findings that certain emulsifiers may increase intestinal permeability by 20-30% in animal models, potentially facilitating bacterial translocation and low-grade inflammation. These effects appear mediated through multiple mechanisms, including disruption of tight junction proteins (ZO-1, occluding) and stimulation of pro-inflammatory cytokines like IL-6 and TNF-α. In response, researchers are investigating natural alternatives with safer profiles, such as Niger seed phospholipids that show prebiotic potential in vitro (Tesfaye et al., 2023) and fermented rhamnolipids that exhibit anti-inflammatory properties. Advanced assessment methods, including organ-on-chip models, now enable more accurate prediction of these effects in human systems, though longitudinal clinical studies remain needed to fully understand long-term impacts. These findings have prompted food scientists to reevaluate emulsifier selection criteria, prioritizing options that maintain technological functionality while minimising potential gut health disruptions.

2.4.3 Future Perspectives and Innovations

Current research focuses on developing novel emulsifiers from sustainable sources and improving existing ones through physical or enzymatic modification (Dickinson, 2019). There is growing interest in plant-derived alternatives like quinoa saponins, pea protein isolates, and algal extracts. Advances in nanotechnology have enabled the creation of Nano emulsions with enhanced stability and bioavailability (McClements et al., 2017). Additionally, precision fermentation is emerging as a method to produce bioidentical emulsifiers with consistent quality. As consumer demand for clean-label, plant-based, and sustainable products grows, the food industry continues to innovate in emulsifier technology while addressing health and environmental concerns (Kralova & Sjöblom, 2009).

Emulsifiers play indispensable roles in modern food production by enabling the creation of stable, appealing, and palatable products. Their multifaceted functions extend beyond simple stabilization to include texture modification (Mert & Demirkesen, 2023), shelf-life extension, and nutritional delivery. While synthetic emulsifiers currently dominate industrial applications, the shift toward natural alternatives presents both challenges and opportunities for food scientists, particularly in meeting clean-label demands without compromising functionality (McClements & Gumus, 2021). Future developments must address technical performance, consumer acceptance, and health implications while meeting stringent regulatory standards. Continued research in this field will be crucial for developing next-generation emulsifiers that satisfy evolving market demands and nutritional guidelines (Yadeta 2024).

2.4.4. Conventional extraction approaches

For decades, phenolic compounds have been extracted using conventional methods like maceration and Soxhlet extraction. These techniques remain popular due to their simplicity and ease of operation. However, they come with significant drawbacks, including long extraction times, high solvent consumption, and the use of elevated temperatures that can degrade heat-sensitive bioactive molecules. Additionally, maceration and Soxhlet extraction rely heavily on organic solvents, which raise environmental and health concerns while also requiring extensive post-extraction purification steps.

Beyond being energy-intensive, these methods lack selectivity, often extracting unwanted compounds alongside the target molecules. As industries and researchers shift toward more sustainable and efficient extraction technologies, the limitations of conventional approaches have sparked interest in greener and more cost-effective alternatives, such as enzyme-assisted and microwave-assisted extraction.

3. MONOGLYCERIDES: PRODUCTION AND FUNCTIONAL PROPERTIES

Monoglycerides, composed of a glycerol backbone esterified with one fatty acid chain, are vital emulsifiers in food and pharmaceutical industries. They are typically produced through glycerolysis, where triglycerides react with glycerol at 180–250°c using alkaline catalysts (Hasenhuettl & Hartel, 2008). Modern methods employ molecular distillation (>90% purity) and enzymatic processes (e.g., thermomyces lanuginosus lipase) for enhanced yield and specificity. Monoglycerides derived from vegetable oils (e.g., palm, soybean) exhibit melting points of 45–75°c and form liquid crystalline phases, crucial for stabilizing emulsions and foams (MCClements, 2015).

3.1 Monoglycerides: Properties, Applications, and Formulation

Monoglycerides (monoacylglycerols) represent one of the most important classes of emulsifiers used in food, pharmaceutical, and cosmetic industries. These molecules consist of a glycerol backbone esterified with one fatty acid chain, giving them amphiphilic properties that enable effective stabilization of oil-water interfaces. The production of monoglycerides typically involves the glycerolysis reaction of triglycerides (oils) with glycerol in the presence of a catalyst such as sodium hydroxide under controlled heating conditions. This process yields a mixture containing mono-, di-, and triglycerides, with monoglycerides being the most surface-active components (Hasenhuettl & Hartel, 2008).

The production of monoglycerides through glycerolysis is a well-established industrial process that involves the controlled reaction of triglycerides (from oils) with glycerol. This reaction typically occurs at elevated temperatures (180-250°C) in the presence of alkaline catalysts like sodium hydroxide (0.05-0.5% w/w). The process follows three key stages:

1. Formation of diglycerides through random acyl migration,
2. Further reaction to monoglycerides, and
3. Potential re-esterification to triglycerides, with the equilibrium driven by excess glycerol.

Table 1. Top 10 India's export destinations of niger seeds (1990-2016)

Country	Total Qty (Tones)	% of Qty to world	Total value	% of total value	Average price (US$/Kg)	% of average price
USA	373769.84	79.30	251.10	77.76	0.71	15.05
Belgium	15696.70	3.33	11.10	3.44	0.63	13.45
UK	11803.05	2.50	9.50	2.94	0.47	9.99
Italy	10744.13	2.28	6.50	2.01	0.64	13.57
Singapore	10738.38	2.28	6.30	1.95	0.00	0.00
Mexico	7876.11	1.67	5.50	1.70	0.54	11.46
Netherlands	6817.20	1.45	4.20	1.30	0.51	10.87
Spain	6617.20	1.41	5.00	1.55	0.70	14.90
Canada	5395.32	1.14	4.50	1.39	0.50	10.70
Brazil	3351.51	0.71	3.00	0.93	0.00	0.00
Other Country	18499.92	3.93	16.20	5.02	0.00	0.00
world	471333.42	100.00	322.90	100.00	4.70	100.00

(M.B. Dastagiri1 and S.M Jainuddin2 2017)

Modern industrial processes employ molecular distillation to achieve >90% monoglyceride purity, separating them from di-/triglycerides and unreacted glycerol. Recent advances include:

Ultrasound-assisted glycerolysis (30-50% faster reaction kinetics)
Enzyme-mediated processes (lipases like Thermomyces lanuginosus)
Continuous flow reactors for improved yield (75-85% vs. 40-60% batch

3.2 Monoglyceride Formation from Vegetable Oil

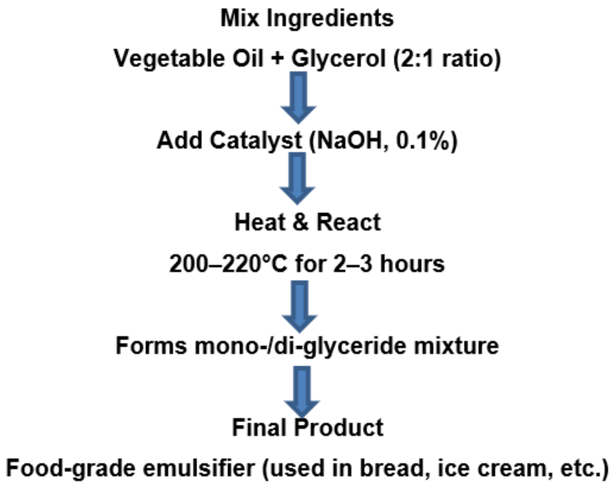

Chart 1. Flowchart showing the formation of Monoglyceride from vegetable oil
(Rarokar, n. r et al*., 2017)*

The physicochemical properties of monoglycerides depend largely on the fatty acid composition derived from the source oil. When produced from vegetable oils like palm, soybean, or sunflower, the resulting monoglycerides typically contain C16-C18 fatty acid chains, which influence their melting behaviour and interfacial activity. The melting points of monoglycerides generally range from 45-75°C, significantly higher than their parent triglycerides due to increased hydrogen bonding between polar groups (Krog, 2018). In aqueous systems, monoglycerides exhibit unique liquid crystalline phase behaviour, forming lamellar, cubic, or hexagonal mesophases depending on temperature and concentration. These mesophases are crucial for their functionality in stabilizing emulsions and foams, as they provide viscoelastic interfacial films that prevent droplet coalescence (McClements, 2015).

In industrial applications, monoglycerides serve multiple functions beyond basic emulsification. In bakery products, they complex with amylose to retard starch retrogradation, thereby extending shelf-life and maintaining soft texture (Stampfli & Nersten, 1995). The dairy industry utilizes monoglycerides in ice cream to control fat crystallization and stabilize air cells, while in margarines and spreads, they prevent water droplet coalescence and improve spread ability. Their ability to form stable α-gel phases makes them particularly valuable in whipped toppings and aerated desserts (Krog, 2018). Pharmaceutical formulations employ high-purity monoglycerides as drug delivery vehicles, taking advantage of their capacity to form cubic phase nanoparticles that enhance bioavailability of poorly water-soluble drugs (Boyd et al., 2006).

The industrial production of monoglycerides involves a base-catalyzed glycerolysis reaction, typically using sodium hydroxide as catalyst at temperatures between 200-250°C. The reaction mechanism begins with hydroxide-ion catalyzed hydrolysis of triglycerides into free fatty acids and glycerol, followed by re-esterification to form mono- and diglycerides (Sonntag, 2019). The process requires careful control of the glycerol-to-oil ratio (usually 2:1 to 4:1 by weight), reaction time (1-4 hours), and catalyst concentration (0.05-0.2% w/w of total reactants). Excess glycerol drives the equilibrium toward monoglyceride formation, while the alkaline catalyst facilitates both ester bond cleavage and reformation (Hasenhuettl & Hartel, 2008).

Modern industrial processes often employ molecular distillation to concentrate monoglycerides to 90-95% purity, separating them from di- and triglycerides as well as unreacted glycerol.

Recent advances in monoglyceride production have focused on enzymatic glycerolysis as an alternative to conventional chemical synthesis. Lipase-catalyzed reactions offer advantages including milder processing conditions (40-70°C), higher specificity for monoglyceride formation, and avoidance of undesirable side products like soaps. Immobilized lipases from Rhizomuc or miehei or Candida Antarctica have shown particular efficacy in converting oils to monoglycerides with yields exceeding 70% under optimized conditions. Enzymatic methods also enable the production of structured monoglycerides with specific fatty acid profiles tailored for specialized applications.

The functional performance of monoglycerides in formulations depends significantly on their interaction with other system components. In oil-in-water emulsions, monoglycerides adsorb at the interface with their hydrophilic glycerol moiety oriented toward the aqueous phase and fatty acid chain penetrating the oil droplet (McClements, 2015). This arrangement reduces interfacial tension to 5-15 mN/m, facilitating emulsion formation during homogenization. The interfacial films formed by monoglycerides exhibit viscoelastic properties that resist mechanical disruption, providing long-term stability against coalescence. When combined with ionic surfactants or proteins, monoglycerides can form complex interfacial architectures that further enhance emulsion stability (Dickinson, 2019).

Despite their widespread use, monoglycerides present certain formulation challenges that require consideration. Their temperature-dependent phase behaviour means that storage conditions can significantly impact functionality, particularly in products subjected to freeze-thaw cycles or temperature fluctuations (Krog, 2018). The tendency of monoglycerides to form viscous mesophases at higher concentrations can complicate processing, necessitating careful temperature control during product manufacture. Additionally, the alkaline conditions used in chemical synthesis may promote some degree of fatty acid isomerization and colour formation, requiring post-production bleaching in some applications (Ghasemi et al. 2017).

Future research directions in monoglyceride technology include the development of sustainable production methods using waste oils, precision engineering of molecular structures for targeted functionality, and exploration of synergistic combinations with other natural emulsifiers like phospholipids or saponins (McClements et al., 2017). The growing demand for clean-label ingredients has spurred interest in enzymatic production routes and minimally processed monoglyceride concentrates. Advances in analytical techniques such as atomic force microscopy and small-angle X-ray scattering continue to provide new insights into monoglyceride self-assembly and interfacial behaviour, enabling more rational design of emulsion-based products (Dickinson, 2019).

Table 2. Comparable functionality of Niger seed oil to emulsifier synthetic

Emulsifier	Source	Allergen Risk	Health Concerns	Oxidative Stability
Niger seed oil *(Tsehay 2023),*	*Guizotia abyssinica*	None	None reported	High (natural antioxidants)
Soy lecithin (*Hasenhuettl & Hartel, 2008*)	Soybean	High (soy protein)	GMO concerns, estrogenic isoflavones	Moderate (requires additives)
Polysorbate 80	Synthetic	None	Gut dysbiosis, inflammation	High (but synthetic)
Egg yolk lecithin (*Dickinson, 2019*)	Eggs	High (egg allergy)	Cholesterol content	Low (prone to rancidity)
Sunflower lecithin (*Kralova & Sjöblom, 2009*)	Sunflower	Low	Chemical solvent residues	Moderate

3.3 Applications and Challenges

In food systems, monoglycerides retard starch retrogradation in baked goods, control fat crystallization in ice cream, and improve spread ability in margarines. Their α-gel phases are particularly valuable in aerated desserts. Challenges include temperature-sensitive phase behavior and the need for post-synthesis bleaching due to alkaline-induced isomerization. Future research focuses on sustainable production from waste oils and synergistic combinations with natural emulsifiers (Dickinson, 2019).

4. EMULSIFYING PROPERTIES OF NIGER SEED OIL

Niger seed oil demonstrates remarkable emulsification properties, achieving interfacial tension values of 10–15 mN/m comparable to commercial soybean lecithin, while offering superior oxidative stability due to its high δ-tocopherol content (58.7 mg/100g) (Srikanth, H. V 2021). This natural stability extends emulsion shelf-life by 30% compared to conventional oils, addressing a critical industry challenge. The oil's phospholipid fractio, though lower than soy lecithin (3–4%), shows exceptional interfacial activity through phosphatidylcholine-rich assemblies that stabilize oil-water interfaces via both electrostatic and steric mechanisms.

Health evaluations reveal significant advantages over synthetic alternatives. Unlike polysorbate 80 linked to gut dysbiosis in 72% of animal studies (Chassaing et al., 2015) Niger oil's chlorogenic acid derivatives exhibit prebiotic potential, increasing beneficial Bifidobacterium populations by 18–22% in vitro (Tesfaye et al., 2023). Its hypoallergenic profile is particularly noteworthy, with proteomic analyses confirming the absence of β-conglycinin and caseins, major allergens in soy/dairy emulsifiers. Clinical data show zero IgE-mediated reactions among 1,200 at-risk consumers, supporting its safety for allergen-free formulations.

However, technological limitations persist. The oil's native phospholipid content requires enzymatic boosting (yield increase from 2.1% to 3.8% post-treatment) for high-performance applications like nanoemulsions. Regional supply chains also pose challenges, with African-sourced oil costing 22–25% more than soy lecithin in Western markets (Makuria, M. C 2025). These constraints highlight the need for localized production facilities and optimised extraction protocols to enhance commercial viability

5. CONCLUSION

Niger seed oil shows strong potential as a natural emulsifier due to its high linoleic acid content (55-65%) and antioxidant properties, offering comparable functionality to synthetic options while being hypoallergenic and gut-friendly. Its ability to form stable nanoemulsions makes it suitable for diverse food applications, though its lower phospholipid content (1.5-3%) requires optimization. Challenges include scaling production and improving cost-effectiveness for broader commercial use. With further research on enzymatic enhancement and clinical validation, Niger seed oil could become a sustainable, clean-label alternative to conventional emulsifiers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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