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A comprehensive review on effect of chia seed, flaxseed, sesame seed and their derivatives on quality of bakery products

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ABSTRACT

Bakery products are among the most widely consumed foods globally, yet their traditional formulations often lack essential nutrients such as high-quality proteins, dietary fiber, and bioactive compounds. To address this gap, a lot of investigation has been done on the use of functional nutrients, especially chia, flax, and sesame seeds. The results of published research on the impact of these seeds are critically summarized in this review and their derivatives on the nutritional composition, physicochemical characteristics, and sensory attributes of bakery products, including bread, cakes, muffins, cookies, brownies, and scones. In order to demonstrate how partial substitution of these seeds for wheat flour or eggs impacts macronutrient balance, water retention, product texture, volume, color, and customer acceptability, a comprehensive review of the literature was conducted. Consistent patterns are highlighted in the discussion, including higher levels of protein, fiber, and unsaturated fatty acids, deeper crust and crumb colors, and varying effects on moisture and specific volume based on the degree of substitution. Although the evaluated research shows that sesame, flax, and chia seeds can enhance the nutritional and functional quality of bakery products. There are still a few limitations such as a decreased loaf volume at greater substitution levels and possible adverse effects on texture or flavor. The review concludes that moderate incorporation of these seeds offers an effective strategy for developing nutrient-enriched bakery items aligned with current consumer demand for functional foods. Further research is recommended to optimize substitution levels, improve sensory appeal, and extend shelf life through advanced processing techniques.

1. Introduction

Bakery products are widely consumed and most popular food in consumer's dietary lifestyle. The term "bakery items" referred to the wide range of products including cakes, bread, muffins, cookies and all baked products containing rich amount of fats and sugar. These products are easy to fortify at home and industrial levels (Rabail et al., 2022). Although wheat flour is commonly used to make muffins, cupcakes, and other pastries, appropriate alternatives are required because around 1 % of the world's population is allergic to wheat, barley, or rye (Sahni &

Sharma, 2023; Shamanin et al., 2024; Zhu, Jet al., 2023). Gluten causes celiac disease, an autoimmune condition that demands the development of substitutes; however, because gluten creates the protein network necessary for baked goods and adds viscoelasticity, Its absence degrades the quality of the dough, leading to research into the best gluten-free products. Moreover, hyperlipidemia (a disease related to high cholesterol) a major risk factor for cardiovascular diseases (CVDs) in humans and animals. It is primarily caused by a diet rich in cholesterol. Therefore, the researchers are increasingly focusing on foods that provide medicinal properties helps to prevent CVDs. There is a substantial

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evidence of linking of compromised maternal nutrition and impaired child growth due to higher incident of CVDs in adulthood and later life (AlMasoud et al., 2024; Rehan et al., 2023). The growing health conscious consumer's demands resulted in safe and nutritious food products (Shelke et al., 2024) and the functional foods are used in daily lifestyle of consumers due to health benefits, regulating body functions and scientific verification of relationship between health and diet (Guedes de Melo et al., 2022). However still some products contain higher sugar and glycemic index (GI), lower protein and mineral contents (Amadi & China, 2022). Consumers are well aware of the functional foods and they prefer ready to eat food products made from natural food or ingredients and contains low caloric density, minimal supplementation, reduced fat content and high fiber content that can be consumed daily as part of diet (Karakoç et al., 2024; Medina-Pérez et al., 2025). The global urbanization and awareness improved the technology of bakery industry in terms of functional and nutraceutical potential (Albaayit et al., 2024; Punia & Dhull, 2019). Consumer attitudes and awareness regarding food safety and quality have a significant impact on their acceptance of functional bread items enriched with seeds like sesame, flaxseed, and chia (Alshaiikh et al., 2023; Amin et al., 2024; Elkhalifa et al., 2024; Hanif et al., 2023; Mithu et al., 2025). Recent studies on utilization of food coproducts not only help in food wastage reduction but also provide improved nutritional benefits to the product (Lucini Mas et al., 2022). Plants have an important role in providing nutraceutical benefits to body with managing diseases and improving body conditions (Abduallah et al., 2023; Kunu et al., 2025; Saleh et al., 2023). The scientists are working on plants to prepare various products from its extract and powder for disease prevention (Abduallah et al., 2024).

Chia (*Sabia hispanica* L.) is an annual herbaceous plant belongs to Lamiaceae family and derived from a Spanish word "Chian" meaning oily with greater levels of alpha-linolenic acid (Shelke et al., 2024; Siddique et al., 2024). Chia seed contains more protein than wheat, corn, rice, oat and barley. It contains rich amount of soluble fibers, oil especially omega-3 and omega-6, polyunsaturated fatty acids mainly linolenic acid, lipid and polyphenols content (Antonini et al., 2020; da Costa Borges et al., 2021; Hatamian et al., 2020; Khatri et al., 2023). The nutritional index with n-3/n-6 PUFA/SFA is beneficial for human health (Ahmad et al., 2023). The higher proportion of fatty acids in chia seeds was responsible for the high fat content, whereas the lower moisture content indicated that the chia seeds were less perishable (Siddique et al., 2024). In addition to nutritional properties the mucilage presence in these seeds provide them the properties of water holding, emulsifying, gelling and shear thinning and act as a food additive to control viscosity, stability, texture and consistency in bakery products (Moreira et al., 2023; Wang et al., 2023). In bakery products due to its hydrating properties, ability to enhance water and maintain freshness it can function as a fat substitute (Iserliyska et al., 2021). In recent years chia seed gain popularity among consumers due to their nutritional, functional and nutraceutical properties and used in different food products such as drinks and bakery (Antonini et al., 2020; Anwar et al., 2024). About 1–3 % of the Pakistan population suffers from celiac diseases, and the effective way to manage it by excluding it from diet, it's challenging as wheat based products (gluten dense) are a major staple food in the country. Gluten free flour can be obtained from variety of sources including chia seed that most of the researchers are using as a gluten free source in bakery products formulations (Ahmad et al., 2024). Flaxseed also called linseed (*Linum usitatissimum*) is an ancient plant belongs to the family of Linaceae. It is an economical and multipurpose oilseed crop that is gaining popularity among consumers due to its high nutritional and medicinal values with the significant quantities of short-chain ω -3 fatty acids (Kausar et al., 2024; Khan et al., 2024). Flaxseed serves as a good source of protein (globulin & albumin), polyunsaturated fatty acids, dietary fibers, minerals, lignans, phenolic compounds, high ratio of omega-3 to omega-6 fatty acids and being used as a raw material in functional foods and as an egg substitute in plant based dishes (Sharma

et al., 2024; İlyasoğlu et al., 2022). The presence of phyto-estrogenic fibers e.g. lignan in flaxseed controls blood sugar levels. The preventive and therapeutic potential of flaxseed in controlling chronic diseases and reducing the risk of degenerative diseases due to its highest biological activity in the presence of alpha linolenic acid, lignans and dietary fibers (Al-Alwani et al., 2023; İlyasoğlu et al., 2022; Rubio et al., 2018). The presence of these 3 bioactive compounds also reduces the risk of cardiovascular disease, body weight and fat accumulation, breast cancer, osteoporosis, heart disease, menopausal symptoms and protects blood vessels from inflammatory damage (Marpalle et al., 2014).

Sesame (*Sesamum indicum* L.) also known as gingelly, beniseed, simsim, and til, is one of the oldest oilseed crops, it is tiny, flat oval seeds with the nutty taste. It is an important oil seed believed to be originated from tropical Africa with the greatest diversity (M et al., 2020). It contains high levels of biological value proteins with the high content of arginine, methionine, tryptophan, phenylalanine, threonine and leucine that helps them to contribute for the daily consumption of essential amino acids (Nouska et al., 2024a). Sesame seed contains high levels of oil and vital minerals including Mn, Fe, Ca, Mg, vitamins and phyto-sterols that plays important role in body (Kiin-Kabari, 2019; Rubio et al., 2018). Sesame seeds are used in confectionary industry and in pastries such as cakes, snacks and condiments and passed through various processes including roasting and by making flour. In roasted seeds sugar is added to enhance flavors (Al-Alwani et al., 2023). Chia, flax and sesame seeds also known as super foods gaining popularity among consumers due to presence of major contributor including protein, fiber, unsaturated fatty acids and antioxidants in diet and these antioxidants reduces the risk of oxidative damage to product (Anwar et al., 2024; Brigante et al., 2022). The need for natural antioxidants has grown recently despite the availability of synthetic antioxidants, primarily as a result of the negative effects of synthetic antioxidants that have been documented (Gul et al., 2024). Different botanicals are well known for their therapeutic and immunomodulatory properties against various disorders of humans and animals (Abbas & Alkheraije, 2023). These seeds contain essential oils that are the complex mixtures of secondary metabolites and volatile compounds (Brenda et al., 2024). Despite increasing research on chia, flax, and sesame seeds in bakery applications, there are still gaps because of disconnected research on individual seeds or specific products. Consistent results on their nutritional value, physicochemical, and sensory impacts are also limited by differences in replacement levels, processing strategies, and evaluation procedures. This review is interesting since it brings together multiple data points to present an organized approach. The objectives are to (i) summarize nutritional contributions, (ii) evaluate effects on physicochemical and textural properties, (iii) assess sensory outcomes and consumer acceptance, and (iv) Emphasize limitations and future research directions. This review offers comprehensive insights to guide both researchers and the bakery industry in developing nutrient-enriched, consumer-preferred bakery products.

2. Chia seed and its derivatives in bakery products

2.1. Moisture retention

Moisture content being a major indicator of food quality effects the softness, freshness and customer acceptability of bakery products including cakes and sweets (Aljobair, 2022). Moisture migration and starch retro-gradation are initial causes of staleness in gluten-free bread, which result in moisture loss, crumb firming, and decreased freshness, and recrystallization of amylopectin playing a crucial role in this process, amylose and amylopectin come apart when they cool down. Chia mucilage act as a hydrocolloid and bind water that resulted in reduction of loaf volume and texture (Asqardokht-Aliabadi et al., 2025; Cakir et al., 2024). Wheat starch and chia mucilage fibers can work together to slow down retro-gradation and moisture loss during baking. Because water retention is limited by the lower starch content at higher flour

replacement levels (6 %) there is less moisture. As a result, compared to chia-enriched samples, control brownies with more flour displayed higher moisture levels (Moreira et al., 2023). The incorporation of chia seed into gluten free bread formulations initially decreased moisture content; however, at concentrations above 6 %, the moisture content remained relatively constant. The higher water retention capacity of mucilage found in chia seeds explains this pattern. High amounts of mucilage permeate the system and stabilize moisture retention, Its impact at lower concentrations is not enough to overcome the gluten-free dough's structural limitations (da Costa Borges et al., 2021). Muffins, on the other hand, showed a clear pattern of decreased moisture content when chia seed flour was added to wheat flour. This is probably because the mucilage and fiber fractions of chia compete for water during baking (Rabail et al., 2022). Replacing eggs with chia seed flour in sponge cake formulations increased moisture content. Because of the mucilage, chia's 7 % substitution was significantly better than the others. It also improves the cake's ability to bind water and stabilizes its structure (Aljobair, 2022). Chia mucilage (25–100 %) significantly increased moisture retention in pound cakes when used in place of fat; the highest values (28.83 g/100 g) were obtained with the 100 % replacement. This impact is explained by the high soluble fiber content of chia mucilage, which enhances its ability to bind water and helps baking matrices retain more moisture (Guedes de Melo et al., 2022). The 15-day study on moisture retention showed that when hydrated chia seeds were used to replace fat in pound cakes, the moisture level was enhanced, resulting in microbial damage and spoiling that shortens the shelf life of cake (Cappuccelli Pinto et al., 2023). Because of its high water-binding properties, chia seed flour lowers specific volume, increases dough viscosity, and decreases gas retention, but it also improves bread freshness in gluten-free bread (Coronel et al., 2021). According to studies, chia fiber and mucilage can prevent water evaporation and help preserve moisture during baking (Adamczyk et al., 2021). Chia mucilage also reduced water activity in pancakes, which inhibited microbiological development and prolonged shelf life (Anwar et al., 2024). Overall, these results demonstrate the dual benefits of chia in retaining moisture and extending shelf life, but more research is necessary to fully understand how it affects texture and volume. The Mechanism of moisture retention of soluble fiber is shown in Fig. 1.

2.2. Nutritional quality

A transparent mucilaginous gel, primarily made of soluble fiber, is released when the chia seed is immersed in water. This gel has properties that enable its use in a variety of food industry products, adding functionality and enhancing the sensory and nutritional qualities of the processed products (Guedes de Melo et al., 2022). Chia seed fortification has been demonstrated to enhance the nutritional profile of bakery goods; research has found that muffins with chia seeds have higher levels of protein, fat, and minerals (Rabail et al., 2022), while gluten-free bread has higher levels of protein, ash, crude fiber, fat and linolenic acid content (Adamczyk et al., 2021; Coronel et al., 2021; Dentice Maidana et al., 2020). The composition of chia seed, which includes approximately 30–33 % fat (rich in omega-3 and omega-6 fatty acids), 15–25 % protein, 18–30 % dietary fiber, and high amounts of minerals that is responsible for these effects (da Costa Borges et al., 2021; Shelke et al., 2024). As a result of replacing the flour, the carbohydrate content drops proportionately. Besides measurable gains, chia provides protein of remarkable quality. The nutritional benefit of chia seeds is increased by their approximately 19 % protein content, balanced amino acid profile, and 77–80 % digestibility (Wang et al., 2023). The nutritional profile of gluten-free bread is greatly improved by chia seed and flour fortification, which lowers carbohydrate level while raising protein (up to 81 %), omega-3 and omega-6 fatty acids, and mineral content. The overall caloric value is essentially unaffected by these compositional changes, highlighting chia's role as a nutrient-dense functional ingredient (da Costa Borges et al., 2021). Chia seed flour fortification dramatically changes the nutritional makeup of baked goods, which is in line with previous research. Crude fat content increased to 21.06 % with 7 % addition, with significant increases in ash and protein; at lower levels (3–5 %), protein changes were negligible. When compared to the control, these increases in protein, fat, and mineral content are accompanied by a notable decrease in carbohydrate levels, confirming chia's function as a nutrient-dense food that modifies the macronutrient balance without significantly increasing caloric value (Aljobair, 2022). Increased fat content from adding seeds has nutritional benefits because it provides natural antioxidants such phenolic, lignans, SDGs, and tocopherols, as well as polyunsaturated fatty acids. These compounds not

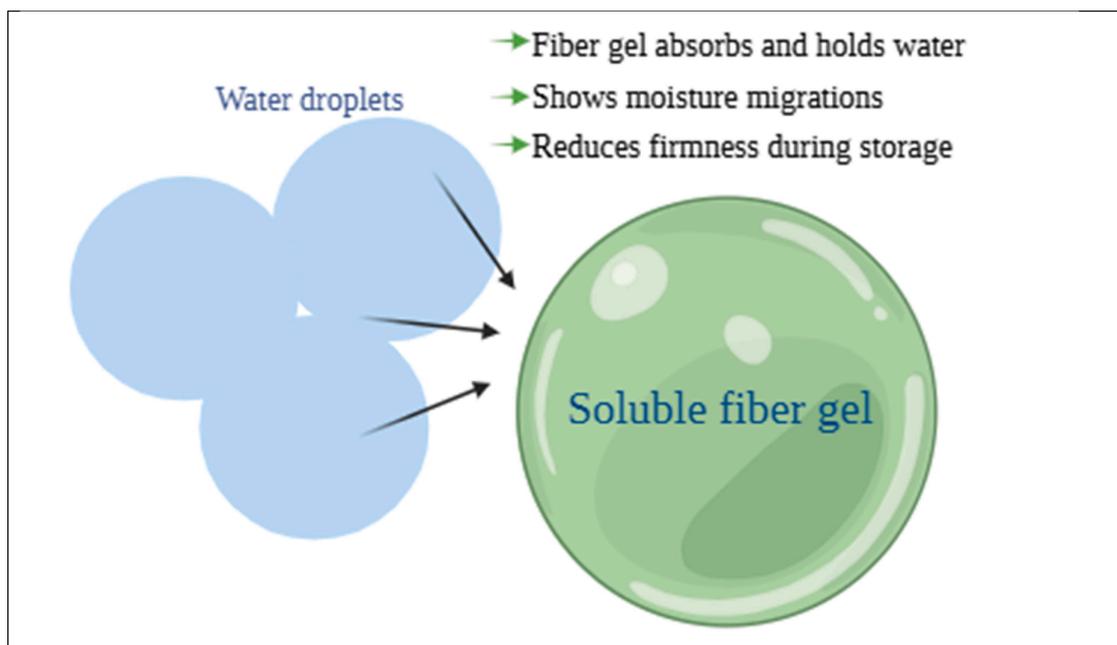


Fig. 1. Mechanism of moisture retention of soluble fiber.

only improve the nutritional profile but also enhance oxidative stability, preventing rancidity and extending product shelf life (Kausar et al., 2024) and fat provides hindrance in gluten development and promote satiety. Remarkably, the crude fat content of M-CHIA6 and M-CHIA12 muffins decreased by 41 % and 38.6 %, respectively, when hydrated chia seed mucilage was substituted for coconut oil. This is in contrast to research that found that adding flour or chia seeds raised fat levels, which may be related to variations in the constituent type. When used as a fat substitute, mucilage mostly provides fiber and water, reducing overall fat, whereas whole chia and chia flour supply lipids through their oil portion (Guedes de Melo et al., 2022). Similarly, when egg is replaced by chia mucilage in brownies the content of protein and fat decreases because eggs contain more proteins however, fiber content will be more in chia mucilage that is from plant source than egg which is from animal origin (Moreira et al., 2023). Functional role of chia seed components in bakery products is explained in Fig. 2. In addition to bread and muffins, chia increases the nutritional value of pancakes and pasta by raising their protein and lipid content (Khatri et al., 2023). In vegan brownies, the fat content increased because of lipid residues in chia phenolic extracts (Anwar et al., 2024). These results support the adaptable function of chia in enhancing the nutritional makeup of various baked goods. The various characteristics including nutritional, sensory and physical properties of bakery items affected by chia seed and its derivatives are shown in Table 1.

2.3. Physical properties and texture

Physical characteristics, for as volume and texture, are important indicators of bakery product quality since they have a direct impact on acceptance, consumer perception, and overall product quality (Guiné, 2022). The specific volume of gluten-free bread is typically decreased by adding a portion of chia flour; however, an improvement is noted at moderate quantities (4–8 %). This is because chia's soluble fibers and mucilage improve dough viscoelasticity by creating a hydrocolloid

network that somewhat resembles gluten. This network increases bread capacity by stabilizing cell structure and enhancing gas retention during baking (da Costa Borges et al., 2021). Loaf volume was affected by the type and amount of chia seeds. Both whole and powdered chia seeds increased volume at 1 % addition, and this improvement was maintained at greater levels (up to 5 %) as compared to the control. Compared to powdered chia seeds (545 cm³), whole seeds yielded a slightly larger loaf capacity (580 cm³) (Adamczyk et al., 2021). However, the specific volume of sponge cakes was decreased when chia seeds were used in place of eggs. At 5–7 % substitution, or 25–50 % replacement of egg protein, acceptable uniformity and volume were maintained; but, at greater levels, volume was reduced and cake symmetry was compromised. This happens because chia proteins don't have the same foaming and structural qualities as egg proteins, which stabilize air bubbles and increase batter density (Aljobair, 2022). Similar to this, chia seed mucilage inhibits CO₂ retention and bread expansion in muffins, whereas coconut oil increases aeration and specific volume. This corresponds to a larger pattern seen in other baking goods, where volume development is limited since chia cannot completely replace the functional responsibilities of traditional ingredients (Guedes de Melo et al., 2022). The specific volume of loaf decreased with chia seed addition in gluten free bread and favors dough development and gas retention in water presence ((Cappuccelli Pinto et al., 2023; Coronel et al., 2021)). According to earlier research, adding chia has varying effects on loaf volume. Chia seeds increased the specific volume of gluten-free pan bread at low concentrations (2–3 %), most likely because mucilage improves dough viscoelasticity and gas retention. However, water competition and increased dough viscosity limit gas expansion at higher levels or when fiber-rich fractions predominate, which eventually reduces loaf volume (Anwar et al., 2024). In case of brownies chia mucilage addition may decrease in volume but did not affect the brownies because denser texture is acceptable in them as compared to other bakery products like cakes (Moreira et al., 2023). In contrast, Dentice Maidana et al. (2020) found that substituting chia and lactic acid

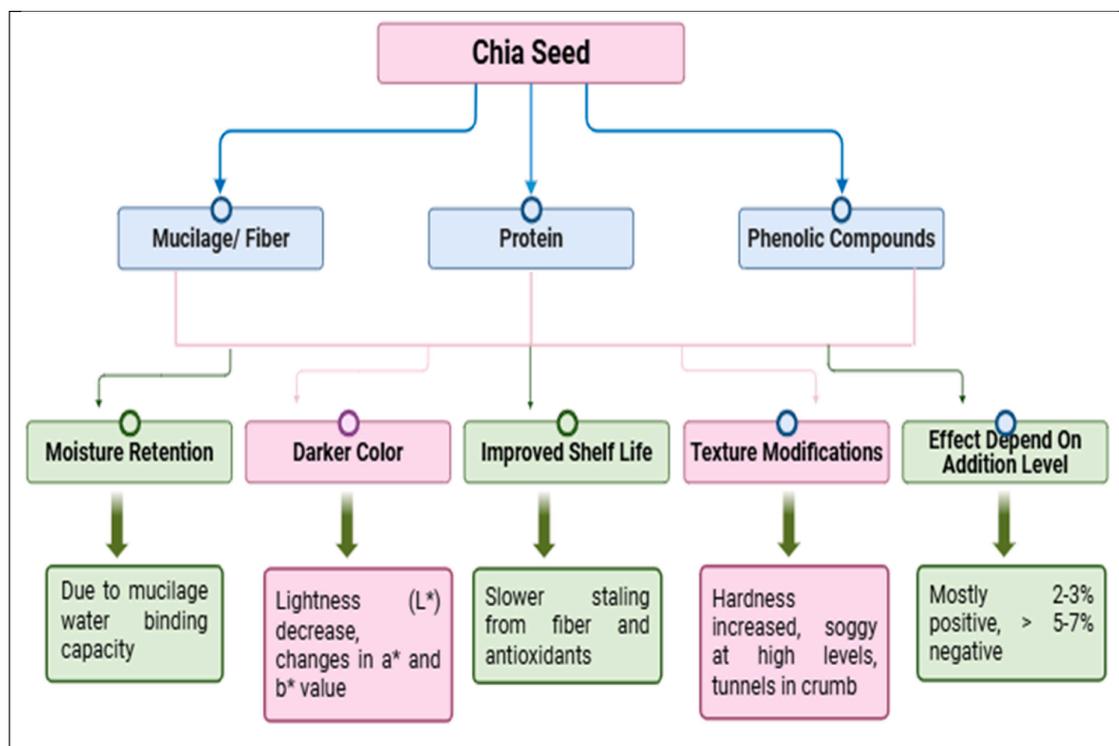


Fig. 2. Functional role of chia seed components in bakery products.

Table 1
Effect of chia, flax and sesame seeds and its derivatives on the colors of bakery products.

Functional ingredient	Color changes in bakery product				
	Biscuits/ cookies	Bread	Cakes	Doughnuts/ muffins	References
Chia seed and derivatives	-	Darker color	Darker color	Darker color	(Aljobair, 2022; Coronel et al., 2021; Guedes de Melo et al., 2022)
Flaxseed and derivatives	Brown and darker color	Redder color	No color change	-	(İlyasoğlu et al., 2022; Papagianni et al., 2023; Sharma et al., 2024)
Sesame seed and derivatives	Slightly darker	Darker color	Slightly darker	Darker color	(Abbas et al., 2020; Lucini Mas et al., 2022; Papagianni et al., 2023)

bacteria-fermented sourdough for sorghum flour greatly increased the specific volume of gluten-free bread, with the highest values at 30–40 % chia–flax sourdough. This suggests that the negative effects of chia on bread growth may be overcome by processing techniques like sourdough fermentation.

2.4. Sensory attributes

The characteristics of food products essentially determine the sensory criteria, such as taste, crumb texture, crumb grain, appearance, crust color, odor, and overall acceptability, as well as consumer preferences and acceptance (Ahmad et al., 2024; Moreira et al., 2023; Nassef et al., 2023). The gluten-free bread appeared significantly darker when chia flour sourdough was used in place of sorghum flour; the darker the crust and crumb, the more chia flour was added, and the color intensity increased as the substitution level increased. Consumer panelists still favored this greatest substitution level (40 %) despite the related hardness and slightly soggy texture, indicating that acceptability was unaffected by darker appearance (Dentice Maidana et al., 2020). A significant aspect of gluten-free bread is color, which is significantly affected by the addition of chia. While a^* and b^* values show red and yellow changes caused by stronger Maillard reactions, higher substitution levels decrease brightness. Chia seeds have a stronger effect on bread color than wheat, causing a greater hue angle variation (69.47–73.86). Despite that fact no significant changes occurred in flavor and texture parameters and well accepted by consumers (da Costa Borges et al., 2021). Chia seed proteins contributed to decreasing L^* values in sponge cakes, however b^* (yellowness) stayed close to the control and a^* (greenness) changed somewhat at 7 % substitution. The crumb was further darker due to carotenoids in the seed coat (Coronel et al., 2021) and 3 % substitution was scored similarly to the control, larger chia levels (7 %) decreased sensory acceptance, especially for crust color, flavor, and taste (Aljobair, 2022). Same results showed that by adding more chia seeds to muffins reduced their L^* (lightness) and b^* (yellowness) values, but their a^* values showed a slight greenness, which is undesirable. Chia seed proteins are responsible for the darker appearance. While 5–15 % fortification was typically deemed acceptable, higher amounts decreased volume, springiness, and the overall appearance of the crust and crumb (Rabail et al., 2022). The addition of chia seed mucilage to muffins had significant effects on the color characteristics (L , a , b), as compared to chia-enriched muffins control samples displayed greater brightness, which could be related to the mucilage's uneven distribution. The brightness is changed by this heterogeneity, which affects the way that light is reflected on the crumb surface and making the control sample more acceptable as compared to chia fortified sample (Guedes de Melo et al., 2022). Darker bread was produced by reducing L values with phenolic chemicals found in chia flour, such as ferulic, caffeic, and chlorogenic acids. In several instances, a value stayed constant, but in others, notable changes were noted. The b^* value was lowest (13.65) in the 5 % chia flour sample and highest (18.73) in the control sample. The bread's internal temperature also affected the crumb color. 1 % addition of chia seed reduces hardness but greater values like 5 % addition increased hardness by reducing loaf

volume making it undesirable for consumption (Adamczyk et al., 2021). The color parameters (L , a , b^*) of pound cakes were impacted by the use of chia seed mucilage as a fat substitute with lower sugar levels. In addition to reducing red and yellow tones and lightness (L^*), higher concentrations caused tunnels and holes in the crumb because of their denser, more compact structure. Because panelists did not prefer chia-incorporated cakes over other formulations, these disadvantages darker color and uneven crumb led to lower customer preference (Cappuccelli Pinto et al., 2023). While higher amounts adversely affected the color of the crumb and crust, 2–3 % chia flour greatly enhanced the smell, taste, internal appearance, and overall acceptance of gluten-free pan bread (Anwar et al., 2024). Although chia flour had no effect on the general acceptance of gluten-free formulations, it greatly improved the flavor and taste of bread. The best acceptance scores, however, were obtained from sourdough fermentation with chia flour, indicating its potential to increase customer preference (Jagelaviciute & Cizeikiene, 2021). The color properties of bread, cakes and muffins are shown in Table 2.

3. Flaxseed and its derivatives in bakery products

3.1. Moisture retention

The moisture level of products made from flaxseeds is greatly influenced by the strong water-binding capacity of the fiber rich mucilage in flaxseeds which retained moisture in food matrices by chemical interactions. However, as seen by the unroasted (2.14 % at 5 %) and roasted (1.70 % at 5 %) samples, where roasting caused moisture losses during cooking, moisture levels may vary (Khan et al., 2024). Similar studies by Jiang et al. (2022) reported a significant moisture reduction in bread when wheat flour replaced by unroasted and roasted flaxseed. Due to heat treatment, bread containing roasted flaxseed exhibited the lowest moisture content compared to that with the unroasted flaxseed. The amount and distribution of moisture in food determines the functionality and physical properties of food. The moisture level of flaxseed biscuits was higher than that of terebinth and sesame biscuits. However, as the substitution quantity was increased, the moisture content rapidly decreased; the control sample had the highest value (5.71 %). When the moisture content dropped out the product's stability during storage is improved because it slows down physical, chemical, and microbiological processes (Karakoç et al., 2024). Bread fortified with 3–4.5 % of flaxseed slurry showed less moisture and volume even though the crumb hardness remained same as control, suggesting that flaxseed did not result in dried or rigid structures however, reduced specific volume and high fiber content were associated with higher crumb hardness in various flaxseed-lentil combinations, but crust hardness was impacted by moisture changes during storage (Papagianni et al., 2023). The gluten-free cookies manufactured with flaxseed flour showed a notable decrease in moisture content, which aided to prolong the product's shelf life (Bashir et al., 2020). The combination of chia and flaxseed in cakes improved moisture retention, improving viscosity and freshness, but decreasing loaf volume because the oil in flaxseed interfered with the production of gluten. A moisture content below 6 % suggests low

Table 2
Effect of chia seed and its derivatives on different properties of bakery products.

Functional ingredients	Processing conditions	Bakery product	Significant increase	Significant decrease	Overall impact	Reference
Chia seed and flaxseed	Baking at 350 °C for 35 min	Gluten free bread	Protein, dietary fiber, essential fatty acids, specific volume, darkness	Saturated fatty acids	Highest acceptability	(Dentice Maidana et al., 2020)
Chia seed	Baking at 175 g dough at 200 °C for 20 min	Gluten free bread	Protein, lipid, ash, specific volume, firmness	Moisture, carbohydrate, baking losses	Satisfactory no significant difference as compared with standard bread	(da Costa Borges et al., 2021)
Chia seed	50 g batter at 130 °C for 6–8 min (lower grill), 3–5 min (lower & higher grills), 2–3 min (upper grill)	Muffins	Protein, ash, fat, fiber, darkness	Moisture, lightness, yellowness, crust, chroma value, Redness	15 % addition is acceptable but further increase may cause detrimental effect to product	(Rabail et al., 2022)
Chia seed	Baking at 180 °C for 25 min	Sponge cake	Linoleic acid, moisture, batter density, fat, fiber content	Carbohydrates, crumb yellowness, cholesterol, springiness, firmness, chewiness, cohesiveness	Chia seed addition will result in lower organoleptic properties	(Aljobair, 2022)
Chia seed	Baking at 150 g at 140 °C for 25 min	Muffins	Unsaturated fat, moisture, ash, specific volume, brightness	Crude fat, saturated fat, specific volume, loss of cooking, CO ₂	Acceptance rate of control sample is more as compared with the product incorporated with chia seed mucilage	(Guedes de Melo et al., 2022)
Chia seed	Baking at 180 °C for 25 min	Pound cake	Specific volume, moisture, firmness, water activity	Density, color, fat, crumb color	Less acceptable as compared with the control	(Cappuccelli Pinto et al., 2023)
Chia seed	Two stages drying 50 °C for 30 min & 85 °C for 60 min	Gluten free pasta	Protein, fat, ash, dietary fiber	Cooking losses, moisture, carbohydrate	Addition of chia flour at certain level improves the binding properties texture & appearance	(Khatiri et al., 2023)
Chia flour	Baking at 165 g at 180 °C for 25 min	Gluten free bread	Protein, fat, crude fiber, ash, WHC	Moisture, carbohydrate, specific volume	Sensory attributes need to study	(Coronel et al., 2021)
Chia flour	Baking at 500 g at 220 °C for 45 min	Gluten free maize bread	Moisture, firmness	Porosity, specific volume	Not influence the overall acceptability of gluten free bread	(Jaglaviciute & Cizeikiene, 2021)
Chia flour	Baking at 220 °C for 20 min	Bread	Fat, fiber, volume (1 % addition), protein, polyphenols	Baking losses, bread volume, (5 % addition), hardness, ash	1 % replacement of chia seed in bread provide effective results as compared with 5 % (w/w)	(Adamczyk et al., 2021)
Defatted chia flour	Baking at 170 °C for 20 min	Vegan brownie	Fiber, fat	Moisture	Softer and less crispy crust similar taste with the traditional brownies	(Moreira et al., 2023)
Chia flour	Baking at 250 °C for 30 min	Gluten free pan bread	Protein, ash, fiber, fat/lipids, specific volume, hardness, chewiness, gumminess, springiness, cohesiveness, resilience	Moisture, carbohydrates	Pan bread with the chia flour addition improved overall acceptability	(Anwar et al., 2024)

TPC: Total phenolic content, RDP: Relative digestibility of protein, WHC (Water holding capacity), TFC (Total flavonoid compounds), RSA: Radical Scavenging Activity.

sensitivity to microbial growth (Murugkar et al., 2021). Flaxseed gel showed higher water binding capacity than eggs, thereby slightly increased the moisture content. In cakes about 40 % flaxseed gel addition rises the moisture content from 21.7 % (control) to 23.4 % (Sharma et al., 2024). In general, the presence of flaxseed improves moisture retention in bakery products because of its soluble fiber content, which is good for keeping softness and delaying staling. However, in low-moisture products like biscuits, this retained moisture may promote cracking during storage. Higher amounts of flaxseed tend to promote moisture retention but may also interfere with texture and structural stability therefore, the level of these effects is entirely dependent on the amount used.

3.2. Nutritional quality

The production of gluten free cookies by adding flaxseed in the product increased the nutritional quality by increasing protein, fat and ash content however carbohydrate content decreases (Bashir et al., 2020; Karakoç et al., 2024) and the results are consistent with the findings across multiple studies reviewed in this work. The nutritional profile of cookies was greatly enhanced by the inclusion of both roasted (RF) and unroasted (URF) flaxseed. For instance, at 15 % addition of

flaxseed crude fiber increased from 1.02 to 1.47 % (URF) and 0.96–1.43 % (RF), ash from 1.35 % (URF) and 2.25 % (RF), protein 9.07 % (URF) and 9.18 % (RF), and fat was 22.64 % (URF) and 22.37 % (RF) (Khan et al., 2024). With minor variations between unroasted and roasted forms, these modifications are attributed to aid in enhancing total phenolic content (TPC), ABTS antioxidant activity, linoleic acid and α -linolenic acids in cookies. Additionally, incorporated cookies contains 5 times and 30 times more PUFAS and α -linolenic respectively as compared to control (İlyasoğlu et al., 2022). However, dietary fiber content is more in roasted flour (11.50 g/100 g) than in unroasted flour (8.50 g/100 g). This is because of combined effect of heat and mechanical shear which disrupts the cell wall and split glycosidic bond of polysaccharides those breakdown macromolecular structures into smaller hydrophilic soluble dietary fibers. The lipid content reduces during roasting treatment as during heating the cell structure breaks caused lipids to leach out from seed (Jiang et al., 2022). These soluble fibers helps in reducing the plasma glucose and cholesterol levels leading to lowering the risk of cardiovascular diseases (Papagianni et al., 2024a). The high levels of TPC and the antioxidants in defatted flaxseed flour was the result of its non-fat nature. Incorporation of flaxseed flour into Chinese steamed bread not only increased its nutrition, mineral and lipid profile but also contains 5 types of fatty acids including unsaturated

fatty acids especially linolenic acid, oleic acid and linoleic acid. From these three linolenic acid is the most abundant followed by oleic acid and linoleic acid (Gao et al., 2022). Because protein slows down the absorption of carbohydrates by limiting starch bioavailability and decreasing enzyme accessibility, flaxseed-oat sourdough bread's high protein content helps it have a lower GI than whole meal bread (25 g vs. 18 g per 50 g carbohydrate) (Johari et al., 2024). In the exceptional cases by changing the replaceable ingredient as we use egg as a replacing agent in cakes and being replaced by flaxseed gel the protein, fat (due to presence of albumin and egg yolk), ash and carbohydrate decreases however omega-3 fatty acids will be higher and omega-6 fatty acids will be lower as compared to control (Murugkar et al., 2021; Sharma et al., 2024). The various characteristics including nutritional, sensory and physical properties of bakery items affected by flaxseed and its derivatives are shown in Table 3.

3.3. Physical properties and texture

Texture is one of the main factors of product quality and represents the sensory perception of a food's structural properties (Noreen et al., 2023). The incorporation of flaxseed in gluten-free cookies reduces dough deformation and increased hardness. The maximum hardness of flaxseed flour is 61.2 N with 22.5 g addition, which is higher than the control's value 24.22 N. As the concentration of flaxseed flour increased, the cookies' breaking strength decreased and hardness increased (Bashir et al., 2020). The flaxseed incorporation into Chinese steamed bread influence its physical properties and a significant increase in hardness and chewiness with a decrease in cohesiveness and springiness of final product. This effect could be a result of a decrease in the gluten network driven by the complex interactions of dietary fibers, protein, wheat gluten, and starch. These interactions may reduce the gas holding capacity, lower the specific volume and ultimately increased the hardness

(Gao et al., 2022). Flaxseed contains dietary fibers that have hydrophilic properties, so they retain water and have high WHC as compared to wheat flour. However roasting treatment damage cell and dietary fiber thus decreasing its capacity to hold water (Jiang et al., 2022). In gluten free breads flaxseed helps to increase and maintains the loaf volume and improves crumb macrostructures, therefore when flaxseed combined by sesame cake a slight reduction in specific volume was observed and this is due to increased protein and fiber contents that caused starch gelatinization and gluten network formations, affecting better expansion at the same time improving moisture retention and reducing staling during storage (Papagianni et al., 2024b). There were no significant changes in cakes quality when up to 50 % of egg is replaced by flaxseed gel however 60 % replacement changes the cake texture and causes cracks on cake surface (Sharma et al., 2024). Cakes prepared by chia and flaxseed gel retain great amount of moisture and higher density but decreased volume and poor texture as compared to egg cake. Soluble fibers present in chia and flaxseed thickens the batter and hence resulted in lower volume. Nan encapsulated flaxseed oil might be a good substitute for eggless cakes because of its textural similarities with the egg cake (Murugkar et al., 2021). Flaxseed oil can also be used as a shortening agent in bakery products which provides a physical barrier by retarding starch retro-gradation and prompting the softness and freshness (Jiang et al., 2022). Despite its excellent nutritional profile, flaxseed may negatively affect the texture of bakery products, which highlights the need for technological strategies to minimize these drawbacks. Functional role of flaxseed components in bakery products is explained in Fig. 3.

3.4. Sensory attributes

The consumer sensory acceptability of bakery items is influenced by their technological characteristics including firmness, specific volume,

Table 3
Effect of flaxseed and its derivatives on different properties of bakery products.

Functional ingredients	Processing conditions	Bakery products	Significant increased properties	Significant decreased properties	Overall results	References
Flaxseed	Baking at 200 °C for 10 min	Gluten free cookies	Protein, fat, ash, hardness	Moisture, carbohydrates	17 g flaxseed flour provide maximum acceptability results	(Bashir et al., 2020)
Flaxseed	Baking at 180 °C for 15 min	Cookies	Fat, fatty acid (linoleic & alpha linolenic acid)	L* value	10–30 g/100 g flaxseed incorporation is well accepted and does not have drastic effect on sensorial properties	(Ilyasoğlu et al., 2022)
Flaxseed	Baking at 175 °C for 40 min	Gluten free bread	TPC ABTS Protein, dietary fibers, hardness, consistency, viscosity, water absorption	Specific volume, brightness, glucose	Higher scores	(Papagianni et al., 2023)
Flaxseed	Baking at 170 °C for 20 min	Biscuits	Protein, ash, fat, TPC, pytholic acid, K, Fe, K, Mg, yellowness	Moisture, carbohydrate, brightness	High acceptability with 5 % substitution of sesame flour and general acceptability for up to 10 % and 25 % substitution of sesame & flaxseed flour respectively	(Karakoç et al., 2024)
Roasted 25 % Flaxseed flour	Steaming at 100 °C for 20 min	Chinese steamed bread	TPC (78.58 mg Gallic/100 g) RSA, DPPH, antioxidant, flavor, shape, viscosity, hardness, chewiness	Specific volume, Color, lightness, cohesiveness, springiness	Flaxseed's flour increases nutritional value and slightly increases flavor, color and texture of CSB	(Gao et al., 2022)
Flaxseed	Roasting at 130 °C for 15 min. Baking at 190 °C for top, 210 °C for bottom for 25 min	Bread	Protein, lipid, dietary fiber, softness, WHC	Moisture, specific volume, hardness	Higher acceptability score with 25 % RF as compared to whole wheat	(Jiang et al., 2022)
Flaxseed defatted cake	Baking at 205 °C for 10 min	Cookies	Darkness (brown)	25 % RF color	Higher substitution improves most sensory parameters	(Rrustemi et al., 2024)
Flaxseed oil	Baking at 180 °C for 50 min	Eggless cake	Shear rate, moisture, antioxidant activity, density Flavonoid activity, omega 3, texture	Shear stress, specific gravity, springiness, cohesiveness Hardness, viscosity, omega- 6	Healthy, tasty and rich omega 3 FA, high quality obtained	(Murugkar et al., 2021)
Flaxseed gel (replace by egg)	Baking at 180 °C for 55 min	Cake	Moisture, fat, omega-3 fatty acids, hardness	Protein, carbohydrate, ash, sponge volume	Slightly less sweet taste, in terms of color and internal texture 50 % FSG replacement is acceptable	(Sharma et al., 2024)

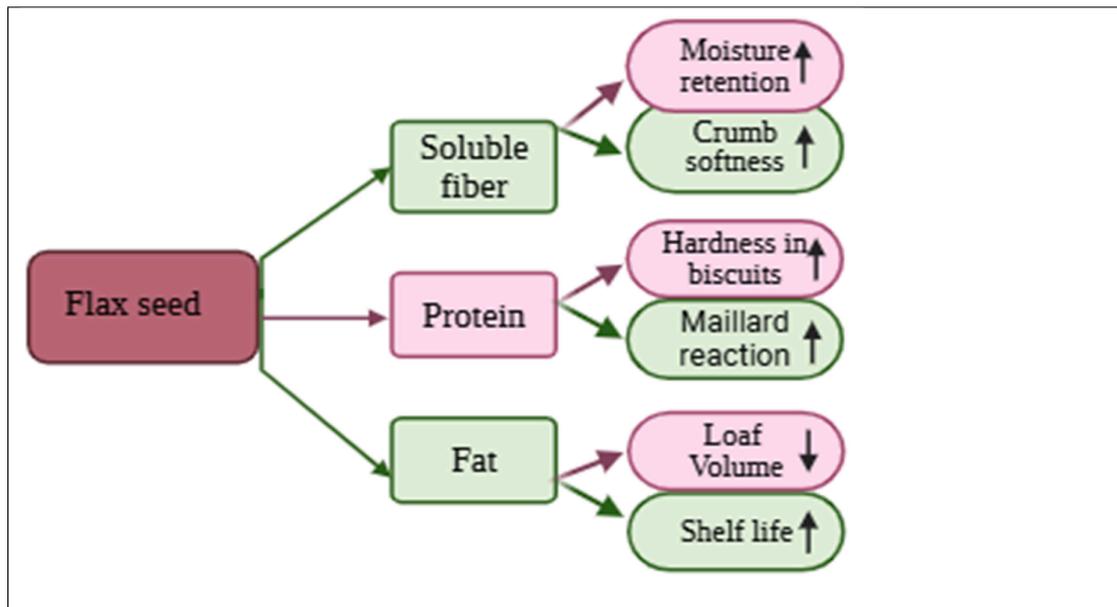


Fig. 3. Functional role of flaxseed components in bakery products.

uniformity and consistency (Moreira et al., 2023). The color of Chinese steamed bread and cookies becomes darker due to significant decrease in L^* value and slight changes in the b^* value. The flaxseed natural dark color imparted darkness in both products so flaxseed amount should be maintained for consumer preference (Gao et al., 2022; İlyasoğlu et al., 2022). Same studies by Rrustemi et al. (2024) represent that the addition of defatted flaxseed cake at 30 % and 60 % in cookies formulation transmitted a brown color to the product as a replacement for wheat flour. 17 g incorporating of flaxseed into gluten free cookies mostly liked by the consumers and provide high nutritive values (Bashir et al., 2020). Flaxseed cookies are acceptable by the consumer and it provides brown appealing color to the product (İlyasoğlu et al., 2022). The addition of flaxseed flour significantly influenced the flavor profile of Chinese steamed bread and increased the aldehydes and ketones content while alcohols content decreased slowly. Aldehydes plays a significant role in Chinese steamed bread and provides them a fatty and fruity aromas (Gao et al., 2022). Bread treated with 25 % roasted flaxseed had a high acceptability and contained combination of roasting and plant fragrance that is highly acceptable by the consumers (Jiang et al., 2022). Defatted flaxseed cake incorporation into cookies provides a good flavor and aroma at 60 % substitution as compared to 30 % substitution, which showed that acceptable sensory characteristics were achieved at high concentration; however, this substitution may compromise the texture of cookies (Rrustemi et al., 2024). Similar studies on 50 % replacement of egg with the flaxseed gel in cake formulations showed that sensory characteristics are acceptable (Sharma et al., 2024). Flaxseed introduces the nutty flavor in gluten free bread thereby contributing in high overall acceptability. Breads with the 3 % and 4.5 % flaxseed had the highest acceptability scores as above 4.5 % least acceptability among consumers (Papagianni et al., 2024a). Flaxseed should be in the acceptable ranges because it enhances the nutritional and sensory appeal; excessive incorporation may affect its texture, color, and taste. The effect on color properties of biscuits, bread and cakes is shown in Table 1.

4. Sesame seed and its derivative in bakery products

4.1. Moisture retention

Bakery goods that contain less than 13 % moisture are resistant to

moisture damage. Every product has a moisture content that is lower than the designated amount. They will have a longer shelf life and be less vulnerable to microbial attack as a result (Amadi & China, 2022). The water in food determines the textural properties of food. The reduction in water by substituting with oilseeds at favorable atmospheric conditions may lower the effect of enzymatic, microbiological and chemical activities of product (Karakoç et al., 2024). Sesame seed, sesame flour, and sesame cake exhibit lower moisture levels, ranging from 3.16 to 3.53 g/100 g, depending on the product type and variety. This low moisture makes the product less prone to microbial attack and provides shelf stability during storage (Malaviya & Yadav, 2022). Similarly, studies on sesame biscuits at different levels showed slight moisture changes thus indicating good storage stability. The moisture percentage of the control sample of wheat biscuits is 6.27 %, whereas the 10 % and 20 % sesame seed substitutions showed 5.90 % and 6.33 %, respectively (Al-Alwani et al., 2023). The addition of sesame seed as a supplement in doughnuts increased the moisture content from 7.53 ± 0.19 to 8.38 ± 0.12 %. The springiness is inversely related to hardness, and consequently, it decreases due to low moisture and fat content in the product (Abbas et al., 2020). The moisture content of biscuits decreased when sesame oilseed was added, and the reduction became more pronounced as the substitution level increased. This reduction is attributed to a decrease in hydration capacity due to the shortening that covers the gluten network and starch particles, which decreases the absorption of water (Karakoç et al., 2024). In sesame meal emulsions for the production of cakes, it retains moisture better due to high water content in Pickering emulsions and provides cakes a moister and softer texture; however, moisture loss occurs during baking (X. Wang et al., 2024).

4.2. Nutritional quality

Sesame is a significant oilseed crop valued for its high-quality protein and oil (Tahir et al., 2024). Sesame seed fortification continuously improves nutritional composition, especially by raising protein, fat, and mineral contents while lowering carbohydrate levels in baked goods. For example, biscuits fortified with sesame showed higher protein (14.43 %) and fat (10.33 %) compared to the control (12.1 % protein, 2 % fat) (Al-Alwani et al., 2023). Similar to this, adding sesame to doughnuts significantly increased their protein (from 10.2 % to 24.9 %) and fat

(from 9.3 % to 14.4 %), while simultaneously lowering their nitrogen-free extract and carbohydrate levels (Abbas et al., 2020). Enrichment of cookies with sesame flour significantly improved mineral contents (zinc, calcium, magnesium, iron), however, scones made with sesame kernels and cashew also showed increases in fiber, fat, and protein (Amadi & China, 2022; M et al., 2020). Sesame protein strengthened the gluten network in cake formulations, improving the texture of the final product (Wang et al., 2024). Although sesame seeds are naturally rich in phytic acid (8.98 %), processing methods such as defatting, germination, fermentation, and cooking substantially reduce anti-nutritional compounds (Karakoç et al., 2024). Overall, these findings indicate that sesame fortification improves the nutritional profile of bakery products, although optimization of substitution levels is essential to balance nutritional benefits with sensory acceptance. The various characteristics including nutritional, sensory and physical properties of bakery items affected by sesame seed and its derivatives are shown in Table 4.

4.3. Physical properties and texture

Sesame supplementation significantly influences the physical and textural properties of bakery products. In doughnuts, sesame cake flour increased hardness, cohesiveness, and chewiness, whereas springiness reduced, showing a structure that had become denser (Abbas et al., 2020). Defatted sesame flour (DSF) enhanced the hardness of cookies by up to 10 % as it improved the interactions between protein, fiber, and water, whereas at 20 % DSF the texture became softer as the starch-protein network weakened, resulting in improved chew ability (Lucini Mas et al., 2022). Sesame flour-fortified biscuits had higher hardness, spread ratio, and diameter but reduced thickness, reflecting the effect of high fat and fiber content on dough rheology (Karakoç et al., 2024). At 6 % substitution, neither low-fat nor high-fat sesame cake changed the specific loaf volume in bread formulations, but higher inclusion levels (12–20 %) significantly reduced loaf volume, likely due to

dilution of the gluten network (Nouska et al., 2024a). Collectively, these studies suggest that sesame incorporation can improve textural attributes up to moderate substitution levels, whereas excessive fortification may compromise volume and springiness. Impact of sesame seed fortification in bakery products is shown in Fig. 4.

4.4. Sensory attributes

In general, adding sesame darkens baked goods by increasing redness (a*) and yellowness (b*) while decreasing lightness (L*). The primary causes of this effect are natural colors and Maillard browning between sesame proteins and amino acids (Abbas et al., 2020; Lucini Mas et al., 2022). Higher proportions of sesame cake flour in doughnuts resulted in darker crusts, and same patterns were noted in cookie and bread recipes (Karakoç et al., 2024; Nouska et al., 2024a). In cakes, sesame meal emulsions slightly reduced lightness and yellowness but did not negatively influence visual appeal (Wang et al., 2024). Sesame fortification generally results in darker, more reddish-brown baked goods, though this changes based on the product matrix and degree of substitution. Sesame supplementation also influences sensory attributes. In doughnuts, up to 20 % sesame cake replacement was acceptable to consumers (Abbas et al., 2020). Cookies with 10 % defatted sesame flour (DSF) showed improved crunchiness and desirable cracked surfaces, even though the fact that increased DSF levels decreased scores for crispness and aroma (Lucini Mas et al., 2022). Scones fortified with sesame seed and cashew kernel were less preferred due to a slightly bitter aftertaste from lignans and anti-nutritional compounds (Amadi & China, 2022). In gluten-free bread, sesame cake enhanced nutty flavor, which became more pronounced at higher inclusion (3–6 %) (Papagianni et al., 2024b). Biscuits that substituted 10–25 % sesame were highly accepted; at lower levels, appearance was preferred, while at larger levels, fracturability was preferred (Karakoç et al., 2024). Collectively, these findings highlight that sesame can enhance flavor complexity, aroma, and textural appeal, but excessive addition may introduce bitterness and reduce

Table 4
Effect of sesame seed and its derivatives on different properties of bakery products.

Functional ingredients	Processing conditions	Bakery products	Significant increased properties	Significant decreased properties	Overall results	References
Sesame seed (processed)	Baking at 200 °C for 15–20 min	Cookies	Mineral content (Zn, Ca, Mg, Fe)	Phytate, oxalates, phenolic	Reduction in anti-nutritional properties enhances sensory characteristics	(M et al., 2020)
Sesame seed	Baking at 180 °C for 15 min	Scones	Moisture, crude fiber, fat, protein, ash	Carbohydrates	15–25 % substitution with sesame flour have best acceptance ratio	(Amadi & China, 2022)
Sesame cake flour	Frying at 175oC	Doughnuts	Protein, crude fat, crude fiber, ash, a* (redness), b* (yellowness)	Moisture, carbohydrates NFE	Up to 20 % addition provide good results	(Abbas et al., 2020)
Defatted sesame flour	Baking at 180 °C for 11 min	Cookies	Protein, fiber, hardness (at 10 %), fractal dimensions, cracking a* (redness), b* (yellowness)	L* value L* value Hardness (at 20 %)	10 % SFC is greatly accepted by the consumers	(Lucini Mas et al., 2022)
Sesame flour	Baking at 170 °C for 10 min	Biscuits	Moisture (at 25 %), protein, fat, ash	Moisture (at 10 %), Carbohydrates		(Al-Alwani et al., 2023)
Sesame cake	Baking at 128 °C for 28 min	Wheat bread	Protein, ash, total dietary fiber, fat	Carbohydrates, specific volume (12 % and 20 %), strength consistency, dough development time	Low fat sesame cake at 6 % substitutions provide balanced taste, texture and loaf volume higher substitutions may cause bitterness.	(Nouska et al., 2024b)
Sesame meal emulsions	Baking at 175 °C for 40 min	Cake	Protein, elasticity, cohesiveness, redness a value	Moisture lightness, yellowness,	Acceptable at 50 % substitution further increase may affect the texture	(Wang et al., 2024)
Sesame cake	Baking at 175 °C for 40 min	Gluten free bread	Hardness, consistency, a* (redness) protein, fat, ash	Moisture, carbohydrates, L* value	–	(Papagianni et al., 2024a)
Sesame oil seed	Baking at 170 °C for 20 min	Biscuits	Protein, fat, ash, phytic acid, TPC, Ca, Fe, Mg, K, P, Zn, b* yellowness, spread, diameter.	Moisture, carbohydrates	Sesame supplementation is recommended, and it have positive impact on nutritional properties of biscuits	(Karakoç et al., 2024)

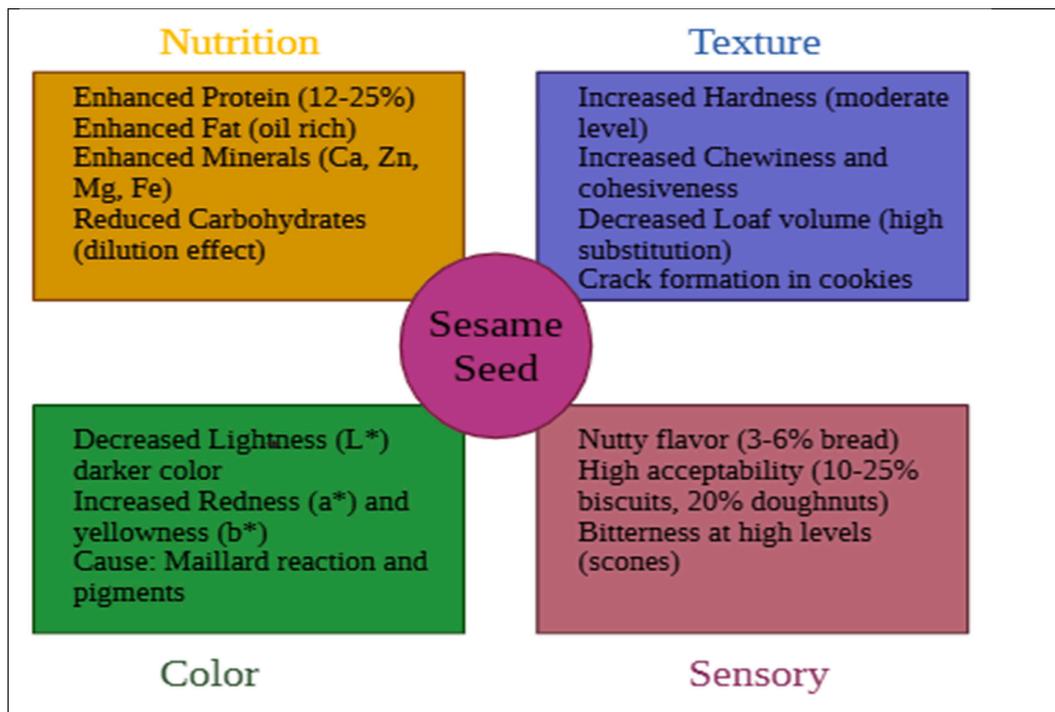


Fig. 4. Impact of sesame seed fortification in bakery products.

consumer preference. The color effect on different bakery products including cookies, bread, cakes and doughnuts are shown in Table 1.

5. Conclusion

Considering the popularity of bakery products and recent trends towards plant based functional ingredients the incorporation of chia, flax and sesame seeds provide nutritional benefits to the people. The consumer's preferences encouraging the use of different formulations in the bakery products to gain healthy and nutrient enrich foods. Chia, flax and sesame seeds provide not only healthy products but also effective against chronic disease, cardiovascular diseases, celiac diseases. Based on sensorial properties, it can be concluded that the acceptability of bakery items totally depend on the amount of chia, flax and sesame seeds being replaced. However, further studies required for the sensory properties and shelf stability of specific bakery items by controlling the amount of chia, flax and sesame seed substitution. The acceptability of the products mainly depends on the substitution levels. Higher substitutions may provide bitter after taste to the products that is highly undesirable character. The substitution levels should fall within optimal ranges that ensures desirable sensory properties, maintains moisture content and preferred by consumers.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

- Abbas, A., & Alkheraije, K. A. (2023). Immunomodulatory effects of Carica papaya extract against experimentally induced coccidiosis in broiler chickens. *Pakistan Veterinary Journal*, 43(3), 628–632. <https://doi.org/10.29261/pakvetj/2023.089>
- Abbas, S., Sharif, M. K., Sultan, M. T., Ahmad, A. N., Anwar, M. J., & Zhu, M. (2020). Development and characterization of micronutrient fortified sesame cake flour supplemented doughnuts. *Progress in Nutrition*, 22(4). <https://doi.org/10.23751/pn.v23i1.8742>
- Abduallah, A. M., Ahmed, A. E., Bajaber, M. A., & Alalwiat, A. A. (2023). Evaluation of the antidiabetic effects of methanolic extracts of neem (*Azadirachta indica*) seeds on the streptozotocin-induced wistar rats. *Pakistan Veterinary Journal*, 43(4), 792–798. <https://doi.org/10.29261/pakvetj/2023.106>
- Abduallah, A. M., Ahmed, A. E., Bajaber, M. A., & Alalwiat, A. A. (2024). Antidiabetic effects of methanolic extract of trigonella foenumgraecum seeds in diabetic rats. *Pakistan Veterinary Journal*, 44(1), 99–104. <https://doi.org/10.29261/pakvetj/2023.108>

- Adamczyk, G., Ivanišová, E., Kaszuba, J., Bobel, I., Khvostenko, K., Chmiel, M., & Falendysz, N. (2021). Quality assessment of wheat bread incorporating chia seeds. *Foods (Basel, Switzerland)*, 10(10), 1–10. <https://doi.org/10.3390/foods10102376>
- Ahmad, H. M., Jabeen, H., Ahmad, S., & Syed, A. (2024). Nutritional and sensory evaluation of gluten-free muffins prepared by using maize. *Sorghum Chickpea*, 7182, 58–68.
- Ahmad, S., Yousaf, M. S., Tahir, S. K., Rashid, M. A., Majeed, K. A., Naseem, M., Raza, M., Hayat, Z., Khalid, A., Zaneb, H., & Rehman, H. (2023). Effects of Co-supplementation of β -galacto-oligosaccharides and methionine on breast meat quality, meat oxidative stability and selected meat quality genes in broilers. *Pakistan Veterinary Journal*, 43(3), 428–434. <https://doi.org/10.29261/pakvetj/2023.043>
- Ahmad, U., Murtaza, S., Raza, U., Momal, U., Iqbal, A., Zazar, U. B., Ahmad, H. M., Jabeen, H., & BI, Fatima (2024). Development and quality evaluation of amaranth and soybean supplemented bread. *Agrobiological Records*, 18, 113–120. <https://doi.org/10.47278/journal.abr/2024.043>
- Al-Alwani, H. I., Fadhil, N. J., & Yousef, S. I. (2023). The effect of replacing wheat flour with sesame and flax flour on the chemical composition, fatty acids, and antioxidant properties of biscuits. *Tikrit Journal for Agricultural Sciences*, 23(4), 74–84. <https://doi.org/10.25130/tjas.23.4.7>
- Albaayit, S. F. A., Amartani, K., Ali, A. M., Hasddin, Shah, S. S., & Aslam, H. K. W. (2024). Mango waste (Peel and Kernel) enhances food dietary fiber and antioxidant properties. *Journal of Global Innovations in Agricultural Sciences*, 12(4), 1043–1049. <https://doi.org/10.22194/JGIAS/24.1567>
- Aljobair, M. O. (2022). Effect of chia seed as egg replacer on quality, nutritional value, and sensory acceptability of sponge cake. *Journal of Food Quality*. <https://doi.org/10.1155/2022/9673074>. 2022.
- Al Masoud, N., Hassan, S. A., Alomar, T. S., Mujahid, W., & Aadil, R. M. (2024). Enhancing biscuits with muskmelon seed flour: A study of physicochemical, textural, and nutritional characteristics. *Quality Assurance and Safety of Crops & Foods*, 16(3), 139–151.
- Alshaiikh, S. M., Al-Zaidi, A. A., Al-Badr, N. A., & Herab, A. H. (2023). Households' attitudes towards food safety guidance in Riyadh, Saudi Arabia. *International Journal of Agriculture and Biosciences*, 12(4), 262–266. <https://doi.org/10.47278/journal.ijab/2023.075>
- Amin, H., Sheikh, U., Anjum, F., Ashraf, I., Rizwan, S., Murtaza, G., & Khan, N. H. (2024). A multidimensional analysis of food security, health, and ecological situation. *Journal of Global Innovations in Agricultural Sciences*, 12(1), 207–213.
- Amadi, G. A., & China, M. A. H. (2022). Analysis of scone (a Biscuit-like Product) developed from composite flours of sweet potato (*pomea batatas*), Sesame (*Sesemum indicum L*) and cashew (*Anacardium occidentale*) kernel. *Journal of Home Economics Research*, 29(1), 69–78.
- Antonini, E., Torri, L., Piochi, M., Cabrino, G., Meli, M. A., & De Bellis, R. (2020). Nutritional, antioxidant and sensory properties of functional beef burgers formulated with chia seeds and goji puree, before and after in vitro digestion. *Meat Science*, 161 (August 2019), Article 108021. <https://doi.org/10.1016/j.meatsci.2019.108021>
- Anwar, D., Eid, H., Rashad, S., & Soliman, S. A. (2024). Nutritional, physical and microbiological properties of gluten free bread with chia seed flour as alternative thickening agent. *Food Technology Research Journal*, 4(2), 92–106. <https://doi.org/10.21608/ftj.2024.290193.1072>
- Anwar, A., Ali, E., Nisar, W., Ashraf, S., Javed, N., Anwar, L., Zulfiqar, A., Nazir, M. A., & Tahir, F. (2024). Development and quality evaluation of functional carbonated pomegranate orange nectar. *Agrobiological Records*, 15, 52–58. <https://doi.org/10.47278/journal.abr/2023.048>
- Asqardokht-Aliabadi, A., Sarabi-Aghdam, V., Homayouni-Rad, A., & Hosseinzadeh, N. (2025). Postbiotics in the bakery products: applications and nutritional values. *Probiotics and Antimicrobial Proteins*, 17(1), 292–314. <https://doi.org/10.1007/s12602-024-10327-y>
- Bashir, S., Yaseen, M., Sharma, V., Purohit, S. R., Barak, S., & Mudgil, D. (2020). Rheological and textural properties of gluten free cookies based on pearl millet and flaxseed. *Biointerface Research in Applied Chemistry*, 10(5), 6565–6576. <https://doi.org/10.33263/BRIAC105.65656576>
- Brenda, V. D., Zain, M., & Agustin, F. (2024). Strategy to reduce methane to increase feed efficiency in ruminants through adding essential oils as feed additives. *International Journal of Veterinary Science*, 13(2), 195–201. <https://doi.org/10.47278/journal.ijvs/2023.087>
- Brigante, F. I., Lucini Mas, A., Erban, A., Fehrl, I., Martinez-Seidel, F., Kopka, J., Wunderlin, D. A., & Baroni, M. V. (2022). Authenticity assessment of commercial bakery products with chia, flax and sesame seeds: Application of targeted and untargeted metabolomics results from seeds and lab-scale cookies. *Food Control*, 140 (May), Article 109114. <https://doi.org/10.1016/j.foodcont.2022.109114>
- Cappuccelli Pinto, L., Rebellato, A. P., & Steel, C. J. (2023). Technological and sensory evaluation of pound cakes with reduced sugar and fat substituted by hydrated chia (*Salvia hispanica L.*). *Cereal Chemistry*, 100(2), 333–345. <https://doi.org/10.1002/cche.10611>
- Cakir, E., ÖZÜLKÜ, G., BEKİROĞLU, H., Arici, M., & SAĞDIÇ, O. (2024). Technological quality, bioactive features, and glycemic index of gluten-free cakes formulated with lyophilized wild *Prunus spinosa* fruit. *Quality Assurance and Safety of Crops and Foods*, 16(2), 1–11.
- Coronel, E. B., Gulotto, E. N., Aspiroz, M. C., Tomás, M. C., Nolasco, S. M., & Capitani, M. I. (2021). Development of gluten-free premixes with buckwheat and chia flours: Application in a bread product. *Lwt*, 141(January), 1–8. <https://doi.org/10.1016/j.lwt.2021.110916>
- da Costa Borges, V., Fernandes, S. S., da Rosa Zavareze, E., Haros, C. M., Hernandez, C. P., Guerra Dias, A. R., de las Mercedes, & Salas-Mellado, M. (2021). Production of gluten free bread with flour and chia seeds (*Salvia hispanica L.*). *Food Bioscience*, 43(August), Article 101294. <https://doi.org/10.1016/j.fbio.2021.101294>
- Dentice Maidana, S., Finch, S., Garro, M., Savoy, G., Gänzle, M., & Vignolo, G. (2020). Development of gluten-free breads started with chia and flaxseed sourdoughs fermented by selected lactic acid bacteria. *Lwt*, 125(March), Article 109189. <https://doi.org/10.1016/j.lwt.2020.109189>
- Elkhalifa, S. M., Altlimisani, N. M., Albishri, F., Gad, H. A., Al-Dubai, T. A., & Al-Wesabi, E. O. (2024). Overview of quality control and safety in public health pest laboratory in Jeddah, Saudi Arabia. *International Journal of Agriculture and Biosciences*, 13(2), 92–100. <https://doi.org/10.47278/journal.ijab/2024.091>
- Gao, Y., Liu, T., Su, C., Li, Q., & Yu, X. (2022). Fortification of Chinese steamed bread with flaxseed flour and evaluation of its physicochemical and sensory properties. *Food Chemistry: X*, 13(February). <https://doi.org/10.1016/j.fochx.2022.100267>
- Guedes de Melo, B., Santos Fernandes, S., Domínguez Razo, A., Us Medina, U., & Segura Campos, M. R. (2022). Chia seeds as functional ingredient of healthy muffins. *Journal of Food Measurement and Characterization*, 16(5), 4251–4261. <https://doi.org/10.1007/s11694-022-01503-1>
- Guiné, R. P. F. (2022). Textural properties of bakery products: a review of instrumental and sensory evaluation studies. *Applied Sciences (Switzerland)*, 12(17). <https://doi.org/10.3390/app12178628>
- Gul, S. T., Raza, R., Hannan, A., & Khaliq, S. (2024). Potential of a medicinal plant urtica dioica (Stinging Nettle) as a feed additive for animals and birds: a review. *Agrobiological Records*, 17, 110–118. <https://doi.org/10.47278/journal.abr/2024.029>
- Hanif, K., Ijaz, M., Sajid, M., Ammar, A., Noor, A., & Haris, M. (2023). Biotechnological approaches in seed quality enhancement: current status and future prospects. *Trends in Animal and Plant Sciences*, 1, 37–48. <https://doi.org/10.62324/TAPS/2023.006>
- Hatamian, M., Noshad, M., Abdanan-Mehdizadeh, S., & Barzegar, H. (2020). Effect of roasting treatment on functional and antioxidant properties of chia seed flours. *NFS Journal*, 21(July), 1–8. <https://doi.org/10.1016/j.nfs.2020.07.004>
- İlyasoğlu, H., Arslan Burnaz, N., & Arpa Zemzemoglu, T. E. (2022). Flaxseed and cornelian cherry: Development of a functional cookie using response surface methodology. *Journal of Food Processing and Preservation*, 46(11), 1–9. <https://doi.org/10.1111/jfpp.16954>
- Iserliyska, D., Zsivanovits, G., & Marudova, M. (2021). Study on the potential of chia gel usage as a natural fat substitute in cake formulation. *Progress in Agricultural Engineering Sciences*, 17(S1), 127–135. <https://doi.org/10.1556/446.2021.30015>
- Jagelaviciute, J., & Cizeikiene, D. (2021). The influence of non-traditional sourdough made with quinoa, hemp and chia flour on the characteristics of gluten-free maize/ rice bread. *Lwt*, 137(October 2020), Article 110457. <https://doi.org/10.1016/j.lwt.2020.110457>
- Jiang, X., Wang, X., & Zhou, S. (2022). Effect of flaxseed marc flour on high-yield wheat bread production: Comparison in baking, staling, antioxidant and digestion properties. *Lwt*, 169(May), Article 113979. <https://doi.org/10.1016/j.lwt.2022.113979>
- Johari, S., Jia, C., Jin, K., & Yeng, L. (2024). Glycemic index evaluation of flaxseed oats sourdough bread. *International Journal of Nutrition and Food Sciences*, 13(4), 140–146. <https://doi.org/10.11648/j.ij.nfs.20241304.12>
- Karakoç, F. B., Ertaş, N., & Aslan, M. (2024). Storage stability, nutritional and qualitative attributes of biscuits enriched with terebinth, flaxseed and sesame seeds. *British Food Journal*, 126(8), 3263–3282. <https://doi.org/10.1108/BFJ-10-2023-0958>
- Kausar, S., Hussain, A., Ashraf, S., Fatima, G., Ambreen, Javaria, S., Abideen, Z. U., Kabir, K., Yaquub, S., Akram, S., Shehzad, A., & Korma, S. A. (2024). Flaxseed (*Linum usitatissimum*): Phytochemistry, pharmacological characteristics and functional food applications. *Food Chemistry Advances*, 4(June 2023), Article 100573. <https://doi.org/10.1016/j.focha.2023.100573>
- Khan, A., Rafiq, S. I., Saini, C. S., Hossain, S., & Rafiq, S. M. (2024). Studies on physico-chemical, functional, textural and sensory properties of flaxseed fortified bakery products. *Journal of Food Measurement and Characterization*, 18(5), 3640–3650. <https://doi.org/10.1007/s11694-024-02434-9>
- Khatiri, M., Singh, A., Singh, R., Kamble, D. B., Dar, A. H., & Sharma, A. (2023). Optimization and evaluation of quinoa and chia based gluten free pasta formulation. *Food and Humanity*, 1(April), 174–179. <https://doi.org/10.1016/j.fooHum.2023.05.009>
- Kiin-Kabari, D. B. (2019). *Effects of processing methods on the nutrient composition and sensory attributes of cookies produced from wheat and sesame seed flour blends effects of processing methods on the nutrient composition and sensory attributes of cookies produced from wheat an. June*. <https://www.researchgate.net/publication/334263327>
- Kunju, W., Meekrasae, R., Peethong, O., Khanma, S., Insamran, Y., & Patathananone, S. (2025). Phytochemical analysis and effectiveness of ripened *Spondias pinnata* fruit extracts against antibiotic-resistant mastitis-causing bacteria. *International Journal of Veterinary Science*, 14(1), 196–203. <https://doi.org/10.47278/journal.ijvs/2024.225>
- Lucini Mas, A., Brigante, F. I., Salvucci, E., Ribotta, P., Martinez, M. L., Wunderlin, D. A., & Baroni, M. V. (2022). Novel cookie formulation with defatted sesame flour: Evaluation of its technological and sensory properties. Changes in phenolic profile, antioxidant activity, and gut microbiota after simulated gastrointestinal digestion. *Food Chemistry*, 389(December 2021), Article 133122. <https://doi.org/10.1016/j.foodchem.2022.133122>
- M, A. O., B, K. K. D., & M, I. E. (2020). Anti-nutrients, bioaccessibility and mineral balance of cookies produced from processed sesame seed flour blends. *International Journal of Food Science and Nutrition Engineering*, 2020(1), 1–11. <https://doi.org/10.5923/j.food.20201001.01>
- Malaviya, R., & Yadav, N. (2022). Exploring nutritional and functional properties of different varieties of sesame seed cakes: an industrial by-product. *Plant Archives*, 22 (1), 328–333. <https://doi.org/10.51470/plantarchives.2022.v22.no1.052>
- Marpalle, P., Sonawane, S. K., & Arya, S. S. (2014). Effect of flaxseed flour addition on physicochemical and sensory properties of functional bread. *Lwt*, 58(2), 614–619. <https://doi.org/10.1016/j.lwt.2014.04.003>

- Mithu, M. M. U., Shormela, S. A., Islam, M. S., & Mubarak, M. (2025). FTIR analysis of pesticide active ingredients into seasonal vegetables: Ensuring food safety and raising awareness. *Journal of Global Innovations in Agricultural Sciences*, 13, 139–147.
- Medina-Pérez, S., Pérez-Falcón, L. F., Rivera-Ashqui, T. A., & Silva-Paz, R. J. (2025). Development of a functional drink based on the yellow variety arracacha (*Arracacha xanthorrhiza*): physicochemical, techno-functional and sensory properties. *International Journal of Agriculture and Biosciences*, 14(1), 22–30. <https://doi.org/10.47278/journal.ijab/2024.199>
- Moreira, M. R., Sanches, V. L., Strieder, M. M., Rostagno, M. A., & Capitani, C. D. (2023). Vegan brownie enriched with phenolic compounds obtained from a chia (*Salvia hispanica* L.) coproduct: Nutritional, technological, and functional characteristics and sensory acceptance. *International Journal of Gastronomy and Food Science*, 34 (October). <https://doi.org/10.1016/j.ijgfs.2023.100835>
- Murugkar, D. A., Zanwar, A. A., & Shrivastava, A. (2021). Effect of nano-encapsulation of flaxseed oil on the stability, characterization and incorporation on the quality of eggless cake. *Applied Food Research*, 1(2), Article 100025. <https://doi.org/10.1016/j.afres.2021.100025>
- Nassef, S., El-Hadidy, G., & Abdelsattar, A. (2023). Impact of defatted chia seeds flour addition on chemical, rheological, and sensorial properties of toast bread. *Egyptian Journal of Agricultural Sciences*, 0(0), 55–66. <https://doi.org/10.21608/ejarc.2023.174785.1008>
- Nouska, C., Tufail, T., Tufail, T., Bader Ul Ain, H., Jaffar, H. M., & Awuchi, C. G. (2023). Cookies enriched with anethole and secoisolaricresinol diglucoside from flaxseed and fennel seeds improve hypercholesterolemia, lipid profile, and liver functions: A pilot study. *Food Science and Nutrition*, 11(7), 4211–4218. <https://doi.org/10.1002/fsn3.3433>
- Nouska, C., Irakli, M., Palakas, P., Lytou, A. E., Bouloumpasi, E., Biliaderis, C. G., & Lazaridou, A. (2024a). Influence of sesame cake on physicochemical, antioxidant and sensorial characteristics of fortified wheat breads. *Food Research International*, 178(December 2023), Article 113980. <https://doi.org/10.1016/j.foodres.2024.113980>
- Nouska, C., Irakli, M., Palakas, P., Lytou, A. E., Bouloumpasi, E., Biliaderis, C. G., & Lazaridou, A. (2024b). Influence of sesame cake on physicochemical, antioxidant and sensorial characteristics of fortified wheat breads. *Food Research International*, 178(October 2023), Article 113980. <https://doi.org/10.1016/j.foodres.2024.113980>
- Papagianni, E., Kotsiou, K., Biliaderis, C. G., & Lazaridou, A. (2023). Flaxseed and sprouted lentil seeds as functional ingredients in the development of nutritionally fortified “clean-label” gluten-free breads. *Food Hydrocolloids for Health*, 4(June), Article 100165. <https://doi.org/10.1016/j.fhfh.2023.100165>
- Papagianni, E., Kotsiou, K., Matsakidou, A., Biliaderis, C. G., & Lazaridou, A. (2024a). Development of “clean label” gluten-free breads fortified with flaxseed slurry and sesame cake: Implications on batter rheology, bread quality and shelf life. *Food Hydrocolloids*, 150(January), Article 109734. <https://doi.org/10.1016/j.foodhyd.2024.109734>
- Papagianni, E., Kotsiou, K., Matsakidou, A., Biliaderis, C. G., & Lazaridou, A. (2024b). Development of “clean label” gluten-free breads fortified with flaxseed slurry and sesame cake: Implications on batter rheology, bread quality and shelf life. *Food Hydrocolloids*, 150(November 2023), Article 109734. <https://doi.org/10.1016/j.foodhyd.2024.109734>
- Punia, S., & Dhull, S. B. (2019). Chia seed (*Salvia hispanica* L.) mucilage (a heteropolysaccharide): Functional, thermal, rheological behaviour and its utilization. *International Journal of Biological Macromolecules*, 140, 1084–1090. <https://doi.org/10.1016/j.ijbiomac.2019.08.205>
- Rabail, R., Sultan, M. T., Khalid, A. R., Sahar, A. T., Zia, S., Kowalczewski, P.L., Jezowski, P., Shabbir, M. A., & Aadil, R. M. (2022). Clinical, nutritional, and functional evaluation of chia seed-fortified muffins. *Molecules (Basel, Switzerland)*, 27 (18), 1–14. <https://doi.org/10.3390/molecules27185907>
- Rehan, S., Qureshi, A. S., Kausar, R., & Saleemi, M. K. (2023). Effects of maternal undernutrition on coronary vasculature of fetuses and neonates in rabbits (*Oryctolagus cuniculus*). *Pakistan Veterinary Journal*, 43(1), 49–54. <https://doi.org/10.29261/pakvetj/2022.090>
- Rustemi, P., Stamatovska, V., Nakov, G., Jukić, M., Pavlovska, G., & Jankuloska, V. (2024). Pumpkin and flax By-Products-Ingredients for better sensory characteristics of cookies. *Journal of Hygienic Engineering & Design*, 47, 25–30.
- Rubio, C., González-Weller, D., Caballero, J. M., Romano, A. R., Paz, S., Hardisson, A., Gutiérrez, Á. J., & Revert, C. (2018). Metals in food products with rising consumption (brewer's yeast, wheat bran, oat bran, sesame seeds, flaxseeds, chia seed). A nutritional and toxicological evaluation. *Journal of Functional Foods*, 48 (March), 558–565. <https://doi.org/10.1016/j.jff.2018.07.051>
- Saleh, M., Ramadan, M., Elmadawy, R., Morsi, M., & El-Akabay, L. (2023). The efficacy of alcoholic extracts of *Morus macroura* (mulberries), *Lepidium sativum* (garden cress seeds) and diclazuril against *E. stiedae* in experimentally infected rabbits. *International Journal of Veterinary Science*, 12(6), 869–878. <https://doi.org/10.47278/journal.ijvs/2023.049>
- Sahni, P., & Sharma, S. (2023). Quality characteristics, amino acid composition, and bioactive potential of wheat cookies protein-enriched with unconventional legume protein isolates. *Quality Assurance and Safety of Crops & Foods*, 15(2), 1–10.
- Shamanin, V. P., Tekin-Cakmak, Z. H., Karasu, S., Pototskaya, I. V., Gordeeva, E. I., Verner, A. O., ... Koxel, H. (2024). Antioxidant activity, anthocyanin profile, and mineral compositions of colored wheats. *Quality Assurance and Safety of Crops & Foods*, 16(1), 98–107.
- Sharma, V., Premi, M., Bansal, V., Bhardwaj, A., Tripathi, N., & Kumar, N. (2024). Effect of Flaxseed gel as an egg substitute on the functional properties of cake: A comparative analysis. *J Food Chem Nanotechnol*, 10(S1), S1–S6.
- Shelke, S., Prasad, S. G., Ranvir, S., Solanke, G., & Kadam, S. (2024). Quality evaluation of nutritional cookies prepared by incorporation with chia seed and garden cress seed powder. *International Journal of Advanced Biochemistry Research*, 8(3), 639–643. <https://doi.org/10.33545/26174693.2024.v8.i3h.810>
- Siddique, F., Hussain, A., Mahdi, A. A., Hassan, M., Noreen, S., Siddique, T., Batool, S. A., Yaqub, S., Gorsi, F. I., Kauser, S., Fatima, H., & Korma, S. A. (2024). Comparison of chemically treated, pasteurized, and microwave-treated (at Different Time Durations) chia seeds added to mango-whey beverage, during different storage periods, for physicochemical and sensory parameters. *Journal of Food Quality*. <https://doi.org/10.1155/2024/6688945>. 2024.
- Tahir, M. N., Habib, A., Sahi, G. M., Sagheer, M., Murad, T., Zahid, K., & Ali, A. (2024). Management of fusarium wilt disease in sesame (*Sesamum indicum*) through seed treatment and soil amendment. *Phytopathogenomics and Disease Control*, 3(2), 261–266.
- Wang, X., Yu, H., Hu, Z., Zhang, C., Liu, B., Liu, H., & Ma, Y. (2024). Construction and characterization of sesame meal-stabilized Pickering high internal phase emulsions and their application in cake production. *International Journal of Biological Macromolecules*, 281(October). <https://doi.org/10.1016/j.ijbiomac.2024.136364>
- Wang, Y., Sánchez-Velázquez, O. A., Martínez-Villaluenga, C., Goycoolea, F. M., & Hernández-Álvarez, A. J. (2023). Effect of protein extraction and fractionation of chia seeds grown in different locations: Nutritional, antinutritional and protein quality assessment. *Food Bioscience*, 56(September). <https://doi.org/10.1016/j.fbio.2023.103238>
- Zhu, J., Cai, J., Sun, B., Xu, Y., Lu, F., & Ma, H. (2023). Inspection and classification of wheat quality using image processing. *Quality Assurance and Safety of Crops & Foods*, 15(3), 43–54.