Food Technology Research Journal, Vol. 9, issue 1, 59-75, 2025

Chemical and Technological Assessment of Gluten-Free Pan Bread Fortified with Chia and Flaxseed Mucilage as a Natural Enhancer

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Original Article

Article information

Received 15/08/2025
Revised 18/09/2025
Accepted 20/09/2025
Published 22/09/2025
Available online
24/09/2025

Keywords:
mucilage; flaxseed; chia; gluten-free pan bread; celiac disease; gel

ABSTRACT

This study evaluated chia mucilage (CM) and flaxseed mucilage (FM) as natural enhancers to improve gluten-free pan bread for celiac patients. Mucilage was extracted from chia and flax seeds (1:9 ratio), chemically analyzed, and incorporated into rice flour at levels of 12%, 14%, and 16%, along with an additional mixed mucilage (MM, 8% CM + 8% FM). These treatments were compared with rice bread (control 2) and wheat bread (control 1). Results showed that chia seeds were richer in fiber, while CM contained higher moisture and fiber than FM. MM bread batter recorded the highest viscosity; CM breads were softer and had lower hardness and water activity than FM breads. FM breads had greater volume and a lighter crumb, with FM16% showing the best color (L* = 70.59). Overall, both CM and FM improved the quality of gluten-free bread: FM (14–16%) provided better sensory properties, while CM16% extended shelf life.

1. Introduction

Celiac disease (CD), also known as gluten-sensitive enteropathy, is characterized by malabsorption resulting from inflammation of the small intestine mucosa after the ingestion of wheat gluten or related proteins from rye and barley (Farrell and Kelly, 2002; Schuppan et al., 2009). Individuals with CD are required to follow a lifelong gluten-free diet, strictly avoiding the prolamins of wheat, barley, and rye (Thompson et al., 2005). The production of gluten-free bakery products depends on an understanding of gluten and its role. Gluten is the protein complex in wheat, barley, and rye that binds dough, provides flexibility and elasticity, and enables kneading and air incorporation. In contrast, gluten-free flours lack this structural protein, making dough less elastic. Therefore, recipes must be adjusted with ingredients such as xanthan gum or additional eggs to improve elasticity (Emerson, 2006; Mostafa, 2014). Gluten-free doughs are typically more fluid than wheat-based doughs, resembling cake batters in viscosity and rheological properties (Cauvain, 2015).

Gluten is essential for achieving the desired volume and texture of baked products due to its role in gas retention and dough structure. Its main components, glutenin and prolamins (gliadin), play complementary roles: prolamins provide viscosity and extensibility, while glutenin contributes elasticity, flexibility, and cohesiveness (Cauvain, 2015; Ngemakwe et al., 2015). Beyond improving appearance, gluten is critical for crumb structure in wheat-based products (Demirkesen et al., 2010). To mimic these properties in gluten-free (GF) systems, hydrocolloids are often used. Hydrocolloids (or gums) are biopolymers widely employed in food technology for their ability to increase dough viscosity, improve texture during proofing and baking, enhance moisture retention, delay starch retrogradation, and ultimately improve product quality and acceptability (Kohajdová and Karovičová, 2009; Ngemakwe et al., 2015). They are derived from diverse sources such as tree exudates, seeds, seaweeds, fruits, tubers, and microorganisms (Chan, 2015).

Journal website: https://ftrj.journals.ekb.eg/
Published by Food Technology Research Institute, ARC
https://10.21608/ftrj.2025.454948

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Among seed-derived hydrocolloids, flaxseed and chia mucilages are promising alternatives (Muñoz et al., 2012; De Lamo and Gómez, 2018; Lu et al., 2021; Williams and Phillips, 2021). Chia (Salvia hispanica L.) was a staple food in pre-Columbian Mesoamerica (Reyes-Caudillo et al., 2008) and remains valued for its high nutritional content, including linolenic acid, dietary fiber, and protein (Peiretti et al., 2009). Chia seeds have been used as whole seeds, flour, oil, and mucilage (Zettel et al., 2018). Mucilage is a thick, glue-like substance produced by many plants and some microorganisms, serving functions such as water retention, seed germination, and membrane thickening, and has long been used in foods for its health benefits (Kassem et al., 2021). Chia seeds contain 5–6% mucilage, which can serve as dietary fiber (Reyes-Caudillo et al., 2008). Carbohydrates in chia seeds range from 24.6% to 41.5%, of which about 90% is fiber (mainly soluble), with the remainder as starch and negligible sugar (Segura-Campos et al., 2016). Chia mucilage (CM), a soluble fiber, is released upon hydration as a gel-like exudate surrounding the seed (Capitani et al., 2013). Its water-retention capacity is particularly useful for extending the freshness of baked goods (Zettel et al., 2018). Flaxseed (Linum usitatissimum L.), one of the oldest cultivated crops, is grown for fiber and oil. Its seeds contain 3–9% mucilage by weight. Flaxseed mucilage, a soluble dietary fiber, is composed of polysaccharides with sugar residues and uronic acids (Kassem et al., 2021). Like chia, flaxseed mucilage absorbs water and forms a gel that aids in binding and structure development. In summary, the present work aimed to utilize chia mucilage and flaxseed mucilage in the production of gluten-free pan bread for individuals with celiac disease and to optimize the technological and nutritional quality of gluten-free bakery products.

2. Materials and Methods

Materials

Wheat flour (72% extraction), rice flour, chia seeds (*Salvia hispanica L.*), and flaxseed (*Linum usitatissimum L.*) were purchased from a commercial retailer in Cairo. Fresh eggs, instant dry yeast, salt, corn oil, dry milk, and sugar were obtained from a local market in Giza.

Methods

Preparation of mucilage

Chia and flaxseed mucilage were prepared according to the method described Borneo et al., 2010). Briefly, the seeds were soaked in tap water at a ratio of 1:9 (seed:water, g/g) and left to rest for 30 minutes. The mixture was stirred gently in the opposite direction for a few minutes before use. The hydrated seeds were left in the gel form and then incorporated directly into the pan bread batter.

Preparation of pan bread samples

A preliminary experiment was carried out to determine the optimal blending ratio of raw materials for pan bread. The formulation of the experimental bread samples is presented in Table 1.

Table 1. Blends used for Pan Bread preparation

Pan bread	Blends	Treatments
Wheat Pan bread. (Prepare according to Table 3)	Prepared using 100% wheat flour 72% extraction (Normal) typically consumed by normal individuals.	Con.1
Gluten-free Pan bread. (Prepare according to Table 2) With no mucilage.	Prepared using 100 % Rice flour	Con.2
Gluten-free pan bread. (Prepared according to Table -2) With addition levels of mucilage.	100% Rice flour +12% Chia mucilage.	CM12%
	100% Rice flour +14% Chia mucilage.	CM14%
	100% Rice flour +16% Chia mucilage.	CM16%
	Mixed mucilage (MM) 16% (8% CM+8% FM).	MM16%
	100% Rice flour+12% flaxseed mucilage.	FM12%
	100 % Rice flour+14% flaxseed mucilage.	FM14%
	100%Rice flour+16% flaxseed mucilage.	FM16%

Rice Pan Bread Preparation

Pan bread was prepared following the method described by Park et al. (2014), with minor modifications summarized as follows:

Table 2. Ingredients of rice pan bread

Ingredients (g)	gm
Rice flour	100.0
Salts	1.6
Sugar	8.00
sunflower oil	8.0
Instant yeast	2.00
Water(ml)	80
Egg	8.00
dry milk	4.00

The ingredient formulations and baking conditions are presented in Table 1. Briefly, 100g of rice flour along with the other solid ingredients listed in the formula were placed in a mixing bowl. The mixture was blended for 1 min using a pin mixer (National Manufacturing Co., Lincoln, NE, USA). Water and egg were then added, and mixing was continued for 4 min, followed by the addition of oil and further mixing for 1 min. For each treatment, 160g of dough was poured into a greased pan and proofed for 60 min at 30 ±1°C and 90±5% relative humidity in a cabinet proofer (National Manufacturing Co.). Baking was carried out at 180°C for 40 min. Two loaves were prepared for each treatment.

Wheat Pan bread Preparation

The straight dough method for pan bread production was performed according to A.A.C.C. (2010), with minor modifications summarized as follows:

Table 3. Ingredients of wheat pan bread

Ingredients	gm
Wheat flour	100.0
Salts	1.0
Sugar	5.0
Corn oil	3.0
Instant yeast	1.5
water	According to pharinogragh absorption test.

After mixing, the dough was allowed to rest for 30 min (first proofing), then divided into 160g portions, rolled, and molded. Each portion was placed into greased baking pans (10×5×6cm) to prevent sticking and fermented for 60 min at 30°C and 85% relative humidity. Baking was performed in an electrically heated oven at 250°C for 25–30 min. After baking, the loaves were removed from the pans and cooled at room temperature for 1h prior to sensory evaluation. The loaves were then weighed, and their volume was determined.

Analytical methods

Chemical analytical methods

Chemical composition of chai seeds, flax seeds, wheat flour, rice flour and gluten-free pan bread

Moisture, crude protein, crude fat, crude fiber, and total ash contents were determined according to the methods of A.O.A.C. (2012). Carbohydrates were calculated by difference, as follows

Carbohydrates = 100 – (% protein + % fat + % ash + % crud fiber).

Caloric value (*Kcal/100g*) = fat % *9 + protein 4%+ total carbohydrates % *4

(James, 1995; Fernandes and de las Mercedes Salas-Mellado, 2017).

Determination of mineral contents of chai seeds, flax seeds, wheat flour, rice flour and gluten-free pan bread

Mineral contents, including calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn), phosphorus (P), and potassium (K), were determined according to A.O.A.C. (2012) using the dry ashing method. A Perkin Elmer 3300 atomic absorption spectrophotometer (USA) was used for mineral analysis.

Chemical composition of dried chia and flaxseed mucilage

Mucilage was spread on a drying dish and dried at 50°C for 10h. The dried mucilage was wrapped in plastic packaging and stored under refrigeration for later use. Protein, fat, ash, carbohydrate, and dietary fiber contents were determined according to the method of Fernandes and de las Mercedes Salas-Mellado (2017).

Physical methods

Volume

The volume of the different types of pan bread was determined using the rapeseed displacement method (A.A.C.C., 2010).

Weight and height

The weight and height of pan bread loaves were measured individually within 1h after baking, and the average values were recorded.

Specific volume

Pan bread was weighed individually within 1h after baking, and the specific volume was calculated according to A.A.C.C. (2010) using the following equation:

Specific volume (L.S.V) = Volume (cm3)/ Weight

Loss of Baking

The weight of the pan bread dough was recorded before baking, and the loss on baking was determined as the ratio of mass loss between the dough and the final product. Mass loss during baking was calculated according to Coelho et al. (2015) using the following equation:

Loss on baking (%)= $(m_{dough}– m_{product} / m_{dough}) \times 100$

Rheological properties

Viscosity and specific gravity of batter

The specific gravity of the batter was determined by dividing the weight of a standard container filled with batter by the weight of the same container filled with distilled water (Jyotsna et al., 2004). The viscosity of the pan bread batter was measured using a Brookfield Digital Rheometer, Model HA DVIII Ultra (Brookfield Engineering Laboratories Inc.), according to the Brookfield manual (1998). Batter samples were placed in a beaker and allowed to rest for 20 min before measurement. Spindle RV-7 was used at a speed of 10 rpm. A thermostatic water bath attached to the instrument was used to maintain the sample temperature. Viscosity was measured at room temperature (25°C).

Determination water activity (a_w) of bakery products during storage time

Water activity (a_w) of the samples was measured using a Decagon AquaLab meter, Series 3TE (Pullman, WA, USA), at 25±2°C. Samples were crushed into small pieces, placed into plastic cups, and analyzed according to Bolandi et al. (2008).

Color of gluten-free pan bread

Color was evaluated using the CIE Lab* system with a Chroma Meter (Minolta, Tokyo, Japan) equipped with a D65 illuminant. Lightness (L^*), redness (a^*), and yellowness (b^*) values were recorded directly from the instrument. Each measurement was performed in triplicate (Lee et al., 2013). The following equation was used to determine the total color Difference (ΔE).

$$\Delta E = \sqrt{(\Delta L^*) + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Where, in respect to parameters at time zero, the variations of the a* coordinate are denoted by Δa*, b* by Δb*, and L* by ΔL*.

The impact of chia and flaxseed mucilage on gluten-free pan bread in terms of hardness and rate of hardness increase (RI %) over time at room temperature ±50°C

The hardness of pan bread was measured using a CT3 Texture Analyzer (Version 2.1, 10,000g unit; Brookfield Engineering Laboratories Inc., USA) following the method of A.A.C.C. (2010). Bread slices approximately 25mm thick, or two slices each about 12.5mm thick, were used. The slices were cut by hand, ensuring that the three end slices were not included and crusts were retained. A cylindrical probe (36mm diameter) was set at a test speed of 2 mm/s. Measurements were taken at the center of the slices, avoiding non-representative crumb areas. Each sample was compressed to 40% deformation with a trigger load of 3 g.

Sensory evaluation

The pan breads were evaluated according to the method described by Azmoon et al. (2021), using ten panelists from the Bread and Pastry Research Department, Food Technology Institute, Agricultural Research Center, Giza. The average total score was converted into descriptive categories as follows: Very Good (V. good), 90–100; Good (G), 80–89; Satisfactory, 70–79; and Questionable, <70.

Statistical analysis

All data were subjected to analysis of variance (ANOVA), and Scheffé's multiple range test at the 0.05 probability level ($P \leq 0.05$) was used to compare the means.

3. Results and Discussion

Chemical composition of raw materials

Table 4 presents the proximate chemical composition of the raw materials. Chia seeds contained 6.93% moisture, 36.96% lipid, 17.90% protein, 5.22% ash, 35.00% crude fiber, and 3.92% nitrogen-free extract. These results are consistent with those reported by Coelho et al. (2014), Barreto et al. (2016), Fernandes and de las Mercedes Salas-Mellado (2017), and De Lamo and Gómez (2018). Flaxseed contained 6.80% moisture, 40.00% lipid, 21.86% protein, 2.13% ash, 27.00% crude fiber, and 9.01% nitrogen-free extract, which is in agreement with previous reports. White rice flour contained 13.77% moisture, 0.62% lipid, 7.01% protein, 0.31% ash, 0.51% crude fiber, and 91.05% carbohydrates, which is consistent with MONA (2006) and Adam Omer Ishag et al. (2020). Wheat flour contained 14.70% moisture, 0.85% lipid, 10.00% protein, 0.61% ash, 0.53% crude fiber, and 88.01% carbohydrates, in agreement with Nilsson et al. (2005).

Table 4. Chemical composition (%) of raw materials on dry weight basis

	Chia seeds	Flaxseed	Rice flour	Wheat flour
Moisture (%)	$6.93^{b}\pm0.015$	$6.80^{a}\pm0.015$	$13.77^{c}\pm0.07$	$14.70^{d}\pm0.015$
Lipid	$36.96^{c}\pm0.015$	$40.00^{d}\pm0.15$	$0.62^{a}\pm.015$	$0.85^{b}\pm0.015$
Protein	$18.90^{c}\pm0.060$	$21.86^{d}\pm0.015$	$7.01^{a}\pm0.062$	$10.00^{b}\pm0.076$
Ash	$5.22^{d}\pm0.015$	$2.13^{c}\pm0.020$	$0.31^{a}\pm0.015$	$0.61^{b}\pm0.015$
Crude fiber	$35.00^{c}\pm0.10$	$27.00^{b}\pm0.13$	$0.51^{a}\pm0.015$	$0.53^{a}\pm0.015$
*Carbohydrate	3.92	9.01	91.55	88.01

Minerals contents of raw materials

The quantification of minerals is presented in Table 5. Chia seeds contained calcium (561.85mg/100 g), sodium (21.52mg/100g), zinc (5.16mg/100g), potassium (326.49mg/100g), phosphorus (790.41mg/100 g), iron (7.00mg/100g), and magnesium (295.30mg/100g). These results are consistent with Barreto et al. (2016), Mohammed et al. (2019), Abd-Elhamid (2021), and Anwar et al. (2024). Flaxseed contained calcium (233.85mg/100g), zinc (4.10mg/100g), potassium (620mg/100g), and other minerals, in agreement with Ganguly et al. (2021) and Kučka et al. (2024). Wheat flour contained calcium (35.11mg/100g), sodium (9.82mg/100g), zinc (0.22mg/100g), potassium (49.56mg/100g), among others, consistent with Tehseen (2013). Rice flour contained calcium (15.80mg/100g), sodium (8.80mg/100g), zinc (2.21mg/100g), and other minerals, which is in line with Nada and Hasan (2015), Hassan et al. (2020), and Mansour et al. (2024).

Chemical composition of both dried chia mucilage and flaxseed mucilage

Table 6 presents the proximate chemical composition of dried chia mucilage and flaxseed mucilage. Chia mucilage had a moisture content of 12.59%, slightly higher than the 10.13% in flaxseed mucilage. This higher moisture may contribute to improved softness, reduced dryness, and extended shelf life particularly important in gluten-free baking. In contrast, the lower moisture content of flax mucilage may make it more suitable for products requiring a firmer texture and reduced mold growth. According to Kučka et al. (2024), flaxseed mucilage exhibits unique functional properties such as high water-holding capacity and formability. As a result, flax mucilage has wide applications in human nutrition, agriculture, medicine, and other industries. Regarding protein content, flaxseed mucilage contained 14.52%, higher than the 10.56% in chia mucilage. This suggests that flax mucilage could be more beneficial for gluten-free products. The higher protein may enhance nutritional value and improve product tolerance through protein network formation, which helps trap gases (e.g., CO_2 during fermentation). Burgos-Díaz et al. (2016) reported that proteins and polysaccharides extracted from linseed were evaluated as bio emulsifiers.

Although chia mucilage had lower protein content, it still contributes to dietary protein intake, particularly in plant-based diets. Both mucilages are suitable for celiac patients, in agreement with Barbary et al. (2009) and Fernandes & de las Mercedes Salas-Mellado (2017). For lipid content, both mucilages contained low fat levels (1.8–2%), with flaxseed mucilage slightly higher at 1.98% compared to 1.79% in chia. Neither is a significant fat source, although flax mucilage may retain slightly more omega-3 fatty acids (ALA), with both seeds preserving some after extraction. Ash content was higher in chia mucilage (13.00%) than in flaxseed mucilage (8.62%), suggesting that chia mucilage likely contains more minerals important for bone health and overall nutrition. Crude fiber content was also markedly higher in chia mucilage (35.23%) compared to flaxseed mucilage (22.11%). The high fiber content in chia mucilage may result in a denser texture, as confirmed by hardness tests. These findings are consistent with Hernandez (2012) and Kadhim AL-Zurfi & Hasan Al-Obaidi (2025). For nitrogen-free extract (NFE), chia mucilage contained 39.42%, considerably lower than the 52.78% in flaxseed mucilage. Flax mucilage also contained more soluble carbohydrates, which may contribute to its gel-forming properties. The higher NFE in flax mucilage enhances natural sweetness and supports the development of a crisp texture, making it particularly suitable for products such as cakes. In contrast, the lower NFE content in chia mucilage may have less impact on the glycemic index, offering potential advantages for blood sugar management. In summary, chia mucilage is richer in moisture, ash, and fiber, which enhances softness, mineral content, and health benefits, while flaxseed mucilage is higher in protein and carbohydrates, improving nutritional value, sweetness, and functional baking properties. Both mucilages complement each other in gluten-free and functional food applications. The caloric value of chia mucilage was 356.95kcal, which is slightly lower than the 375.43kcal of flaxseed mucilage. In brief, chia mucilage is nutritionally superior in terms of fiber and mineral content, making it ideal for public health benefits and for fortifying gluten-free bakery products. On the other hand, flaxseed mucilage excels in carbohydrate and protein content, which is valuable for improving gluten-free product texture as well as contributing to public health.

Table 5. Minerals content (mg/100g) of raw materials on dry weight basis

*Minerals	Chia seeds	Flaxseed	Rice flour	Wheat flour	*RDA
Ca	591.85±0.012	233.85±1.13	15.80±0.16	35.11±0.03	1000
Na	21.52±0.005	27.20±0.524	8.80±0.002	9.822±0.045	2300
Zn	5.16±0.03	4.10±0.053	2.2±0.001	0.22±0.156	11
K	326.49±0.023	830.50±3.01	68.90±0.09	49.5600±132	3500
P	790.41±0.12	620.00±0.40	66.450±0.04	67.4200±0.14	1250
Fe	7.00±0.011	2.68±0.60	1.01±016	0.5420±0121	16
Mg	295.30±0.005	430.10±0.01	29.40±0.18	41.2100±0.06	400

*Values in the same row have the same letters are not significantly different at level 0.05.

*(mineral) = Std. Deviation calculated by atomic absorption spectrophotometer.

*RDA=Recommended daily allowance according to FDA

Table 6. Chemical composition (%) of both dried chia mucilage and flaxseed mucilage

Chemical composition		Chia mucilage	Flaxseed mucilage
On Dry Weight Basis	Moisture	2.59 ±0.026	10.13 ±0.025
	Protein	10.56±0.020	14.52 ±0.015
	Lipids	1.79 ±0.040	1.98 ±0.055
	Ash	13.00 ±0.020	8.62 ±0.12
	Crude fiber	35.23 ±0.020	22.11 ±0.015
	Carbohydrate	39.42	52.78
Caloric value(Kcal/100g)		356.95	375.42

*No statistical analysis of carbohydrates was performed, since the values were calculated by difference.

Chemical composition of gluten-free pan bread samples

Table 7 presents the chemical composition of several gluten-free pan bread samples prepared with chia mucilage (CM) and flaxseed mucilage (FM) at varying concentrations. There were no significant differences in crude protein content between the mucilage-based samples and the rice control, with values ranging from 7.68% for the rice control to 7.95% for CM16% and 8.00% for FM16%. This indicates that FM breads contained slightly higher protein than CM breads. As expected, the wheat control recorded the highest protein value (10.70%), attributed to its gluten content. These findings suggest that mucilages may contribute to nutritional enhancement through their protein quality. Fat content showed a slight increase in the mucilage breads compared with the rice control (9.42%), rising to 10.05% for CM16% and 10.37% for FM16%. This increase reflects the residual seed oils present in the mucilages. By contrast, the wheat control had the lowest fat content (2.60%). Fiber content increased significantly in the mucilage breads, from 2.61% in the rice control to 3.52% in CM16% and 3.34% in FM16%, confirming that CM breads had higher fiber levels than FM breads. The wheat control, again, had the lowest fiber content (0.38%). This demonstrates that mucilage addition particularly chia mucilage enhances soluble fiber content, which supports digestion, lowers the glycemic index, and improves gluten-free bread texture. Ash content also increased with mucilage incorporation, with CM16% recording the highest value (2.46%), followed by FM16% (2.36%), compared with 2.31% for the rice control and only 0.86% for the wheat control. Carbohydrate content decreased in the mucilage breads, from 77.98% in the rice control to 75.94% in FM16%. This reduction was due to the relative increase in other proximate components (fiber, fat, ash, and protein). These results align with previous findings (Nada and Hasan, 2015; Hargreaves et al., 2018). In summary, the incorporation of mucilages improved moisture retention, enhanced freshness, and reduced crumb firmness, resulting in softer bread (Sabanis and Tzia, 2011). Nutritional value was also enhanced, particularly through higher fiber, omega-3, and mineral contents. An incorporation level of 16% CM or 16% FM proved optimal for achieving nutritional improvements while maintaining desirable physical properties. The mixed mucilage treatment (MM16%, 8% CM + 8% FM) showed intermediate values between CM and FM treatments, potentially providing a more balanced nutritional profile. Overall, breads fortified with chia and flaxseed mucilages represent a healthier alternative to rice bread, especially for celiac patients and consumers seeking functional foods.

Table 7. Chemical composition (%) of gluten-free pan bread samples prepared from both chia and Flaxseed mucilage on dry weight basis

***Pan Bread Samples**	On dry weight basis (%)					
	*Crude protein	*Fats	*Crude fiber	*Ash%	*Carbohydrate	Caloric values (Kcal/100g)
Control 1	$10.70^{d}\pm0.015$	$2.60^{a}\pm0.020$	$0.38^{a}\pm0.015$	$0.86^{a}\pm0.015$	85.46	409.56
Control 2	$7.68^{a}\pm0.015$	$9.42^{b}\pm0.020$	$2.61^{b}\pm0.015$	$2.31^{b}\pm0.015$	77.98	437.86
Chia mucilage 12%	$7.90^{b}\pm0.015$	$9.90^{c}\pm0.015$	$3.30^{de}\pm0.030$	$2.40^{bc}\pm0.025$	76.5	439.9
Chia mucilage 14%	$7.92^{bc}\pm0.015$	$9.97^{c}\pm0.020$	$3.41^{f}\pm0.020$	$2.43^{bc}\pm0.030$	76.27	440.13
Chia mucilage 16%	$7.95^{bc}\pm0.020$	$10.05^{d}\pm0.020$	$3.52^{g}\pm0.025$	$2.46^{bcd}\pm0.020$	76.02	440.41
Mixd Mucilage 16%	$7.96^{bc}\pm0.015$	$10.21^{f}\pm0.015$	$3.42^{f}\pm0.020$	$2.36^{bcd}\pm0.015$	76.05	441.61
Flaxseed mucilage 12%	$7.92^{b}\pm0.020$	$10.14^{e}\pm0.020$	$3.16^{c}\pm0.030$	$2.33^{cde}\pm0.015$	76.45	441.38
Flaxseed mucilage 14%	$7.95^{bc}\pm0.020$	$10.25^{f}\pm0.025$	$3.25^{cd}\pm0.025$	$2.34^{de}\pm0.025$	76.21	441.89
Flaxseed mucilage 16%	$8.00\,^{c}\pm0.068$	$10.37^{g}\pm0.020$	$3.34^{ef}\pm0.020$	$2.36^{e}\pm0.025$	75.93	442.41

* Pan Bread Samples (According to Table -1).
*Each values with the same column are followed by the same letters are not significantly different at level of 0.05.
*No statistical analysis for carbohydrates as it was calculated by the difference.

Mineral content (mg/100g) in gluten-free Pan Bread made with chia mucilage and flaxseed mucilage

Table 8 presents the concentrations of Magnesium (Mg), Calcium (Ca), Zinc (Zn), Iron (Fe), Sodium (Na), Potassium (K), and Phosphorus (P) in various pan bread preparations. For instance, Magnesium (Mg) in CM 12% reached 27.15mg/100g, showing a slight increase over Control 2. As the percentage of CM increased, Mg generally rose, reaching 33.09 mg/100 g at CM 16%. Comparatively, CM treatments recorded higher Mg levels than FM treatments. FM treatments showed a clearer trend of Mg increase with higher substitution levels, recording 25.61mg/100 g at FM 16%. Meanwhile, MM 16% contained 27.97 mg/100 g, falling between FM 12% and FM 14%, indicating a valuable contribution of Mg from the mixed mucilages. In conclusion, incorporating chia and flaxseed mucilages into pan bread offers a viable strategy to enhance its mineral profile. Chia mucilage appears to contribute more significantly to most mineral increases than flaxseed mucilage when used individually. However, the mixed mucilage (MM16%) stands out as the most effective overall, providing superior enrichment for critical elements such as Zinc and Iron, while also maintaining high levels of other essential minerals. The elevated sodium levels observed in the samples are likely a consequence of fertilization practices and agricultural processing. These results are consistent with previous findings (Boriy et al., 2021; Zyada et al., 2025).

Table 8. Mineral content (mg/100g) in gluten-free pan bread samples made with chia and flaxseed mucilage

*Pan Bread samples	*Minerals (mg/100g)						
	Mg	Ca	Zn	Fe	Na	K	P
Control 1	21.25±0.045	31.81±0.070	1.76±0.083	1.5±0.195	388.17±0.17	123.25±0.12	107.88±0.14
Control 2	23.97±0.058	26.15±0.032	1.12±0.217	1.62±0.208	430.14±0.14	127.77±0.054	140.93±0.083
CM 12%	27.15±0.035	34.71±0.023	1.91±0.20	2.22±0.037	507.94±0.01	133.81±0.022	174.56±0.06
CM 14%	28.52±2.024	38.38±0.68	1.93±0.360	2.41±2.52	572.72±0.15	137.11±2.72	185.±0.63
CM 16%	33.09±0.605	48.74±0.67	1.96±1.002	2.6±0.488	603.17±0.17	162.86±0.302	198.9±0.63
MM16%	27.97±1.37	39.47±0.029	2.27±0013	4.77±1.104	669.08±0.37	140.43±1.0622	184.52±1.66
FM 12%	24.3±0.0019	28.54±0.001	1.14±0.0018	1.74±0.001	435.66±0.08	127.8±0.01	149.12±0.012
FM 14%	25.14±0.007	30.12±0.002	1.74±0.0057	1.8±0.009	435.9±0.06	130.16±0.05	163.83±0.011
FM 16%	25.61±0.013	34.43±0.004	1.86±0.0100	2.01±0.007	467.72±0.02	130.58±0.03	165.65±0.024

* Pan Bread Samples (According to Table -1).

Physical properties of gluten-free pan bread prepared from using chia and flaxseed mucilage at different levels of addition

Data presented in Table 9 show the impact of adding chia mucilage (CM) and flaxseed mucilage (FM) on the weight, volume, and specific volume of pan bread. It should also be noted that there is a relationship between specific gravity and bread volume, which will be discussed later when addressing specific gravity. The addition of CM increased the volume of pan bread from 320g for the Control 2 sample to 329.6 g at CM 16%. Similarly, the volume of FM samples rose from 348.4g to 355.5g as the FM level increased up to 16%. Specific volume also improved: for Control 2, it was 2.22, rising to 2.28 at CM 16%. For FM pan bread, specific volume values were 2.42, 2.46, and 2.53 at FM 12%, 14%, and 16%, respectively. These findings are consistent with Anwar et al. (2024) and agree with earlier reports by Kulp et al. (1974) and Roman et al. (2019), who stated that hydrocolloids are essential for achieving desirable physical properties and improving bread volume. Results from Table 9 further revealed that 16% mixed mucilage (MM) produced a volume and specific volume comparable to CM 14%, but slightly lower than FM 16%, recording 324.4g and 2.26, respectively.

Notably, baking loss for CM pan breads was lower than for FM breads, likely due to the higher moisture content in CM formulations. The MM sample showed performance close to CM 14% and FM 14%, further supporting its intermediate behavior.

Table 9. Physical properties of gluten-free pan bread prepared from using chia and flaxseed mucilage at different addition levels

*Pan bread samples	Weight	Volume	Specific volume (cm^3/gm)	Loss of baking
Control 1	140^{b}±2.00	355^{c}±5.00	2.88^{d}±0.01	23.12^{b}±3.00
Control 2	123^{a}±1.00	308^{a}±5.00	2.2^{a}±0.02	12.50^{a}±1.0
CM 12%	143^{b}±1.00	318.42^{a}±2.00	2.22^{a}±0.02	10.62^{a}±4.00
CM 14%	143.3^{b}±1.00	319.4^{a}±1.00	2.25^{ab}±0.03	10.43^{a}±1.00
CM 16%	146.3^{b}±4.00	329.6^{ab}±2.00	2.28^{ab}±0.02	8.56^{a}±2.00
MM 16%	143.3^{b}±1.00	324.4^{b}±2.00	2.26^{b}±0.02	10.43^{a}±1.00
FM 12%	138.3^{b}±13.89	348.4^{c}±3.00	2.42^{c}±0.11	13.56^{a}±1.00
FM 14%	143.3^{b}±3.00	350.5^{c}±2.00	2.46^{cd}±0.03	10.43^{a}±2.00
FM 16%	144.3^{b}±2.00	355.5^{c}±5.00	2.53^{d}±0.02	9.80^{a}±3.00

The Effect of adding both chia and flaxseed mucilage on moisture content and water activity of gluten-free pan bread over time:

Data presented in Table 10 show that the highest moisture levels were recorded for MM16% at 49.56%, CM16% at 48.26%, and FM16% at 46.14%. These results are similar to those reported by Phillips and Williams (2009) and Lu et al. (2021), who explained that the ability of mucilage to retain water is due to the gelling properties of soluble fiber in both flax and chia. This increase enhances freshness, slows down the hardening process, and consequently extends the bread's shelf life. For all treatments presented in Table 10, moisture levels decreased as storage time progressed. This is expected due to the natural loss of moisture over time, particularly in open or non-hermetic conditions. For example, the moisture content of CM16% decreased from 48.26% at zero time to 35.53% after 72 hours. In summary, treatments with higher concentrations of CM and FM, especially at 16%, showed better moisture retention during storage compared to lower concentrations (12% and 14%). According to the results, both CM and FM contain soluble fiber that can absorb water and reduce the availability of free water in the mixture. The higher the percentage of CM and FM, the more water is absorbed, resulting in lower water activity (Aw). For instance, Aw decreased at zero time from 0.924 to 0.905 as the chia mucilage concentration increased from 12% to 16%. This finding is in agreement with Fernandes and Salas-Mellado (2017). Similarly, for FM samples, Aw decreased from 0.934 to 0.915 as FM concentration increased from 12% to 16%. The MM16% sample showed a cumulative effect, with Aw measured at 0.915, similar to the values for 16% CM and 16% FM. Over time, water loss through evaporation and the gradual concentration of solutes such as sugar and salt further decreased water activity. Additionally, the water-binding capacity of chia and flaxseed mucilages contributed to this reduction. According to food safety guidelines, reduced water activity hinders microbial growth and helps extend the product's shelf life (Fernandes and de las Mercedes Salas-Mellado, 2017).

The Effect of adding chia and flaxseed mucilage on the rate of moisture decrease over time in gluten-free pan bread stored at room temperature ±5°C

The results in Table 11 concerning the rate of moisture decrease (RD %) show that Control 2 exhibited a much higher rate of moisture loss compared to Control 1 and the rate of moisture reduction increased over time; where the CM values were the lowest; for instance CM16% was 26.37% after 72 hours, while FM16% was 28.84%. Hence here are the general Observations :

All treatments showed an increase in the rate of moisture reduction with time, progressing from 24 to 72 hours.

moisture reduction with time, progressing from 24 to 72 hours.

- Control 2, made with rice flour only, showed a significantly higher RD% compared to Control 1.
- Treatments with 12% concentration of both CM and FM recorded the highest RD% values compared to the higher concentrations (14% and 16%).
- The rate of moisture reduction for FM was higher than CM across all treatments.
- The MM16% treatment showed the lowest rate of decrease, which may be attributed to its strong water-binding capacity.

These findings are consistent with the results of Fernandes et al. (2021).

Table 10. The Effect of adding both chia and flaxseed mucilage on the moisture content and water activity of gluten-free pan over time

*Pan Bread Samples	Moisture (%) over time (hours)				Water activity(a_w) over time (hours)			
	0	24	48	72	0	24	48	72
Control 1	38.6^{a} ±0.004	34.1^{b} ±0.002	32.54^{f} ±0.004	30.23^{e} ±0.002	0.914^{ab} ±0.002	0.889^{a} ±0.002	0.885^{a} ±0.002	0.880^{a} ±0.003
Control 2	43.02^{b} ±0.002	28.12^{a} ±0.002	25.14^{a} ±0.002	21.29^{a} ±0.002	0.963^{e} ±0.002	0.957^{c} ±0.003	0.957^{e} ±0.002	0.954^{e} ±0.002
CM 12%	46.38^{g} ±0.002	38.26^{d} ±0.002	35.15^{b} ±0.014	32.60^{b} ±0.002	0.924^{c} ±0.002	0.921^{c} ±0.002	0.918^{c} ±0.002	0.915^{c} ±0.002
CM 14%	47.48^{h} ±0.001	40.74^{g} ±0.003	36.16^{g} ±0.013	33.52^{g} ±0.002	0.915^{bc} ±0.002	0.912^{c} ±0.002	0.909^{c} ±0.002	0.906^{c} ±0.002
CM 16%	48.26^{i} ±0.002	45.16^{i} ±0.003	40.18^{i} ±0.002	35.53^{h} ±0.002	0.905^{a} ±0.003	0.902^{b} ±0.003	0.899^{b} ±0.003	0.896^{b} ±0.003
MM16%	49.56^{e} ±0.002	48.4^{e} ±0.002	47.00^{d} ±0.002	45.10^{i} ±0.002	0.915^{bc} ±0.004	0.912^{c} ±0.004	0.909^{c} ±0.004	0.906^{c} ±0.004
FM 12%	44.7^{c} ±0.003	35.18^{c} ±0.002	29.34^{c} ±0.002	27.28^{c} ±0.002	0.934^{d} ±0.002	0.931^{d} ±0.004	0.928^{d} ±0.00	0.925^{d} ±0.001
FM 14%	44.8^{d} ±0.002	38.25^{f} ±0.004	32.17^{e} ±0.002	29.38^{d} ±0.002	0.924^{c} ±0.002	0.921^{c} ±0.001	0.918^{c} ±0.003	0.915^{c} ±0.003
FM 16%	46.14^{f} ±0.012	43.30^{h} ±0.002	36.18^{h} ±0.002	32.83^{f} ±0.002	0.915^{bc} ±0.004	0.912^{c} ±0.002	0.909^{c} ±0.002	0.906^{c} ±0.002

* Pan Bread Samples (According to Table- 1).

Table 11. The Effect of adding chia and flaxseed mucilage on the rate of moisture decrease over time in gluten-free pan bread stored at room temperature $\pm 5^{0}C$

*Pan bread samples	Rate Moisture Decrease (RD %)		
	24hr	48hr	72hr
Control 1	11.65	15.69	21.68
Control 2	34.63	41.56	50.51
CM 12%	19.66	24.21	29.71
CM 14%	14.19	23.84	29.40
CM 16%	4.35	16.74	26.37
MM 16%	2.34	5.16	8.999
FM 12%	21.29	34.36	37.76
FM 14%	14.62	28.19	34.41
FM 16%	6.15	21.58	28.84

* Pan Bread Samples (According to Table- 1).

Viscosity and specific gravity of gluten-free pan bread batter

The mucilage, as the primary component found in the shell of flaxseed, consists mainly of arabinoxylans (high–molecular weight branched sugars), glucuronic acid, and monosaccharides, which enhance its molecular crosslinking ability. Flaxseed mucilage contains up to 28 g of soluble fiber per 100 g of seed weight. The chains in flaxseed mucilage are longer and more crosslinked due to the presence of β-(1→4) and α-(1→6) glycosidic bonds, creating a denser three-dimensional network. Moreover, its high water-holding capacity results from stronger hydrogen bonding with water, attributed to the carboxyl (-COOH) groups in glucuronic acid, thereby increasing viscosity. These findings are in line with Qian et al. (2012) and Korus et al. (2015). In contrast, chia mucilage mainly consists of oligosaccharides, which are less branched than flaxseed arabinoxylans and contain a lower percentage of sugar acids. However, chia mucilage has a higher soluble fiber content (34 g/100 g of seed weight). The polymer chains in chia are shorter and less crosslinked, with α-(1→6) glycosidic bonds contributing to high viscosity. As shown in Table 12, the mixed mucilage (MM) demonstrated a markedly higher viscosity compared to individual treatments. This may be attributed to the interaction between chia and flaxseed mucilages, forming a more complex polysaccharide network capable of trapping more water, thereby increasing viscosity—a clear "synergistic effect." The study also revealed that specific gravity increased with higher concentrations of both CM and FM compared to Control 2. This generally indicates lower bread volume; however, in practice, the opposite was observed. With increased levels of CM and FM, the mucilages formed a more viscoelastic gel network, similar to gluten, which allowed yeast-produced gas bubbles to expand during baking without rupturing. Although the dough became denser, this stronger gel network stabilized the structure, preventing collapse and ultimately yielding greater bread volume (Hargreaves et al., 2018). Additionally, the higher mucilage content retained more water within the dough, delaying crust formation, reducing rapid moisture loss, and keeping the dough elastic during rising, thereby supporting further expansion. Conversely, the MM treatment exhibited an excessively high specific gravity, which hindered volume development and had a counterproductive effect.

Table 12. Viscosity and specific gravity of gluten-free pan bread batter

*Gluten-free Pan bread batters								
Parameters	Con 2.	Chia mucilage			Mixed mucilage	Flaxseed mucilage		
		12%	14%	16%	16%	12%	14%	16%
Viscosity (cp)	2400	4400	4800	5400	6800	3200	3400	3600
Specific gravity	1.1	1.11	1.13	1.15	1.22	1.11	1.14	1.16

*Gluten-free Pan bread batter According to table-1

Sensory Evaluation of gluten-free pan bread

The data in Table 13 and Figure 1 indicate that the sensory characteristics of pan bread improved with increasing addition levels of CM (from 12% to 16%) and FM (from 12% to 16%). Statistical analysis revealed a significant difference between the Control 2 sample and the CM16%, FM14%, and FM16% treatments for all sensory attributes, while these treatments were closer in score to Control 1. Pan bread samples containing CM12% and CM14% were rated as having good acceptability by the panelists, whereas CM16% received very good acceptability. Similarly, FM12% and MM16% were rated as good, while FM14%, FM16%, and CM16% achieved full satisfaction. In contrast, MM16% did not achieve full satisfaction. These findings are in harmony with those reported by Nada and Hasan (2015) and Hargreaves et al. (2018).

Table 13. Sensory evaluation of gluten-free pan bread prepared from chia mucilage and flaxseed mucilage

*Treatments	Crust color (15)	Crumb color (15)	Grains (10)	Mouth feel (20)	odour (20)	Taste (20)	Total score (100)	Grade
Control 1	13.70^{d} ±0.48	14.70^{c} ±0.48	9.80^{c} ±0.42	19.80^{b} ±0.63	17.70^{a} ±3.02	19.90^{bc} ±0.31	95.60^{c} ±3.80	VG
Control 2	10.60^{a} ±0.69	11.70^{ab} ±0.94	6.90^{a} ±0.31	17.90^{a} ±0.31	17.90^{ab} ±0.31	17.70^{a} ±0.48	82.70^{a} ±2.83	G
CM 12%	10.90^{a} ±0.56	10.90^{a} ±0.56	8.00^{bc} ±0.81	17.90^{a} ±0.56	17.90^{ab} ±0.56	19.50^{bc} ±0.84	85.10^{ab} ±3.57	G
CM 14%	11.90^{ab} ±0.31	11.90^{ab} ±0.31	8.10^{bc} ±0.73	18.00^{a} ±0.47	19.00^{ab} ±0.47	19.20^{bc} ±0.42	88.10^{b} ±1.19	G
CM 16%	12.60^{bc} ±0.69	12.50^{a} ±0.42	8.40^{c} ±0.84	18.20^{a} ±0.42	18.90^{ab} ±0.31	19.80^{bc} ±0.42	90.4^{b} ±1.37	VG
MM 16%	11.00^{a} ±0.00	11.00^{a} ±0.00	7.800^{abc} ±0.42	17.80^{a} ±0.42	18.20^{ab} ±0.42	19.80^{bc} ±0.42	85.60^{ab} ±0.84	G
FM 12%	11.60^{ab} ±0.69	11.70^{ab} ±0.48	7.90^{abc} ±0.31	18.20^{a} ±0.63	19.10^{ab} ±0.31	19.10^{b} ±0.31	87.60^{b} ±0.84	G
FM 14%	13.40^{cd} ±1.07	12.70^{b} ±0.67	7.90^{ab} ±0.42	17.80^{a} ±0.63	18.90^{ab} ±0.31	19.70^{bc} ±0.67	90.45^{b} ±2.21	VG
FM 16%	13.50^{d} ±1.26	13.40^{c} ±1.34	7.70^{c} ±0.67	18.60^{b} ±0.84	18.80^{b} ±0.42	19.00^{c} ±0.00	91.00^{c} ±4.32	VG

Each values with the same column are followed by the same letters are not significantly different at level of 0.05.
(90 – 100) very good (V) (80 – 89) Good (G) (70 – 79) Satisfactory (S) Less than 70 Questionable (Q).
Treatments *(*According to Table -1*)*.

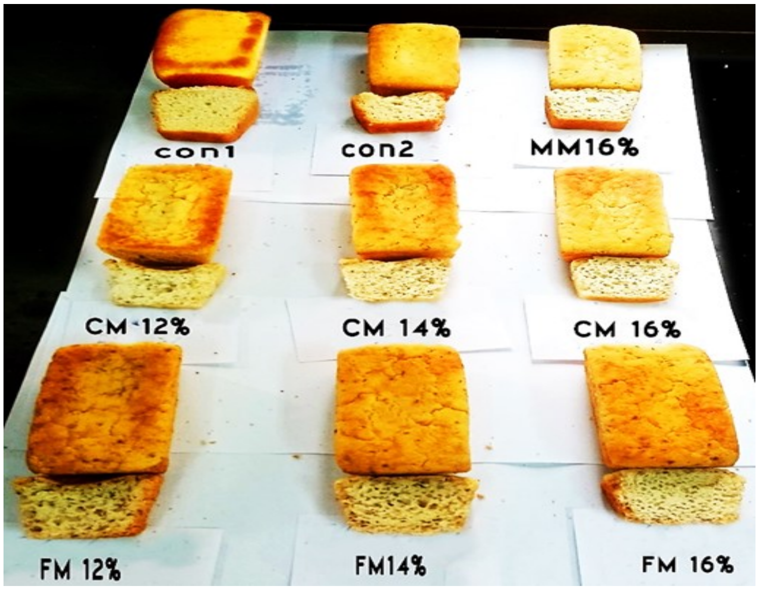

Figure 1. Gluten Free Pan Bread samples with different addition levels of chia and flaxseed mucilage (According to Table -1).

The impact of both chia and flaxseed mucilage on the hardness of gluten-free Pan Bread and rat of Hardness increase RI % over time at room temperature ±5°C

Table 14. presents the hardness measurements of pan bread over time (0, 24, 48, and 72h). A clear trend of increasing hardness was observed across all samples as storage time progressed. For instance, the hardness of Control 1 increased from 8.91 at 0 h to 25.87 at 72 h, while Control 2 (rice flour) showed a dramatic rise from 17.96 to 80.79, highlighting its tendency to harden more rapidly. This is in harmony with Aaliya et al. (2021), who noted that gluten in wheat bread retards the movement of water molecules, while its absence enhances water migration from crumb to crust, resulting in a firmer structure.

All CM and FM samples also showed an increase in hardness with time; however, their values remained lower than Control 2 (rice flour) but higher than Control 1 (wheat flour). For example, CM16% recorded hardness values of 14.0 at 0 h and 27.79 at 72 h, compared to Control 2, which reached 17.96 and 80.79 at the same time points. This indicates the role of natural improvers (CM and FM) in moderating hardness development compared to rice flour. Increasing the addition levels of CM and FM further reduced hardness compared to Control 2. At 0 h, CM samples showed values of 15.1, 14.8, and 14.0 for 12%, 14%, and 16% concentrations, respectively, while FM samples decreased from 13.45 to 13.0 as the level increased from 12% to 16%. These findings are consistent with Kohajdová and Karovičová (2009) and Hassan et al. (2020). Similarly, Bárcenas and Rosell (2005) and Davidou et al. (1996) reported that hydrocolloids increase crumb moisture content, prevent water loss during storage, and form hydrogen bonds with starch, delaying retrogradation, softening the crumb (Sabanis and Tzia, 2011), and retarding hardness (González et al., 2025). Comparing CM and FM, CM samples demonstrated greater tenderness. For instance, hardness of CM16% reached 27.79 at 72 h, while FM16% reached 34.32, indicating the stronger water-binding capacity of CM. As generally observed, the higher the water retention, the lower the hardness. CM also forms a gluten-like elastic structural network, maintaining tenderness and reducing hardness (Sciarini et al., 2010; Hargreaves et al., 2018). On the other hand, MM16% exhibited high viscosity, which enhanced water retention but limited dough expansion during baking. This resulted in a denser, more uniform, and less brittle crumb, though with a firmer texture.

Table 14. The Hardness evaluation of Gluten-free Pan Bread over time

Time	*Hardness of gluten free Pan Bread								
	Con1	Con2	CM 12%	CM 14%	CM 16%	MM16%	FM 12%	FM 14%	FM 16%
Zero	8.91^{a} ±.01	17.96^{f} ±0.02	15.1^{cd} ±.066	14.8 ^{bc} ±.01	14^{ab} ±1.00	17.57^{f} ±.01	13.45^{d} ±0.01	13.3^{cd} ±0.01	13^{bc} ±1.00
24H	17^{a} ±1.00	39.95^{g} ±.01	27^{cd} ±1.00	26^{cd} ±1.00	20 ^{b} ±1.00	31^{f} ±1.00	28^{d} ±1.00	27.5^{d} ±.10	24.16^{c} ±.01
48H	20.74^{a} ±.01	41.95^{h} ±.01	30.93^{c} ±.01	30.4^{c} ±.10	27.29^{b} ±.01	38.58^{g} ±.01	36.74^{f} ±.01	32.94^{d} ±.01	30^{c} ±1.0
72H	25.87^{a} ±.01	80.79^{i} ±01	40.08^{e} ±01	38.31^{d} ±01	27.79^{b} ±01	53.42^{j} ±01	50.76^{h} ±01	49.9^{g} ±01	34.32^{c} ±01
	Rate of Hardness increase (RI%)f gluten free Pan Bread								
24H	90.79	122.43	78.8	75.67	42.85	76.43	108.17	106.76	85.84
48H	32.77	33.57	104.83	105.4	94.92	119.57	173.15	147.66	130.76
72H	190.77	349.83	165.43	158.85	98.5	204.04	277.39	275.18	164

*Pan bread samples according to table-1

Color analysis of the gluten-free pan bread prepared from using both chia mucilage and flaxseed mucilage

Color is an important quality attribute of foods and plays a major role in sensory evaluation and consumer acceptance. Table (15) shows crumb lightness (L*). Control 1 (L*=68.50) indicates a light crumb. Among FM samples, FM16% had the lightest crumb (L*=70.59), while among CM samples, CM16% was the best (L*=66.40). Meanwhile, MM16% showed a value (L*=62.99), slightly better than Control 2. These results are consistent with the sensory evaluation and align with (Korus et al., 2015; Hargreaves et al., 2018; Boriy et al., 2021). For the Red-Green Axis (a*), most samples exhibited negative values, indicating a slight greenish hue. The exception was CM16% (a*=1.22), which showed a faint reddish tint, possibly due to the Maillard reaction resulting from the high CM addition level. Mixed mucilage (a*=−1.48) aligned closely with the general trend of mild green dominance, followed by FM16% (a*=−1.46), which was also close to Control 2. These results agree with (Korus et al., 2015). For the Yellow-Blue Axis (b*), all samples displayed positive values, indicating a yellowish hue. The control samples had the highest yellowness (b*=14.16 and 15.09), followed by FM16% (b*=14.33) and MM16% (b*=15.77), which were close to Controls 1 and 2. Among CM samples, CM12% (b*=12.9) was next. These results are consistent with (Korus et al., 2015). Color difference (ΔE*) values, which measure total color deviation from the reference, were highest for FM16% (ΔE*=48.59) and lowest for FM14% (ΔE*=38.29), indicating considerable variation among samples.For crust lightness (L*), the crust was generally darker than the crumb. Control 2 was the lightest (L*=68.16), followed by CM16% (L*=57.21), FM16% (L*=54.10), and MM16% (L*=53.82), which was close to FM16%. For the Red-Green Axis (a*), positive values dominated, indicating a reddish hue. Control 2 (a*=8.10) was followed by CM16% (a*=7.13), while the highest redness was recorded in FM16% (a*=13.02). For the Yellow-Blue Axis (b*), all crust samples exhibited strong yellowness, with b* values ranging from 35.65 to 27.33. FM16% had the highest yellowness (b*=35.65), followed by CM16% (b*=33.66), while MM16% showed the lowest (b*=27.33). These results are in agreement with the hedonic test. Color difference (ΔE*) values for the crust were also high, with FM16% and CM16% showing the largest differences (ΔE*=46.09 and 45.13, respectively). These findings are in line with (Muna et al., 2024) and consistent with sensory evaluation.

Table 15. The color of gluten-free pan bread prepared from using both chia mucilage and flaxseed mucilage

Parameters		*Pan Bread samples								
		Con 1	Con 2	chia mucilage			Mixed Mucilage	Flaxseed mucilage		
				12%	14%	16%	16%	12%	14%	16%
crumb	L*	68.50	61.12	63.946	64.01	66.40	62.99	60.35	66.98	70.59
	α*	-1.92	-1.47	-2.00	-2.12	1.22	-1.48	-0.98	-1.12	-1.46
	b*	14.16	15.09	12.96	11.25	10.38	15.77	12.83	12.40	14.33
	ΔE*	46.57	40.03	41.96	43.70	41.06	42.01	44.68	38.29	48.59
crust	L*	49.63	68.16	52.63	54.00	57.21	53.82	49.16	51.44	54.10
	a *	11.87	8.10	3.84	6.41	7.13	6.59	5.43	5.52	13.02
	b *	32.71	29.00	29.54	31.40	33.66	27.33	28.99	30.44	35.65
	ΔE*	43.73	53.01	44.43	44.95	45.13	41.33	40.72	43.55	46.09

* Pan Bread Samples (According to Table-1)

4. Conclusion

Chia mucilage and flaxseed mucilage have a significantly positive impact on gluten-free pan bread. According to the study, if the goal is to obtain pan bread with good sensory qualities, the best choice would be bread prepared with 14% or 16% flaxseed mucilage. However, if the aim is to achieve a product with a longer shelf life, pan bread prepared with 16% chia mucilage is the best option.

References

A.A.C.C. (2010). Approved methods of the American Association of Cereal chemistry. America association of cereal chemists,Inc, St.Paul.

A.O.A.C. (2012). Official Methods of Analysis Association of Official Analytical Chemists International,19th Ed., Maryland, USA.

Aaliya, B., Navaf, M., and Sunooj, K.V. (2021). Dough Handling Properties of Gluten-Free Breads. *I*n "Gluten-free Bread Technology", pp. 49-70. Springer.

Abd-Elhamid, A.H. (2021). utilization of chia (*salvia hispanica)* seeds product by organic agriculture to produce some speial bakery product., Benha University.

Adam, O.I., Khalid, A., Abdi, A., Yaagoub Erwa, I., Babiker Omer, A.H. Nour, A.J.A.R. and Biology, R.I. (2020). Proximate composition, physicochemical properties and antioxidant activity of flaxseed. 34, 1-10.

Anwar, D., Eid, H., Rashad, S., and Soliman, S.A.J. F.T.R.J. (2024). Nutritional, Physical and Microbiological Properties of Gluten Free Bread with Chia Seed Flour as Alternative Thickening

Agent. 4, 92-106.

Azmoon, E., Saberi, F., Kouhsari, F., Akbari, M., Kieliszek, M., and Vakilinezam, A.J.F. (2021). The effects of hydrocolloids-protein mixture as a fat replacer on physicochemical characteristics of sugar-free muffin cake: Modeling and optimization. 10, 1549.

Barbary, O., Al-Sohaimy, S., El-Saadani, M., and Zeitoun, A.J.J.A.A.R. (2009). Extraction, composition and physicochemical properties of flaxseed mucilage. 14, 605-621.

Bárcenas, M.E., and Rosell, C.M.J.F.H. (2005). Effect of HPMC addition on the microstructure, quality and aging of wheat bread. 19, 1037-1043.

Barreto, A.D., Gutierrez, É.M.R., Silva, M.R., Silva, F.O., Couto, N.O., Lacerda, I.C.A., Labanca, R. A., and Carreira, R.L.J.A.J.O.P.S. (2016). Characterization and Bioaccessibility of Minerals in Seeds of Salvia hispanica L.

Bolandi, M., Shahidi, F., Sedaghat, N., Farhoush, R., and Mousavi-Nik, H. (2008). Shelf-life determination of saffron stigma: water activity and temperature studies.

Boriy, G., Yousef, E.A., and Abd Rabou, E.A.J.A.F. S.J. (2021). Preparation and evaluation of pan bread from chia seeds powder as substitute wheat flour. 20, 1-10.

Borneo, R., Aguirre, A., and Leon, A.E. (2010). Chia (*Salvia hispanica L*) gel can be used as egg or oil replacer in cake formulations. J Am Diet Assoc 110, 946-9.

Burgos-Díaz, C., Rubilar, M., Morales, E., Medina, C., Acevedo, F., Marqués, A.M., Shene, C.J.E. J.O.L.S., and Technology (2016). Naturally occurring protein–polysaccharide complexes from linseed (Linum usitatissimum) as bioemulsifiers. 118, 165-174.

Capitani, M.I., Ixtaina, V.Y., Nolasco, S.M., Tomás, M.C.J.J.O.T.S.O.F., and Agriculture (2013). Microstructure, chemical composition and mucilage exudation of chia (Salvia hispanica L.) nutlets from Argentina. 93, 3856-3862.

Cauvain, S. (2015). Bread: the product. *I*n "Technology of breadmaking", pp. 1-22. Springer.

Cauvain, S. (2015). Other cereals in breadmaking. *I*n "Technology of breadmaking", pp. 377-397. Springer.

Chan, P.N.A. (2015). Chemical Properties and Applications of Food Additives: Flavor, Sweeteners, Food Colors, and Texturizers. *I*n "Handbook of Food Chemistry", pp. 101-129.

Coelho, M.S., de las Mercedes Salas-Mellado, M.J. L.F.S., and Technology (2015). Effects of substituting chia (Salvia hispanica L.) flour or seeds for wheat flour on the quality of the bread. 60, 729-736.

Coelho, M.S., Salas-Mellado, M.D.l.M.J.J.O.F., and Research, N. (2014). Chemical characterization of chia (Salvia hispanica L.) for use in food products. 2, 263-269.

Davidou, S., Le Meste, M., Debever, E., and Bekaert, D.J.F.H. (1996). A contribution to the study of staling of white bread: effect of water and hydrocolloid. 10, 375-383.

De Lamo, B., and Gómez, M.J.F. (2018). Bread enrichment with oilseeds. A review. 7, 191.

Demirkesen, I., Mert, B., Sumnu, G., and Sahin, S.J. J.O.F.E. (2010). Rheological properties of gluten-free bread formulations. 96, 295-303.

Emerson, R.J.C.D.A.G.T.L.W.G.I., Three Rivers Press, Inc., New York (2006). Eating and baking gluten-free. 59-69.

Farrell, R. J., and Kelly, C.P.J.N.E.J.O.M. (2002). Celiac sprue. 346, 180-188.

Fernandes, S. S., and de las Mercedes Salas-Mellado, M. J. F. c. (2017). Addition of chia seed mucilage for reduction of fat content in bread and cakes. 227, 237-244.

Fernandes, S.S., Filipini, G., and de las Mercedes Salas-Mellado, M.J.F.B. (2021). Development of cake mix with reduced fat and high practicality by adding chia mucilage. 42, 101148.

Fernandes, S.S., and Salas-Mellado, M.L. (2017). Addition of chia seed mucilage for reduction of fat content in bread and cakes. Food Chem 227, 237-244.

Ganguly, S., Panjagari, N.R., and Raman, R.K. (2021). Flaxseed (Linum usitatissimum). *I*n "Oilseeds: Health Attributes and Food

Applications", pp. 253-283. Springer.

González, L.C., Barreto, C.I.Á., and Tolaba, M.P.J.F. B. (2025). Effect of different hydrocolloids on the quality and aging of gluten-free bread based on pre-hydrated rice grains. 106857.

Hargreaves, S.M., Zandonadi, R.P.J.J.O.C.S., and Technology (2018). Flaxseed and chia seed gel on characteristics of gluten-free cake. 16, 378-388.

Hassan, E.M., Fahmy, H.A., Magdy, S., and Hassan, M.I.J.E.J.O.C. (2020). Chemical composition, rheological, organoleptical and quality attributes of gluten-free fino bread. 63, 4547-4563.

Hernandez, L.M. (2012). "Mucilage from chia seeds (Salvia hispanica): Microestructure, physico-chemical characterization and applications in food industry," Pontificia Universidad Catolica de Chile (Chile).

James, C. (1995). General food studies. *I*n "Analytical Chemistry of Foods", pp. 137-171. Springer.

Jyotsna, R., Prabhasankar, P., Indrani, D., and Rao, G. V.J.J.O.F.S. (2004). Improvement of rheological and baking properties of cake batters with emulsifier gels. 69, SNQ16-SNQ19.

Kadhim AL-Zurfi, Z.A., and Hasan Al-Obaidi, L. F. J.K.J.F.A.S. (2025). Extraction of gum from Chia seeds and study of its chemical Composition and its Antibacterial ability. 17.

Kassem, I.A., Ashaolu, T.J., Kamel, R., Elkasabgy, N. A., Afifi, S.M., Farag, M.A.J.F., and function (2021). Mucilage as a functional food hydrocolloid: ongoing and potential applications in prebiotics and nutraceuticals. 12, 4738-4748.

Kohajdová, Z., and Karovičová, J. (2009). Application of hydrocolloids as baking improvers. Chemical Papers 63.

Kohajdová, Z., and Karovičová, J.J.C.P. (2009). Application of hydrocolloids as baking improvers. 63, 26-38.

Korus, J., Witczak, T., Ziobro, R., Juszczak, L.J.L.F. S., and Technology (2015). Linseed (Linum usitatissimum L.) mucilage as a novel structure forming agent in gluten-free bread. 62, 257-264.

Kučka, M., Harenčár, Ľ., Ražná, K., Nôžková, J., Kowalczewski, P.Ł., Deyholos, M., Dziedzic, K., Rybicka, I., Zembrzuska, J., Kačániová, M.J.E. F.R., and Technology (2024). Great potential of flaxseed mucilage. 250, 877-893.

Kulp, K., Hepburn, F., and Lehmann, T.J.B.D. (1974). Preparation of bread without gluten. 48, 34-37.58.

Lee, K.-H., Wu, T.Y., Siow, L.F.J.I.J.O.F.S., and Technology (2013). Spray drying of red (Hylocereus polyrhizus) and white (Hylocereus undatus) dragon fruit juices: Physicochemical and antioxidant properties of the powder. 48, 2391-2399.

Lu, W., Li, X., and Fang, Y. (2021). Introduction to Food Hydrocolloids. *I*n "Food Hydrocolloids", pp. 1-28. Springer.

Mansour, A., Elgammal, R.E., Rabie, M., El Bana, M. J.J.O.F., and Sciences, D. (2024). Physicochemic-al Characteristics and Grain Quality of Novel Egyptian Rice Cultivars. 15, 115-121.

Mohammed, O.B., El-Razek, A., Mohamed, A., Bekhet, M.H., and Moharram, Y.G.E.D.J.E.J.O. F.S. (2019). Evaluation of Egyptian Chia (Salvia hispanica L.) Seeds, Oil and Mucilage as Novel Food Ingredients. 47, 11-26.

MONA, D. (2006). Production and evaluation of gluten free cake. Bull.Fac.Agri.,Caieo Universty 57, 665-684.

Mostafa, S. (2014). Production and evaluation of some functional foods for celiac patients, M. Sc. Thesis, Food Sci. Dept., Fac. of Agric., Cairo Univ.

Muna, S., Akmalia, D., Noviasari, S., Safriani, N., and Muzaifa, M. (2024). Effect of hydrocolloid type on physicochemical and sensory characteristics of gluten-free white bread. *In* "IOP Conference Series: Earth and Environmental Science", Vol. 1356, pp. 012018. IOP Publishing.

Muñoz, L., Cobos, A., Diaz, O., and Aguilera, J.J.J. O.F.E. (2012). Chia seeds: Microstructure, mucilage extraction and hydration. 108, 216-224.

Nada, F. A., and Hasan, S.K.J.S. (2015). Preparation and evaluation of gluten free pan bread and noodles. 5, 1273-1286.

Ngemakwe, P.H., Le Roes-Hill, M., and Jideani, V. A. (2015). Advances in gluten-free bread technology. Food Sci Technol Int 21, 256-76.

Nilsson, B.L., Soellner, M.B., and Raines, R.T. (2005). Chemical synthesis of proteins. Annu Rev Biophys Biomol Struct 34, 91-118.

Park, J.H., Kim, D.C., Lee, S.E., Kim, O.W., Kim, H., Lim, S.T., Kim, S.S.J.F.S., and Biotechnology (2014). Effects of rice flour size fractions on gluten free rice bread. 23, 1875-1883.

Peiretti, P., Gai, F.J.A.F.S., and Technology (2009). Fatty acid and nutritive quality of chia (Salvia hispanica L.) seeds and plant during growth. 148, 267-275.

Phillips, G.O., and Williams, P.A. (2009). "Handbook of hydrocolloids," Elsevier.

Qian, K., Cui, S., Wu, Y., and Goff, H.J.F.H. (2012). Flaxseed gum from flaxseed hulls: Extraction, fractionation, and characterization. 28, 275-283.

Reyes-Caudillo, E., Tecante, A., and Valdivia-López, M.J.F.C. (2008). Dietary fibre content and antioxidant activity of phenolic compounds present in Mexican chia (*Salvia hispanica L.*) seeds. 107, 656-663.

Roman, L., Belorio, M., and Gomez, M. (2019). Gluten-Free Breads: The Gap Between Research and Commercial Reality. 18, 690-702.

Sabanis, D., and Tzia, C. ((2011)). Effect of hydrocolloids on selected properties of gluten-free dough and bread. Food Sci Technol Int 17, 279-91.

Schuppan, D., Junker, Y., and Barisani, D.J.G. ((2009)). Celiac disease: from pathogenesis to novel therapies. 137, 1912-1933.

Sciarini, L.S., Ribotta, P.D., León, A.E., Pérez, G.T. J. I.J.O.F.S., and technology (2010). Effect of hydrocolloids on gluten-free batter properties and bread quality. 45, 2306-2312.

Segura-Campos, M.R., Chel-Guerrero, L.A., and Betancur-Ancona, D.A. (2016). Salvia hispanica: Nutritional and functional potential. In "Functional Properties of Traditional Foods", pp. 115-118. Springer.

Tehseen, S. (2013). Phytic Acid In Relation To Minerals Availability At Different Extraction Rates of Wheat Flour, University of Agriculture Faisalabad, Pakistan.

Thompson, T., Dennis, M., Higgins, L., Lee, A., Sharrett, M.J.J.O.H.N., and dietetics (2005). Gluten-free diet survey: are Americans with coeliac disease consuming recommended amounts of fibre, iron, calcium and grain foods? 18, 163-169.

Williams, P.A., and Phillips, G.O. (2021). Introduction to food hydrocolloids. *I*n "Handbook of hydrocolloids", pp. 3-26. Elsevier.

Zettel, V., Hitzmann, B.J.T.I.F.S., and Technology (2018). Applications of chia (Salvia hispanica L.) in food products. 80, 43-50.

Zyada, M., Elgharably, A., Yousef, E.E., and Saleh, M.J.E.J.O.C. (2025). Influence of Partial Substitution of Wheat Flour with Chia Seeds Powder on Dough Rheology and Quality Attributes of Pan Bread. 68, 291-309.