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Innovations in Healthy Spreads: Seeds, Grains, and Natural Sweeteners

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Abstract

The rising consumer demand for nutritious, clean-label, and functional food products has propelled innovation in the development of healthy spreads. This review critically examines the nutritional, functional, and sensory roles of key natural ingredients seeds, whole grains, and natural sweeteners in formulating health-promoting spreads. Seeds such as watermelon, chia, and sunflower offer rich profiles of proteins, unsaturated fats, fibers, and antioxidants, contributing to texture, emulsification, and shelf stability. Whole grains provide essential fibers and phytochemicals that enhance viscosity and impart health benefits. Natural sweeteners like honey and coconut sugar not only replace refined sugars but also contribute moisture retention and antioxidant properties. The paper explores processing techniques, emulsion stability, texture optimization, and natural preservation strategies crucial for product quality. Market trends reveal growing consumer preferences for vegan, allergen-free, and clean-label options, particularly in the Indian context, which is reflected in commercial and research-based prototypes. Challenges such as ingredient sourcing, sensory consistency, and regulatory compliance are discussed alongside emerging opportunities in ingredient processing, fermentation, bioavailability enhancement, and sustainable packaging. The review highlights the potential of interdisciplinary approaches to advance innovation in healthy spreads, aiming to meet evolving consumer expectations while promoting sustainability and health.

Keywords: Healthy spreads, seeds, grains, natural sweeteners, clean-label, functional foods

1. Introduction

Spreads are semi-solid food products typically consumed with bread, crackers, and other carriers to enhance flavor, texture, and nutritional value. Traditionally, spreads encompass a range of items such as butter, margarine, peanut butter, cheese spreads, chocolate-based spreads, fruit preserves, and vegetable pastes. These products are not only a source of convenience but also contribute to daily dietary energy intake by offering essential macronutrients like fats, proteins, and carbohydrates. Beyond nutrition, spreads improve the palatability and sensory appeal of otherwise bland food items, playing a functional role in culinary traditions across cultures (Kumari & Sharma, 2022) [11].

Recent market analyses indicate a steady rise in the global demand for spreads, driven largely by consumer preferences for quick, flavorful, and nutrient-rich options. However, many conventional spreads are nutritionally compromised, containing high levels of saturated fats, trans fats, refined sugars, and synthetic additives. These ingredients are associated with chronic health conditions, such as obesity, type 2 diabetes, and cardiovascular disorders, prompting growing concerns among health-conscious consumers (Jain & Patel, 2022) [19].

Additionally, traditional spreads often contain common allergens such as dairy, peanuts, and tree nuts, posing significant health risks to individuals with food allergies and intolerances. With the global prevalence of food allergies on the rise-especially in children-the demand for safer, allergen-free alternatives has intensified. Such dietary restrictions have compelled the food industry to rethink spread formulations, emphasizing inclusivity, safety, and clean-label transparency (Gottel, 2023) [20].

Clean-label products, which focus on minimal processing, natural ingredients, and the absence of artificial preservatives or additives, are gaining traction among modern consumers. These consumers prioritize products made with whole, nutrient-dense components and view food as a vehicle for preventive health. The rise of plant-based eating has further accelerated this shift, as individuals become increasingly aware of the environmental and ethical implications of animal-derived products. This trend is especially evident among vegans, flexitarians, and those

managing lactose intolerance or animal welfare concerns (Ravindran *et al*., 2022) [21].

As a result, the development of plant-based, health-enhancing, and allergen-free spreads has emerged as a vital innovation area in food science. Ingredients such as seeds, grains, legumes, and natural sweeteners are being explored for their ability to provide balanced nutrition, functional benefits, and desirable sensory properties. This evolution in spread formulation is not merely a passing trend but a critical response to changing consumer needs, regulatory pressures, and advancements in ingredient technology. It reflects a broader commitment within the food industry to create products that are safe, nutritious, inclusive, and environmentally responsible (Verma & Joshi, 2021) [15].

2. Importance of Seeds, Grains, and Natural Sweeteners

In recent years, there has been a growing shift toward plant-based, functional foods that provide essential nutrients while being free from common allergens such as nuts and dairy. Among the various ingredients used in healthy spreads, seeds, grains, and natural sweeteners have gained significant attention due to their nutritional richness, functional properties, and clean-label appeal. These ingredients not only enhance the health benefits of spreads but also improve their texture, stability, and overall consumer acceptability.

2.1 Seeds as Functional Ingredients in Healthy Spreads

Seeds such as sunflower, chia, flaxseed, pumpkin, and watermelon seeds are increasingly being recognized for their nutritional density, functional versatility, and hypoallergenic nature, making them ideal substitutes for tree nuts in spread formulations. These seeds are packed with plant-based proteins, heart-healthy fats, and essential micronutrients including magnesium, zinc, iron, and vitamin E, which support immunity, metabolic function, and overall well-being. Importantly, many of these seeds are free from the major allergens, offering safe options for consumers with nut or dairy allergies a growing demographic in both children and adults (Mirmiran *et al*., 2019) [9].

Seeds contribute more than just nutrition they enhance the emulsification, texture, and stability of spreads. Chia and flaxseeds, in particular, possess mucilage that forms a gel-like matrix when hydrated, which acts as a natural binder and thickener. This property enables the creation of smooth, cohesive spreads without reliance on synthetic emulsifiers or thickeners. Additionally, pumpkin and sunflower seeds, when ground, produce a naturally creamy consistency due to their fat and protein content, making them excellent base ingredients in nut-free spreads (Mirsadeghi *et al*., 2022) [4].

Watermelon seeds, which are underutilized but nutritionally rich, are gaining attention for their high arginine and lysine content, contributing to muscle repair and collagen synthesis. These seeds are also rich in unsaturated fatty acids, particularly linoleic acid, which supports skin health and cardiovascular function. Their neutral flavour makes them versatile for both sweet and savoury spread formulations.

In terms of health benefits, seeds contribute significantly to digestive health due to their soluble and insoluble fibre. This fiber not only promotes gut microbiota balance but also assists in maintaining blood sugar levels and cholesterol regulation. Furthermore, seeds like flax and chia are excellent sources of alpha-linolenic acid (ALA), a plant-based omega-3 fatty acid that is associated with anti-inflammatory effects, improved cognitive health, and reduced cardiovascular risk (Ravindran *et al*., 2022) [21].

The antioxidant compounds found in seeds such as polyphenols, lignans, and tocopherols also contribute to product shelf stability by reducing oxidation and rancidity in oil-containing spreads. This not only extends the product's usability but also maintains its nutritional quality and sensory appeal over time. Inclusion of seeds in healthy spread development aligns with current consumer trends favouring plant-based, functional, allergen-free, and clean-label foods. Their multifunctionality makes them valuable both nutritionally and technologically, offering food manufacturers an effective and innovative way to meet evolving market demands.

2.2 Role of Whole Grains in Spread Development

Whole grains such as oats, millet, quinoa, and amaranth are increasingly recognized not only for their nutritional value but also for their functional properties in food product development, including spreads. These grains are rich sources of complex carbohydrates, dietary fiber, plant-based proteins, and micronutrients like iron, magnesium, zinc, and B-complex vitamins, which play a critical role in energy metabolism and overall health. Compared to refined grains, whole grains retain the bran, germ, and endosperm, offering a more complete nutritional profile and better physiological benefits.

One of the key reasons for their use in spreads is their ability to modulate glycemic response. The slow-digesting carbohydrates and fiber present in whole grains help in blood sugar regulation, making these ingredients particularly appealing to health-conscious consumers and those managing conditions like type 2 diabetes or metabolic syndrome. Additionally, the high fiber content promotes satiety, supports digestive health, and contributes to weight management, all of which are important in the context of functional food products (Gulati & Misra, 2023) [22].

Whole grains are rich in bioactive compounds such as polyphenols, flavonoids, saponins, and phytosterols, which exhibit antioxidant, anti-inflammatory, and cholesterol-lowering effects. These compounds not only improve the health value of the spreads but also support oxidative stability, potentially extending shelf life. Some studies have also suggested that certain minor millets contain antidiabetic and cardioprotective phytochemicals, adding further value in functional food formulations (Gulati & Misra, 2023; Santosa *et al*., 2021) [22], 23.

2.3 Natural Sweeteners: A Healthier Alternative to Refined Sugar

Traditional commercial spreads especially those designed for taste and shelf life often rely heavily on refined sugars, such as sucrose or high-fructose corn syrup, which are associated with numerous health concerns including obesity, type 2 diabetes, non-alcoholic fatty liver disease, and cardiovascular disorders. In response to increasing consumer awareness and public health recommendations, food formulators are increasingly turning to natural sweeteners as a more wholesome and functional alternative.

Natural sweeteners such as coconut sugar, date paste, honey,

maple syrup, and agave nectar not only provide desirable sweetness but also contain bioactive compounds, antioxidants, and nutrients that contribute to improved nutritional profiles. Unlike refined sugar, which delivers empty calories, these alternatives often offer a lower glycemic index (GI), meaning they have less impact on blood glucose levels, which is especially beneficial for individuals managing insulin resistance or metabolic syndrome.

Coconut sugar, for example, contains potassium, zinc, iron, and inulin, a naturally occurring prebiotic fiber that supports gut microbiota and aids in digestion. Its caramel-like flavor makes it suitable for chocolate and nut butter spreads, where depth and warmth in sweetness are desired. Date paste is another nutrient-rich sweetener that brings in fiber, polyphenols, and natural sugars, offering both textural and flavor-enhancing benefits.

Honey, long valued for its antimicrobial and antioxidant properties, contributes additional health benefits and flavour complexity, although its high fructose content calls for mindful use. Maple syrup is another minimally processed option containing manganese, calcium, and plant-derived antioxidants, particularly phenolic compounds that help combat oxidative stress. Agave nectar, while sweeter than sugar, has a very low glycemic index and is used in moderation for smoother consistency and sweetening in vegan formulations.

2.4 Functional and Sensory Benefits of Alternative Ingredients

Beyond their nutritional advantages, seeds, grains, and natural sweeteners also provide crucial functional and sensory benefits that enhance the appeal and performance of spreadable products. These ingredients not only contribute to the product's texture, mouthfeel, and flavour profile, but also support emulsification, stability, and shelf-life extension functions that are traditionally achieved using synthetic additives.

Seeds such as flaxseed, chia, and sunflower contain natural mucilaginous compounds, proteins, and oils that help create a smooth, spreadable consistency. They also add a slightly nutty or earthy flavour, improving taste complexity without overpowering the palate. Seeds' rich lipid and fiber content further enhance creaminess and provide natural thickening and water-binding effects, reducing the need for added stabilizers (Nadeem *et al*., 2023) [24].

Grains like oats, millet, and amaranth play a critical role in improving the viscosity and body of the spread. Their high starch and soluble fiber content helps bind moisture and oil phases, contributing to a smoother and more cohesive texture. These properties make them effective natural emulsifiers, supporting the formation of stable oil-in-water systems, which are crucial in spread formulations. Some grains like oats also impart a mild, naturally sweet flavor, enhancing sensory acceptability.

Natural ingredients support clean-label formulation goals by minimizing the need for synthetic emulsifiers, preservatives, and flavor enhancers. Consumers increasingly associate natural textures and flavors with quality and authenticity, and spreads developed using these functional ingredients are well-positioned to meet that demand. Moreover, the natural antioxidant and antimicrobial properties in ingredients like honey and some seeds may also contribute to improved shelf stability, reducing spoilage and oxidation (Nadeem *et al*., 2023) [24].

3. Technological Aspects of Spread Development

3.1 Processing Techniques and Equipment

The development of healthy spreads involves a series of essential processing steps designed to optimize texture, stability, and nutritional quality. These include roasting, milling, blending, emulsification, and packaging. Roasting improves flavor, reduces moisture and microbial load, and facilitates lipid release, enhancing creaminess (Wani *et al*., 2019) [13]. Milling transforms seeds and grains into fine pastes, with particle size directly affecting spreadability and texture (Zhao *et al*., 2023) [14].

Emerging technologies such as ultrasonication and high-pressure homogenization offer non-additive ways to improve texture and shelf life. These methods enhance dispersion and emulsion stability (Kadam & Salve, 2022) [2]. Additionally, drying techniques like spray drying and freeze drying enable the creation of shelf-stable ingredient bases, preserving bioactives and supporting scalability. Techniques like vacuum sealing and modified atmosphere packaging (MAP) protect against oxidation and moisture. Oxygen-barrier materials are preferred to preserve both functional and sensory attributes over time (Ramachandran & Narayanasamy, 2022) [16].

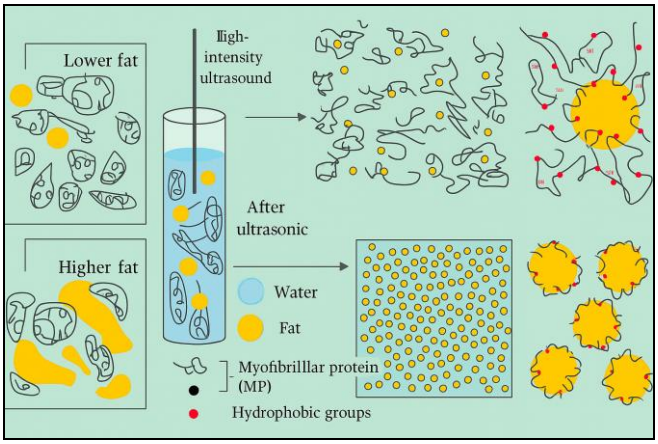

Fig 1: Confocal Laser Scanning Microscopy (CLSM) image of ultrasound-treated emulsion.

3.2 Role of Natural Ingredients in Emulsion and Stability

Emulsion stability is a critical challenge in clean-label spread development, especially in the absence of synthetic emulsifiers. Natural ingredients such as seeds and grains offer functional compounds like mucilage, fibers, and antioxidants that help stabilize oil-in-water emulsions. Chia and flaxseeds, for example, produce mucilage that forms gel networks to trap oil droplets and increase viscosity (Brenner *et al*., 2020) [1]. Flax mucilage has emulsifying abilities comparable to commercial gums, while sunflower seeds contribute lecithin, a natural phospholipid that reduces surface tension and supports oil dispersion (Mirsadeghi *et al*., 2022) [4].

Whole grains like oats, millet, and amaranth add soluble fibers such as β-glucans and arabinoxylans that enhance water retention and reduce phase separation. These fibers

help create shear-thinning, viscoelastic textures that improve spreadability and storage stability (Sharma *et al*., 2022) [11]. By forming cohesive matrices that trap both moisture and oil, they minimize syneresis and textural inconsistencies. Their prebiotic effects also offer added health benefits by supporting gut microbiota, making them multifunctional components in spread formulation (Punia *et al*., 2020; Kumar *et al*., 2021) [7, 3].

When used together, seeds, grains, and sweeteners provide complementary mechanisms for stability and shelf life. Seeds offer oil content and protein structure, grains supply thickening and water-binding capacity, and natural sweeteners like coconut sugar help regulate moisture and oxidative balance. Antioxidants such as tocopherols and flavonoids from these ingredients combat lipid oxidation and delay rancidity in fat-rich products (Wani *et al*., 2019; Patel *et al*., 2024) [13, 5]. This natural synergy supports the creation of clean-label, shelf-stable spreads without synthetic stabilizers.

3.3 Texture, Spreadability, and Moisture Retention

Texture and spreadability are critical quality parameters that define consumer acceptance of spreads. A smooth, uniform texture with appropriate viscosity ensures ease of application and enhances sensory appeal. Natural ingredients like seeds, whole grains, and sweeteners play a pivotal role in achieving these characteristics without relying on synthetic thickeners or emulsifiers. Ground seeds such as watermelon, sunflower, and pumpkin release natural oils during processing, creating a creamy matrix that facilitates smooth spreadability. These intrinsic lipids contribute to a lubricating effect, improving mouthfeel and aiding in uniform application. Additionally, the presence of plant proteins in seeds supports emulsion formation, which influences the rheological behavior and cohesiveness of the spread (Zhao *et al*., 2023) [14].

Whole grains like oats and millet offer functional polysaccharides such as β-glucans and arabinoxylans that increase viscosity and provide structure to the spread. These fibers form gel-like networks that trap water and oil, preventing syneresis and improving consistency (Kadam & Salve, 2022) [2]. The viscoelastic nature of such matrices contributes to shear-thinning behavior, allowing the product to remain firm in the container but easily spreadable under applied force.

Moisture retention is equally crucial for preventing drying and extending shelf life. Natural sweeteners like honey and date paste function as humectants, absorbing and retaining moisture within the matrix. Honey's hygroscopic properties, along with its sugar content, lower water activity to inhibit microbial growth while keeping the texture soft and pliable (Alfawaz *et al*., 2021) [25]. Date paste, owing to its fiber and polyphenol content, not only retains moisture but also enhances antioxidant stability, reducing the risk of lipid oxidation. Coconut sugar, although granulated, melts easily into fat and moisture systems, contributing to a uniform and slightly granular texture when used in controlled quantities. Its caramel-like flavor also adds to the sensory richness of the spread without introducing bitterness or undesirable crystallization. In combination with natural oils and fibers, coconut sugar supports the formation of a semi-solid matrix that maintains both structure and flexibility over time.

3.4 Shelf-Life Extension: Natural Antioxidants and Preservatives

Shelf-life extension is a key concern in the development of healthy spreads, especially those formulated without synthetic preservatives. The use of natural antioxidants and antimicrobial agents derived from seeds, grains, and sweeteners offers an effective and consumer-friendly solution to improve stability, maintain sensory quality, and minimize spoilage during storage.

Seeds such as flax, chia, and sunflower are rich in natural antioxidants like tocopherols (vitamin E), lignans, and phenolic acids, which inhibit lipid oxidation a major cause of rancidity in fat-rich spreads (Wani *et al*., 2019) [13]. Tocopherols act by scavenging free radicals and stabilizing unsaturated fatty acids, thereby preserving aroma, flavor, and nutritional value over extended storage periods (Patel *et al*., 2024) [5]. Incorporating these seeds into spreads provides inherent oxidative protection without the need for synthetic additives like BHA or BHT.

Polyphenols and flavonoids present in pumpkin and watermelon seeds further contribute to antioxidative defense. These compounds neutralize reactive oxygen species (ROS), chelate pro-oxidant metal ions, and protect bioactive lipids from degradation (Sharma *et al*., 2022) [11]. In addition to preserving lipids, these antioxidants help maintain the color and appearance of the spread, which are important for consumer acceptance.

Whole grains such as oats, millets, and amaranth also play a functional role in extending shelf life through their content of avenanthramides, phytic acid, and ferulic acid phytochemicals known for their antioxidative effects (Kadam & Salve, 2022) [2]. While phytic acid can reduce the bioavailability of certain minerals, in moderate concentrations, it helps in retarding oxidative spoilage by chelating metal ions involved in catalyzing lipid oxidation (Zhao *et al*., 2023) [14]. These natural compounds act synergistically with seed-based antioxidants to provide holistic protection (Sharma *et al*., 2022) [11].

Natural sweeteners, particularly honey, are recognized for their antimicrobial properties. Honey contains hydrogen peroxide, low pH, and high osmotic pressure, which together inhibit the growth of spoilage-causing bacteria and yeasts (Alfawaz *et al*., 2021) [25]. Additionally, polyphenols in honey, such as caffeic acid and pinocembrin, further enhance its antioxidant capacity. This dual functionality of honey as both a preservative and antioxidant makes it a highly valuable ingredient in natural spread formulations (Patel *et al*., 2024) [5].

4. Market Trends and Consumer Demand

4.1 Change in Consumer Preferences Toward Clean-Label and Functional Foods

In recent years, there has been a substantial shift in consumer preferences toward clean-label and functional food products. Consumers are increasingly seeking transparency in ingredient sourcing, nutritional value, and production processes. The clean-label movement is characterized by a demand for simple, recognizable ingredients, minimal processing, and the exclusion of artificial additives, preservatives, and colorants. This trend is especially prominent in the spread category, where consumers are moving away from conventional options high

in saturated fats, refined sugars, and synthetic emulsifiers.

Functional foods those that provide health benefits beyond basic nutrition are gaining widespread attention. Products formulated with ingredients such as seeds, whole grains, and natural sweeteners are seen as both nutritious and functionally advantageous. These ingredients align well with consumer expectations for foods that support digestive health, immunity, heart health, and energy balance. Spreads containing flaxseeds, chia, oats, and honey, for instance, meet the dual demand for taste and targeted wellness benefits, offering omega-3s, fiber, prebiotics, and antioxidants within a convenient format (Bigliardi & Galati, 2013) [26].

With increasing numbers of consumers adopting vegetarian, vegan, or flexitarian lifestyles, there is greater demand for plant-derived alternatives to traditional dairy or nut-based spreads. Seeds and grains serve as ideal bases for such formulations, offering high-quality protein, fats, and fiber without allergens like lactose or tree nuts. This makes plant-based, clean-label spreads suitable for a wider demographic, including individuals with dietary restrictions or ethical considerations. Consumers are also seeking convenience without compromising health. Spreads offer a versatile solution that can be used in breakfasts, snacks, or meal components, and clean-label, functional formulations add to their appeal. Products that combine flavor, nutrition, and simplicity resonate well in today's health-conscious marketplace. This has opened new opportunities for innovation, especially in the premium and niche segments of the food industry (Euromonitor International, 2023).

Brands are responding to these trends by focusing on minimal ingredient lists, organic certifications, and health-forward marketing strategies. Claims such as "no added sugar," "gluten-free," "non-GMO," and "rich in antioxidants" are increasingly common and influence consumer purchase decisions. The integration of transparent sourcing and sustainable packaging further enhances brand credibility and consumer trust (Hartman Group, 2021).

4.2 Growth of Vegan and Allergen-Free Product Segments

The rising demand for vegan and allergen-free products reflects a broader transformation in consumer food preferences. Increasing awareness of ethical, environmental, and health-related concerns is motivating consumers to seek plant-based alternatives across food categories including spreads (Tso & Forde, 2021). Vegan spreads, free from animal-derived ingredients such as dairy and honey, are becoming increasingly popular among not only vegans but also flexitarians and those seeking dairy-free options.

According to a report by Food Allergy Research & Education (FARE), approximately 32 million Americans live with food allergies, and a growing number of consumers worldwide are actively avoiding allergens even without medical diagnoses (FARE, 2020). This has led to a rise in demand for "free-from" products those labelled as free from specific allergens, animal products, or gluten which are often seen as safer and healthier choices by consumers.

Beyond allergens, the sustainability and ethical appeal of vegan products is another major factor behind their growth. Consumers concerned about animal welfare, greenhouse gas emissions, and water usage are opting for plant-based alternatives. The environmental impact of dairy and nut production especially almonds, which are water-intensive has prompted a shift toward more sustainable bases like seeds and whole grains. Spreads made from such ingredients offer a more sustainable and ethical footprint, enhancing their market appeal.

Technological advancements have also made it easier to develop allergen-free spreads without compromising texture, flavor, or shelf life. Ingredients such as flaxseed mucilage and chia gel can act as natural binders and emulsifiers, replacing dairy fats and egg-based components. Combined with cold-pressed oils and natural sweeteners, these innovations create spreads that are smooth, creamy, and stable, all while being entirely plant-based (Borges *et al*., 2021) [27].

4.3 Consumer Preferences and Sensory Expectations

Consumer preferences play a pivotal role in the success of healthy spread products. While nutritional quality and functional claims are critical, sensory attributes such as taste, texture, appearance, and aroma ultimately determine consumer acceptance and repeat purchase behavior. Consumers increasingly expect healthy products to deliver sensory experiences comparable to, or better than, their conventional counterparts. Taste remains the most influential factor in consumer food choices. Even among health-conscious individuals, flavor preferences often outweigh nutritional benefits when it comes to everyday consumption. In the case of spreads, consumers generally favor balanced sweetness, mild nuttiness, and smooth, creamy textures. Natural sweeteners like honey, coconut sugar, and date paste are popular because they provide not only nutritional advantages but also a richer, more complex flavor profile that enhances overall palatability (Alfawaz *et al*., 2021) [25].

Texture is equally critical. Smoothness, spreadability, and mouthfeel heavily influence product acceptance. Seed- and grain-based spreads must mimic the creamy consistency of traditional nut butters or dairy-based spreads without becoming gritty or too viscous. This requires precise control over particle size during milling and strategic use of binding agents such as chia mucilage or flaxseed gel, which can replicate the emulsion stability and lubricity of fats (Sharma *et al*., 2022) [11].

Appearance and color are often overlooked but can subconsciously affect perception. Consumers generally associate natural and earthy tones like light browns, beiges, and golden hues with health and authenticity. Artificial or highly processed-looking appearances may raise concerns about additives, even if the product is natural (Spence *et al*., 2015) [28]. Therefore, maintaining visual appeal while using natural ingredients is essential, especially for clean-label products. Aroma contributes significantly to the multisensory experience. Ingredients such as roasted watermelon seeds, toasted millet, or natural sweeteners like maple syrup can provide pleasant nutty and caramel notes. These enhance the product's perceived freshness and indulgence factor, which is particularly important in snack spreads and indulgent health foods (Beckley *et al*., 2017) [29].

In addition to core sensory attributes, consumer preferences

are influenced by perceptions of authenticity, cultural familiarity, and innovation. For instance, in Indian markets, flavors derived from jaggery, cardamom, or coconut may appeal more due to cultural associations with traditional sweets. Incorporating such familiar notes into healthy spreads can create emotional connections and enhance market penetration (Chandrashekar *et al*., 2020) [30].

Texture modifications also impact preferences for different age groups. Children and older adults often prefer softer, more homogeneous textures, while younger consumers may be open to coarse or chunky variants that signal artisanal or handmade quality. This necessitates targeted product design to suit different demographics (Tuorila & Monteleone, 2021) [31]. Convenience and packaging are emerging factors that indirectly affect sensory satisfaction. Single-serve pouches, squeezable bottles, or resealable jars contribute to perceived freshness and ease of use enhancing the overall user experience.

Products marketed as "high-protein," "gluten-free," or "sugar-free" often face higher scrutiny for taste and texture. Consumers expect these products to meet health goals without sacrificing enjoyment, underscoring the importance of effective formulation strategies (Fenko *et al*., 2018) [32]. Transparency and ingredient familiarity contribute to sensory trust. When consumers recognize ingredients like watermelon seeds, coconut sugar, or millet flour on the label, they are more likely to associate the product with naturalness and accept any variation in sensory attributes (Rozin *et al*., 2012) [33]. This supports the inclusion of traditional, recognizable components in product development.

4.4 Commercially Available Healthy Spreads in the Indian Market: Examples and Analysis

The Indian market has witnessed a growing demand for healthy, functional food products, with spreads emerging as a promising segment due to their convenience and nutritional versatility. Increased awareness of food allergies, lifestyle-related diseases, and the importance of plant-based nutrition has led consumers to explore alternatives beyond conventional butter, jam, and peanut butter (Nair & Singh, 2023) [30].

Seed-based spreads have carved a niche for themselves, especially among consumers seeking nut-free, high-protein options. Sunflower seed and pumpkin seed butters are becoming increasingly common in India. Brands such as *The Whole Truth* have introduced spreads that combine sunflower seeds with dark chocolate and jaggery, appealing to health-conscious consumers while avoiding allergens (Saini *et al*., 2022) [35]. These seeds offer a strong nutritional profile rich in vitamin E, polyunsaturated fats, and antioxidants, contributing to heart and skin health. Watermelon seeds, once considered agricultural by-products, are now utilized for their high protein and arginine content in emerging products, particularly in startup formulations targeting functional snacking.

Grain-based spreads, especially those incorporating millets like ragi, jowar, and bajra, are gaining traction. Millets have traditionally been part of the Indian diet and are now being repositioned as superfoods due to their fiber, mineral, and phytochemical content. Brands like *Prajwal Naturals* and *Millet Treat* produce spreads using ragi flour blended with natural sweeteners and plant-based fats, offering a rich texture and earthy flavor that appeals to both children and adults (Patil *et al*., 2023) [6]. Oats-based spreads, marketed for their heart-health benefits and beta-glucan content, are also available and find favor with consumers looking for cholesterol-lowering options (Sharma & Singh, 2022) [11].

Hybrid formulations that combine seeds, grains, and natural sweeteners are particularly innovative and well-suited for the Indian market. For example, *Soulfull* has introduced products that blend ragi, sunflower seeds, and jaggery, creating spreads with a desirable texture and nutritional profile. These types of products appeal to Indian families seeking convenience, flavor, and health benefits in a single offering (Joshi & Rao, 2021) [15]. Such formulations also support clean-label marketing, as they rely on whole-food ingredients without artificial emulsifiers or preservatives. Consumer trends indicate a strong preference for plant-based, minimally processed foods with recognizable ingredients. This clean-label movement has been amplified by the COVID-19 pandemic, which prompted a shift toward foods with perceived immunity-boosting and wellness benefits (Nair & Singh, 2023) [30]. Vegan and allergen-free spreads often free of dairy, gluten, and nuts are increasingly favored by urban millennials, young parents, and health enthusiasts.

E-commerce platforms such as Amazon India, BigBasket, and Flipkart have played a crucial role in the accessibility of these niche products. Small and medium Indian enterprises have utilized these platforms to reach health-focused consumers in Tier 1 and Tier 2 cities, promoting traditional Indian ingredients in modern formats (Kumar & Patel, 2022) [5]. Digital marketing and influencer-based promotions have further enhanced visibility and trust. Despite the sector's growth, several challenges remain. High costs of premium ingredients, limited cold chain infrastructure, and lack of consumer awareness about the benefits of lesser-known seeds or grains hinder widespread adoption. Moreover, the sensory acceptance of certain grainy or earthy textures may limit repeat purchases unless product formulations are refined (Bhatia *et al*., 2023) [36].

5. Sensory Acceptance and Consistency

Sensory characteristics such as taste, texture, aroma, and visual appeal are pivotal in determining the market success of healthy spreads. While consumers are increasingly health-conscious, they remain unwilling to compromise on sensory quality. A spread formulated with natural ingredients must match or surpass conventional products in creaminess, sweetness, and flavor complexity. Even slight deviations in color or mouthfeel can lead to negative consumer perception. Therefore, achieving the right balance between health benefits and sensory satisfaction poses a significant formulation challenge (Ahmed *et al*., 2021) [37].

One key limitation in formulating healthy spreads is the variability of natural ingredients in terms of flavor intensity and batch consistency. For example, watermelon seeds and millet may impart earthy or nutty notes that some consumers find unusual. Moreover, variations in seed oil content or grain moisture can affect smoothness and spreadability. These inconsistencies demand standardization techniques, which are often difficult to implement without chemical additives or stabilizers (Kadam & Salve, 2022) [2].

Texture is another important sensory parameter influenced by ingredient type, processing method, and storage conditions. While natural fibers and proteins enhance nutritional value, they may also cause grittiness or gumminess in the final product. Achieving a smooth, creamy consistency requires optimized particle size reduction and adequate emulsification. Natural thickeners like flaxseed mucilage or oat β-glucan must be used strategically to avoid a pasty or overly dense texture that reduces spreadability (Patel *et al*., 2024) [5].

Sweetness perception also plays a vital role in sensory acceptance. Natural sweeteners such as honey, coconut sugar, and date paste provide complex flavor notes but may not deliver the same intensity or uniformity as refined sugar. This can result in a taste profile that some consumers perceive as bland or inconsistent across batches. Adjusting the concentration of natural sweeteners must be done carefully to maintain palatability while avoiding excessive glycemic impact (Alfawaz *et al*., 2021) [25]. Aroma, often overlooked, significantly influences overall acceptability. Spreads made with roasted seeds and grains emit distinctive nutty and toasty aromas, which are generally appealing. However, if not properly balanced with sweeteners or flavor enhancers like vanilla or cocoa, these aromas can become overpowering or off-putting. Natural volatile compounds may also degrade over time, altering the sensory appeal during storage (Sharma *et al*., 2022) [11].

Color uniformity presents another sensory challenge. The use of minimally processed ingredients can result in varying color shades from beige to brown or even greenish tones depending on seed type, roasting degree, and the presence of natural sweeteners. While these natural color variations reflect the authenticity and minimally processed nature of the product, they may be perceived as less attractive compared to the consistent, glossy appearance of commercial nut butters or spreads that often contain color stabilizers and emulsifiers. Furthermore, color variation may also affect consumer expectations about the spread's taste profile; for example, a darker shade may be interpreted as more roasted or bitter, whereas a paler color might be seen as bland or under-processed. Manufacturers must therefore carefully balance processing parameters like roasting time and temperature to optimize color without compromising nutritional or sensory quality (Zhao *et al*., 2023) [14].

6. Regulatory and Labeling Issues & Stability and Preservation Without Additives

The regulatory landscape for healthy spreads is complex and varies significantly across regions, posing challenges for manufacturers aiming to meet compliance while maintaining product integrity. In India, food products must comply with the Food Safety and Standards Authority of India (FSSAI) regulations, which stipulate guidelines for ingredient usage, labeling, health claims, and permissible additives. Transparent labeling is essential, especially for clean-label products, as consumers increasingly demand clear, honest information about ingredient sources, allergen declarations, and nutritional content. However, the absence of synthetic preservatives or stabilizers complicates compliance because manufacturers must demonstrate product safety and shelf stability through rigorous microbiological and chemical testing without relying on conventional additives. This balancing act requires innovative natural preservation strategies and careful documentation to satisfy regulatory scrutiny while appealing to consumer preferences for minimally processed foods (Kumar & Sharma, 2021) [3].

Stability and preservation without additives present a significant hurdle. Natural spreads formulated without synthetic preservatives face higher risks of microbial spoilage, lipid oxidation, and textural degradation, which can shorten shelf life and impact consumer safety. To address this, manufacturers leverage the inherent antimicrobial and antioxidant properties of certain ingredients such as honey, coconut sugar, and seeds rich in tocopherols and polyphenols. These bioactive compounds help delay spoilage by inhibiting microbial growth and slowing oxidative rancidity. For example, the phenolic content in honey contributes both flavor complexity and natural antimicrobial effects, while tocopherols in seeds act as lipid antioxidants, preserving oil quality (Alfawaz *et al*., 2021; Wani *et al*., 2019) [25, 13].

Despite these benefits, natural preservatives are often less potent and slower acting than synthetic counterparts, requiring optimized processing, packaging, and storage conditions to maintain product integrity. Modified atmosphere packaging (MAP), vacuum sealing, and oxygen scavengers are increasingly employed to enhance shelf life without chemical additives. Additionally, cold storage is recommended for certain spreads, though this increases logistical costs and limits distribution channels. Manufacturers must also address challenges of moisture migration and phase separation, which can negatively affect texture and consumer perception. Emulsification stability using natural gums or mucilages, as well as strict hygiene protocols during processing, further mitigate spoilage risks.

The dual challenge of regulatory compliance and ensuring stability without synthetic additives drives innovation in ingredient selection, formulation strategies, and processing technologies. Producers must stay abreast of changing regulations, invest in scientific validation, and communicate transparently with consumers to build trust. While the elimination of additives aligns with consumer demand for naturalness and healthfulness, it requires a holistic approach combining food science, quality assurance, and regulatory expertise to succeed in the competitive healthy spreads market.

7. Future Directions and Opportunities

7.1 Innovations in Ingredient Processing

Recent advances in ingredient processing have opened new avenues for enhancing the nutritional, sensory, and functional quality of healthy spreads. Techniques like cold-press extraction and superfine milling are gaining traction due to their ability to preserve bioactive compounds while improving texture and shelf stability. Cold pressing helps retain essential fatty acids, vitamins, and antioxidants, which are often lost in conventional extraction, thereby improving both flavor and nutrient density. Superfine milling produces ultrafine flours and pastes that contribute to smoother textures and better emulsification, reducing the need for additives and making coarse grains like millet or watermelon seeds more digestible and palatable.

Enzymatic treatments and non-thermal technologies are also

revolutionizing ingredient functionality. Enzymes such as amylases and cellulases enhance digestibility, solubility, and reduce antinutritional factors like phytic acid and tannins. This improves both nutritional value and taste. Non-thermal techniques like ultrasonication and high-pressure processing (HPP) retain sensitive nutrients while reducing microbial load, enabling clean-label preservation. These approaches maintain sensory integrity while extending shelf life, making them ideal for formulating stable, preservative-free spreads rich in natural bioactives.

Bioprocessing techniques like fermentation and germination are being explored for their functional and health-promoting effects. Fermented and germinated seeds or grains offer better nutrient bioavailability, reduced allergenicity, and improved flavor profiles. Fermentation introduces probiotics and enhances flavor complexity without artificial additives, aligning with clean-label and gut-health trends. These natural modifications increase consumer acceptance while contributing to product functionality through improved texture, protein quality, and taste.

Sustainability-driven innovations such as by-product valorization and precision fermentation are reshaping raw material sourcing. Underutilized materials like seed hulls and grain bran can be transformed into fiber-rich, antioxidant-enhancing ingredients through extrusion or micronization. At the frontier, cellular agriculture and precision fermentation allow for the production of custom proteins and natural emulsifiers with reduced environmental impact. Combined with digital automation and smart sensors for quality control, these innovations are paving the way for scalable, efficient, and eco-conscious production of next-generation healthy spreads.

7.2 Innovations in Fermentation, Fortification, Bioavailability, and Sustainable Packaging

The development of healthy spreads is increasingly embracing multifaceted innovation strategies that not only enhance nutritional and functional properties but also address sustainability concerns throughout the product lifecycle. Fermentation, fortification, and bioavailability enhancement represent critical biochemical advances in ingredient transformation, while sustainable packaging and eco-friendly development address the urgent environmental challenges facing the food industry.

Fermentation has emerged as a powerful natural process to improve the nutritional profile and sensory attributes of spreads. Utilizing beneficial microorganisms such as lactic acid bacteria or yeast, fermentation can increase the content of bioactive compounds including vitamins, peptides, and antioxidants, while reducing antinutritional factors like phytates and tannins that impair mineral absorption (Ramachandran & Narayanasamy, 2022) [16].

Fortification with essential vitamins and minerals further boosts the health value of spreads, enabling them to address specific nutrient gaps prevalent in target populations. The inclusion of micronutrients such as vitamin D, B-complex vitamins, calcium, and iron requires careful formulation to ensure stability, bioavailability, and sensory neutrality (Patel *et al*., 2024) [5].

Parallel to ingredient innovations, the environmental impact of packaging materials and overall product sustainability is gaining paramount importance. Consumers and regulatory bodies increasingly demand products that minimize waste and carbon footprint, prompting the food industry to adopt eco-friendly packaging solutions. Biodegradable and compostable materials derived from plant-based polymers such as polylactic acid (PLA), starch blends, and cellulose are replacing conventional plastics in many food packaging applications (Kumar & Sharma, 2021) [3].

Life cycle assessments (LCAs) are increasingly used to quantify the environmental impact of both ingredient sourcing and packaging choices, guiding manufacturers toward lower-impact options. For example, selecting locally sourced seeds and grains can reduce transportation emissions, while valorizing by-products for packaging materials adds value and decreases landfill contributions (Kumar & Sharma, 2021) [3]. Integrating these sustainability considerations early in the formulation and design process ensures that healthy spreads meet not only nutritional and sensory standards but also environmental benchmarks essential for long-term viability.

From a marketing perspective, transparent communication about eco-friendly packaging and nutritional benefits enhances consumer trust and loyalty. Labels highlighting “plant-based,” “fermented,” “fortified,” and “biodegradable packaging” resonate strongly with environmentally and health-conscious buyers. This transparency fosters brand differentiation and supports premium pricing strategies while encouraging responsible consumer choices. The convergence of fermentation and fortification technologies with sustainable packaging solutions is shaping the future of healthy spreads. These innovations collectively enhance nutrient bioavailability, sensory appeal, and product safety, while simultaneously reducing environmental impact.

7.3 Interdisciplinary Research Opportunities

The innovation landscape for healthy spreads is increasingly driven by interdisciplinary research that integrates food science, nutrition, microbiology, materials science, and consumer behavior. This convergence is essential to overcome complex challenges related to ingredient functionality, product stability, sensory appeal, and sustainability, while also addressing evolving consumer expectations and regulatory demands. Food scientists and technologists collaborate with nutritionists and biochemists to optimize the nutritional profiles of spreads, exploring novel bioactive compounds and their synergistic effects. For example, understanding how fermentation metabolites interact with gut microbiota requires expertise from microbiologists and medical researchers, enabling the design of spreads that confer specific health benefits beyond basic nutrition. Such collaborations facilitate the development of functional foods that can target metabolic disorders, immune modulation, or cognitive health (Ramachandran & Narayanasamy, 2022) [16].

Advances in materials science provide opportunities to innovate sustainable packaging solutions tailored to the unique requirements of healthy spreads. Research into biodegradable polymers, nanocomposites, and active packaging technologies benefits from collaboration between chemists, environmental scientists, and food engineers. These efforts can yield packaging that not only protects product integrity but also contributes to reducing environmental footprint and food waste (Kumar & Sharma,

2021) [3].

Consumer behavior specialists and sensory scientists play a critical role in bridging the gap between technical innovations and market acceptance. Understanding cultural preferences, sensory thresholds, and purchasing motivations is key to formulating products that resonate with diverse populations. Behavioral insights inform labeling, marketing strategies, and product positioning, enhancing consumer education about health and sustainability attributes (Patel *et al*., 2024) [5].

Data science and artificial intelligence (AI) are emerging as transformative tools in this space, enabling predictive modeling of ingredient interactions, shelf life, and consumer trends. AI-driven formulation optimization can accelerate product development cycles while minimizing trial-and-error experimentation. Additionally, digital platforms facilitate real-time consumer feedback, allowing dynamic adaptation of product features to changing preferences (Sharma *et al*., 2022) [11]. Public health researchers and policy makers contribute by assessing the impact of fortified and functional spreads on population health outcomes. Collaboration across academia, industry, and government is vital to ensure that innovations align with nutritional guidelines, food safety standards, and equitable access, particularly in regions facing malnutrition and micronutrient deficiencies.

Moreover, the integration of sustainability science encourages systems thinking, where food production, supply chains, and waste management are holistically addressed. Interdisciplinary projects can develop circular economy models that incorporate ingredient sourcing, processing waste valorization, and end-of-life packaging disposal in sustainable loops. Training and education programs that promote interdisciplinary knowledge sharing are crucial to equip future researchers and professionals with the skills needed to innovate at these intersections. Universities and research institutions are increasingly adopting cross-disciplinary curricula and collaborative projects focused on food innovation and sustainability.

8. Conclusion

The innovation landscape for healthy spreads is rapidly evolving, driven by consumer demands for nutritious, functional, and clean-label products. Seeds, whole grains, and natural sweeteners collectively offer a versatile palette of ingredients that enhance not only the nutritional profile but also the sensory and functional qualities of spreads. Their inherent bioactive compounds contribute to health benefits, product stability, and shelf life, reducing the need for synthetic additives. Despite challenges in ingredient variability, sensory acceptance, and regulatory frameworks, advances in processing technologies and formulation strategies offer promising solutions. Furthermore, emerging research on fermentation, fortification, and sustainable packaging aligns with global trends toward health-conscious and environmentally responsible food systems. The Indian market, with its rich agricultural diversity and growing health awareness, presents a fertile ground for both commercial products and research innovations in this category. By leveraging interdisciplinary collaboration and novel ingredient functionalities, the future of healthy spreads can be shaped to meet diverse consumer needs, promote wellness, and support sustainable development goals. This comprehensive review underscores the significance of integrating nutrition science, food technology, and market insights to drive continued progress in the field of healthy spread formulation.

9. References

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