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Effect of basil seed gum concentration on the physical, textural and sensory properties of quinoa pancakes

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A R T I C L E I N F O

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Yellowness index.

A B S T R A C T

Recent studies have highlighted the potential of hydrocolloids to enhance the appearance, texture, and sensory attributes of gluten-free products. Accordingly, the present study aimed to investigate the effect of basil seed gum addition on the quality characteristics of quinoa pancakes. Incorporating basil seed gum (BSG) at concentrations ranging from 0 to 0.75% significantly influenced the physical, rheological, and sensory properties of quinoa pancakes. Batter viscosity increased with gum addition, rising from 5.0 Pa•s in the control to 19.1 Pa•s at 0.75% BSG (10 RPM), while maintaining shear-thinning behavior. Batter lightness decreased from 73.57 to 69.45, redness shifted towards zero (–3.95 to –1.44), and yellowness increased from 30.71 to 36.28. In baked pancakes, internal lightness increased to 63.11 at 0.75% BSG, while internal yellowness decreased from 39.04 to 34.11. Product moisture content and weight increased significantly, rising from 32.1% to 39.0% and from 11.3% to 13.41%, respectively, while baking loss decreased significantly from 24.5% to 10.6% with increasing levels of gum ($p<0.05$). Pancake volume ranged from 11.8 to 17.1 cm^3, while density declined from 962.3 to 783.7 kg/m^3 with rising gum concentrations. Crust hardness increased from 0.20 N in the control to 0.31 N at 0.75% BSG. Sensory evaluation revealed that appearance (8.85), aroma (7.25), flavor (7.65), and overall acceptance (8.20) peaked at 0.25% BSG, whereas texture acceptance reached its highest value (8.90) at 0.75%. Overall, moderate BSG addition (0.25%) increases the sensory acceptance of the product by the consumer and improving product quality.

1. Introduction

Gluten-related disorders, such as celiac disease and wheat allergy, have become prominent global health concerns, driving increased scientific and commercial focus on gluten-free product development. This has intensified research aimed at enhancing the nutritional, sensory, and technological qualities of gluten-free foods to meet both medical and consumer demands [1-3]. Despite the increasing demand for gluten-free products, many still exhibit inferior sensory qualities such as texture, flavor, and appearance, due to the absence of gluten, which is essential for structure and mouthfeel in baked goods. Consequently, significant research has focused on developing gluten-free pancake formulations that replicate the sensory attributes of traditional products while fulfilling nutritional and functional requirements [4-7].

Pancakes are a widely consumed staple in many cultures, valued for their simplicity, versatility, and rapid preparation. Typically made from a batter consisting of flour, eggs, milk, and a leavening agent, pancakes offer a soft and tender texture that can be adapted through various ingredients and processing techniques [5, 8, 9].

Quinoa (*Chenopodium quinoa* Willd.) is a nutrient-rich pseudocereal from the Andes, valued for its high-quality protein, fiber, vitamins, and minerals [10]. Naturally gluten-free, quinoa is increasingly used in gluten-free formulations to enhance texture, moisture retention, and overall quality of baked products, making it a key ingredient in nutritious gluten-free foods [4, 11]. Vejdanivahid and Salehi [4] investigated pancakes made with sprouted quinoa flour and reported improved phenolic content, antioxidant capacity, and sensory properties. Their results support the use of sprouted quinoa flour in gluten-free formulations for enhanced nutritional and sensory quality.

Hydrocolloids, commonly referred to as gums, are a class of food additives comprising high-molecular-weight hydrophilic biopolymers. When incorporated into baked products, they regulate water absorption, thereby enhancing dough rheology, extending shelf life through moisture retention, and delaying the onset of staling [3, 12, 13]. Hydrocolloids can substantially enhance the textural and sensory attributes of gluten-free products by improving structural integrity, promoting moisture retention, and contributing to a more desirable overall mouthfeel [3, 14-17]. BSG is a naturally occurring hydrocolloid that can be utilized in diverse food applications to improve textural characteristics, enhance

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product stability, extend shelf life, and contribute to desirable sensory qualities [3, 18-21]. Peighambardoust *et al.* [19] investigated the influence of BSG on the physical attributes, sensory characteristics, and staling behavior of sponge cake. Their findings indicated that the formulation containing 0.5% BSG achieved significantly greater sensory acceptability compared to the control sample. The findings of Asgari Verjani *et al.* [18] demonstrated that incorporating BSG into the formulation of low-fat chocolate cake enhances the product's overall consumer acceptability.

Recent research has recommended the incorporation of hydrocolloids and natural gums to enhance the structural integrity, sensory quality, and overall acceptance of gluten-free products [3, 18, 19]. Therefore, this study aimed to evaluate the effects of varying BSG concentrations (0.0–0.75%) on the physical, textural, color, and sensory properties of gluten-free pancakes made with quinoa flour. Key parameters included batter viscosity, moisture content, volume, and consumer acceptance to identify the optimal BSG concentration for balanced technological and sensory quality.

2. Materials and methods

2.1. Materials

Quinoa seeds (OAB, Iran), vanilla (Golha, Iran), baking powder (Golestan, Iran), sugar (Mojeze, Iran), pasteurized full fat milk (3.4% fat, Damdaran, Iran), fresh eggs (Telavang, Iran), and oil (Famila, Iran) used in pancake preparation were procured from local markets in Hamedan, Iran. The quinoa seeds were milled using an industrial grinder produced by Best Company (China). BSG was extracted and dried according to the method of Salehi and Inanloodoghouz [22], then ground into a fine powder.

2.2. Pancake preparation

Based on a comprehensive literature review and experimental trials, an optimal gluten-free pancake formulation was developed, comprising 26.62% quinoa powder, 0.38% vanilla, 1.52% baking powder, 9.51% sugar, 38.02% pasteurized full-fat milk, 21.62% fresh egg, and 2.28% oil. Initially, the dry ingredients were thoroughly mixed and sifted. The eggs were beaten with an electric mixer for 3 min. The liquid ingredients (milk and oil) were added and mixed. The dry ingredients were added to the mixture and mixing continued for 5 min. The prepared batter was allowed to rest at room temperature for 10 min. For baking, the pan was heated to 170-180°C, and 13 g of batter was baked in the pan for 2 min until bubbles appeared on the surface of the pancake, then the other side of the pancake was baked for another 1 min. After cooling, the baked pancakes were packaged and stored in moisture and oxygen resistant polyethylene containers. The cooking temperature was measured with a digital thermometer. BSG was used to replace oil at four levels of 0.0%, 0.25%, 0.5%, and 0.75%, on a percentage basis, ensuring that the proportions of the other ingredients remained constant across all formulations.

2.3. Evaluation of pancake batter viscosity

The apparent viscosity of the pancake batter was evaluated using a rotational viscometer (Brookfield DV2T, RV model, USA) fitted with spindle RV-06. Measurements were taken at varying spindle rotation speeds of 5, 10, and 15 revolutions per minute (RPM) over a duration of 0 to 120 seconds to assess the batter's flow behavior. All viscosity tests were performed at a controlled temperature of 25°C to ensure consistency and accuracy of the results.

2.4. Color parameters determination

Image processing techniques were utilized to evaluate the color parameters of the pancake batter, as well as the crust (outer layer) and crumb (inner portion) of the pancakes. Photographs of the samples were taken using a 48-megapixel camera (iPhone 15 Pro Max, Apple Co., China) (Fig. 1.). The captured images were then analyzed by converting the RGB color space to L^*, a^*, and b^* values using ImageJ software (version 1.42e, USA) with a specialized plugin [23].

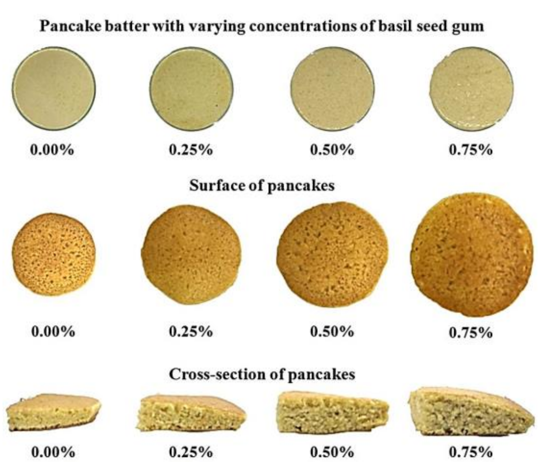


Fig. 1. Visual and color differences in quinoa-based pancake batter and baked pancakes at varying basil seed gum concentrations (0 to 0.75%)

2.5. Moisture content determination

The moisture content of the pancake samples was determined using a digital moisture analyzer (DBS60-3, Kern, Germany). Each sample was weighed and analyzed under controlled conditions, and the results were automatically calculated and reported by the device as a percentage of moisture based on weight loss during drying.

2.6. Weight and baking loss determination

The weight of the pancakes was measured using a digital balance (GM-300p, Lutron, Taiwan) with a precision of 0.01 g. The baking loss of pancakes was determined according to the method described by Vejdanivahid and Salehi [4], using the following formula: Baking loss (%) = [(mass of pancake batter before baking − mass of baked pancake) / mass of pancake batter before baking] × 100."

2.7. Volume and density determination

The volume of the baked pancakes was measured using the canola seed displacement method, whereby the volume of canola seeds displaced by the pancake sample was recorded in a graduated container to accurately determine the sample's volume. Subsequently, the density of the baked pancakes was calculated according to the procedure outlined by Amin Ekhlas *et al.* [24], which involves dividing the sample's mass by its measured volume to provide an accurate assessment of its physical properties.

2.8. Puncture test

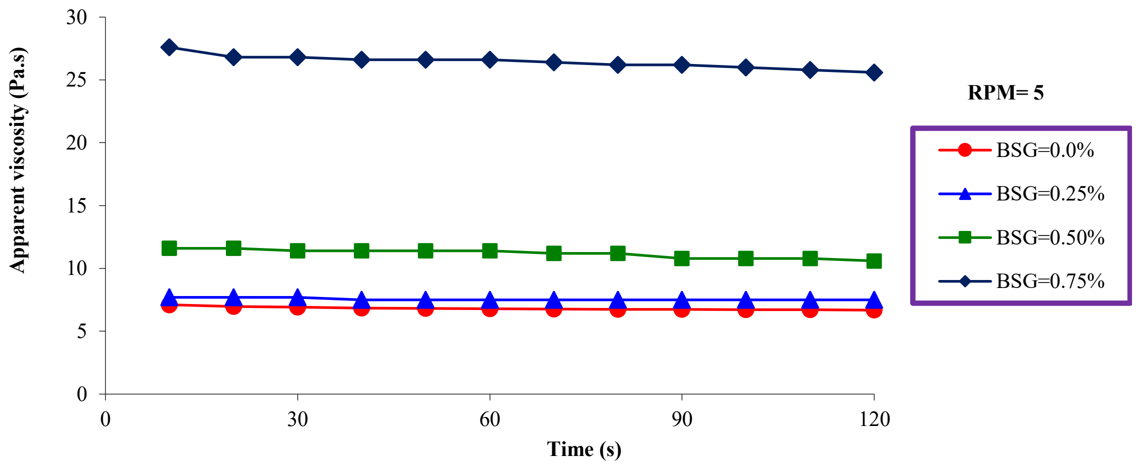
The crust hardness of the pancake samples was evaluated through a puncture test performed using a texture analyzer (Santam, STM-5, Iran). A cylindrical probe with a diameter of 0.5 cm was utilized, applying a consistent penetration speed of 0.1 cm/s until reaching a depth of 1 cm. This method allowed precise measurement of the resistance of the pancake crust to deformation, providing an objective assessment of texture hardness.

2.9. Sensorial evaluation of pancake

The sensory analysis was carried out at the Laboratory of New Technologies, Bu-Ali Sina University. A panel consisting of 20 individuals, representing a diverse range of age groups, was carefully selected to evaluate the sensory attributes of the pancake samples. The assessment criteria encompassed multiple dimensions of quality, including appearance, aroma, flavor, texture, and overall acceptability. Panelists were provided with standardized evaluation forms and instructed to score each attribute using a structured scale to ensure consistency and reliability of the sensory evaluation.

2.10. Statistical analysis

All measurements were performed in triplicate to ensure the reliability and reproducibility of the data, and the results are presented as mean values accompanied by their corresponding standard deviations. Statistical analysis was conducted using one-way analysis of variance (ANOVA) implemented through SPSS software (version 21; SPSS Inc., Chicago, IL, USA) to determine significant differences among treatment groups. For post hoc comparisons, Duncan's multiple range test was applied, with statistical significance established at a confidence level of $p < 0.05$.



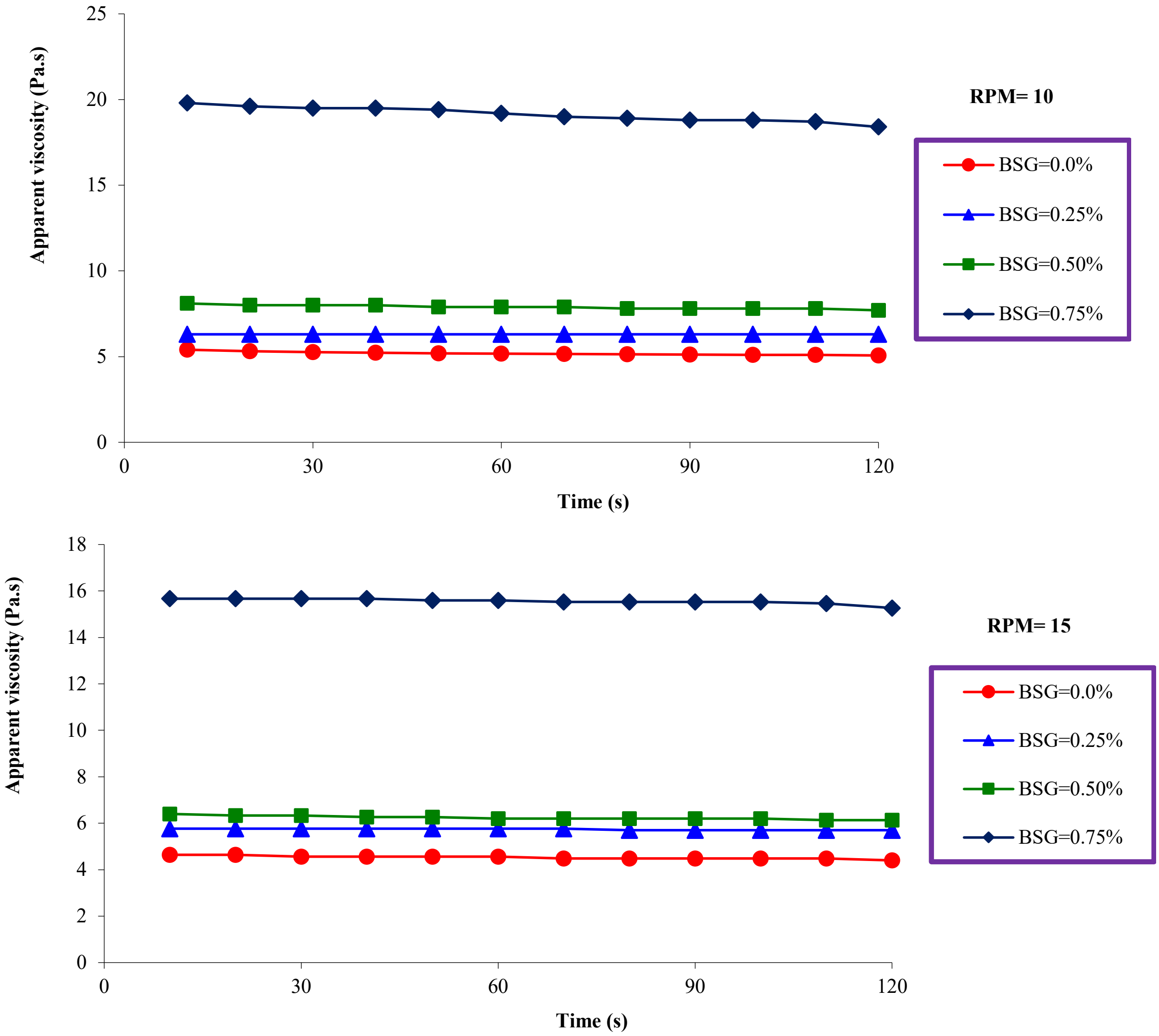


Fig. 2. Influence of basil seed gum (BSG) levels and spindle rotation speed (RMP) on the apparent viscosity of quinoa-based pancake batter

3. Results and discussion

3.1. Effect of BSG on pancake batter viscosity

Fig. 2. illustrates the influence of BSG levels (ranging from 0 to 0.75%) and spindle rotation speed (ranging from 5 to 15 RPM) on the apparent viscosity of quinoa-based pancake batter. As spindle speed increased, corresponding to higher shear rates, a marked decrease in apparent viscosity was recorded. This shear-thinning behavior reflects the pseudoplastic nature of the batter, which is a typical characteristic of many non-Newtonian food systems. Notably, this rheological trend was consistent across all formulations, regardless of BSG concentration. This indicates that while BSG enhances batter viscosity, it does not fundamentally alter the batter's flow behavior, maintaining its pseudoplastic properties across varying shear conditions. Asgari Verjani *et al.* [18] also demonstrated that increasing the concentration of BSG results in a higher viscosity of chocolate cake batter.

Fig 3. illustrates the influence of different concentrations of BSG on the apparent viscosity of pancake batter across varying spindle rotation speeds. The results indicate that increasing the BSG level led to a proportional rise in the batter's apparent viscosity, reflecting its role as a hydrocolloid in thickening the mixture. The results demonstrated that increasing BSG concentrations from 0.00% to 0.75% led to a significant rise in batter viscosity, increasing from 5.0 to 19.1 Pa·s at a spindle speed of 10 RPM. This substantial increase confirms the effective thickening capability of BSG in gluten-free batter formulations. In a study by Ghaemi et al. [20], the effects of incorporating whey protein concentrate and soy protein isolate, in combination with BSG, on certain dough quality attributes and the quality characteristics of gluten-free rice flour-based cakes were investigated. The results indicated that increasing the concentration of BSG significantly enhanced the consistency and adhesiveness of the cake batter.

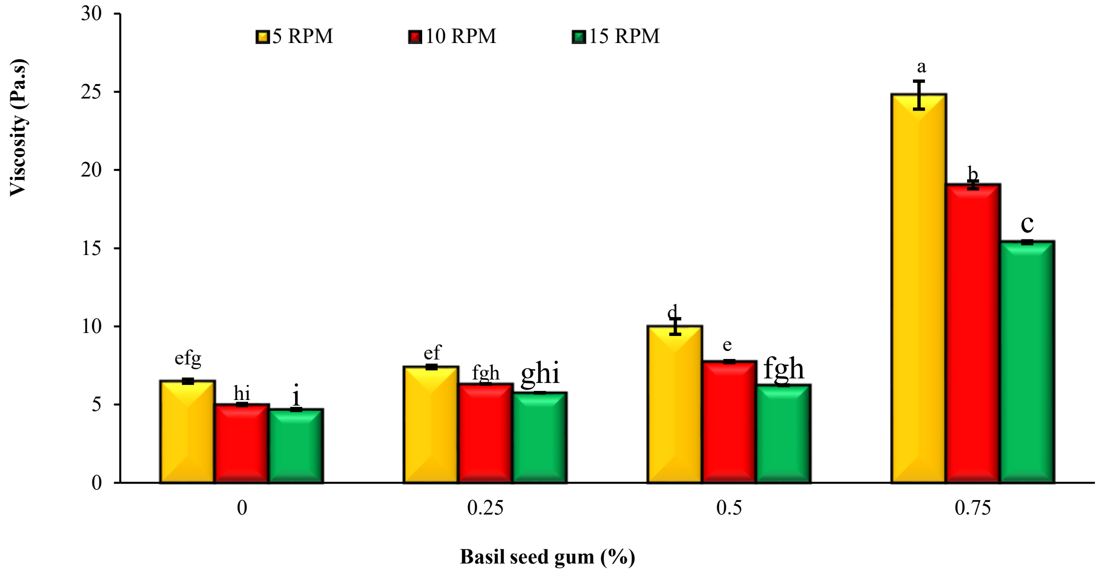


Fig. 3. Impact of basil seed gum concentration on the apparent viscosity of quinoa-based pancake batter
Distinct letters above the columns denote statistically significant differences at the p<0.05 level.

3.2. Effect of BSG on the color indexes of pancake batter

The results presented in Table 1 indicate that increasing BSG concentration significantly affected the color parameters of quinoa-based pancake batter ($p<0.05$). Lightness (L*) showed a progressive decline from 73.57 in the control sample to 69.45 at 0.75% gum, revealing a darker batter with higher gum levels. Redness (a*) values also increased towards zero with gum addition, shifting the color from a more negative (greenish) tone in the control (–3.95) to a less negative value at 0.75% gum (–1.44). Similarly, yellowness (b*) increased significantly from 30.71 in the control to 36.28 at 0.75% gum, suggesting a more intense yellow hue. These changes could be attributed to the gum's interaction with batter components and pigment dispersion, ultimately modifying the visual appearance of the batter.

Table 1. Impact of basil seed gum concentration on the color indexes of quinoa-based pancake batter

Basil seed gum (%)	Lightness	Redness	Yellowness
0.00%	73.57±0.54 a	-3.95±0.10 d	30.71±0.51 c
0.25%	71.89±0.09 b	-3.11±0.07 c	34.08±0.43 b
0.50%	69.74±0.87 c	-2.71±0.04 b	35.75±0.06 a
0.75%	69.45±0.86 c	-1.44±0.03 a	36.28±0.55 a

Data are shown as mean ± standard deviation (N = 3). Distinct letters within the columns denote statistically significant differences at the p<0.05 level.

3.3. Effect of BSG on color indices of pancakes

The data in Table 2 demonstrate that BSG concentration significantly influenced the crust and crumb color parameters of quinoa-based pancakes ($p<0.05$). Lightness values for the crust remained relatively stable across treatments, ranging from 48.12 to 49.90, while crumb lightness increased slightly with higher gum levels, reaching the highest value (63.11) at 0.75% gum. Redness values for the crust increased from 8.79 in the control to a peak of 9.19 at 0.50% gum before slightly decreasing, whereas crumb redness shifted from negative values in the control (–0.72) towards positive values (0.32) at the highest gum level, indicating a transition from greenish to reddish tones. Yellowness in the crust showed minimal variation, with values between 36.70 and 40.39, while crumb yellowness decreased progressively from 39.04 in the control to 34.11 at 0.75% gum. These results suggest that BSG modifies both surface and internal coloration, likely due to its impact on moisture retention, pigment distribution, and Maillard browning during baking.

Table 2. Impact of basil seed gum concentration on the color indexes of quinoa-based pancakes

Basil seed gum (%)	Lightness		Redness		Yellowness	
	Crust	Crumb	Crust	Crumb	Crust	Crumb
0.00%	49.90±0.54 a	60.54±1.11 b	8.79±0.14 ab	-0.72±0.15 a	38.76±0.48 b	39.04±0.76 a
0.25%	49.26±0.55 a	61.90±0.29 ab	8.95±0.42 a	-0.38±0.82 a	40.39±0.28 a	37.50±0.37 b
0.50%	48.99±1.33 a	62.78±1.06 a	9.19±0.16 a	0.21±0.21 a	36.70±0.77 c	34.31±0.77 c
0.75%	48.12±1.98 a	63.11±0.88 a	8.25±0.19 b	0.32±0.21 a	39.42±0.86 ab	34.11±0.18 c

Data are shown as mean ± standard deviation (N = 3). Distinct letters within the columns denote statistically significant differences at the p<0.05 level.

3.4. Effect of BSG on pancake moisture content

Gums enhance the water absorption capacity of the crumb owing to their hydrophilic nature, which is likely attributable to the presence of hydroxyl groups within their molecular structure that can form hydrogen bonds with water molecules [19]. Fig.4. illustrates the impact of varying BSG levels (0–0.75%) on the moisture content of pancakes. Increasing the concentration of BSG led to a gradual increase in moisture content, ranging from 32.1% in the control sample (0% gum) to 39.0% at the highest concentration of BSG (0.75% gum). The addition of BSG, particularly at higher concentrations, led to a noticeable increase in the moisture content of the product, likely due to its strong water-binding and retention properties.

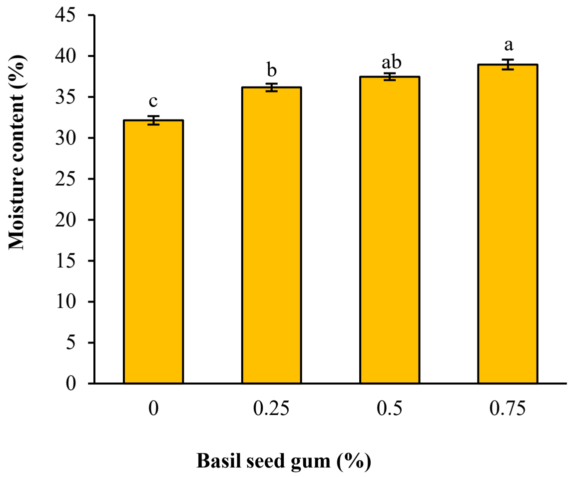


Fig. 4. Impact of basil seed gum concentration on the moisture content of quinoa-based pancakes
Distinct letters above the columns denote statistically significant differences at the p<0.05 level.

3.5. Effect of BSG on pancake weight and baking loss

Fig 5. illustrates the effect of varying BSG concentrations on the weight and baking loss of quinoa-based pancakes. As shown in Fig.5a., the addition of BSG led to a statistically significant increase in pancake weight ($p < 0.05$). The control sample (0% BSG) had the lowest weight, while the sample with 0.75% BSG exhibited the highest weight. This trend may be attributed to the superior water-holding capacity of BSG, which reduces moisture evaporation during baking, resulting in higher final product weight.

Similarly, Fig.5b. shows that baking loss decreased significantly with increasing BSG concentration ($p < 0.05$). The control sample had the highest baking loss, while the lowest loss was observed at 0.75% BSG. This reduction is likely due to BSG's ability to retain water within the matrix, thereby minimizing moisture loss during the baking process.

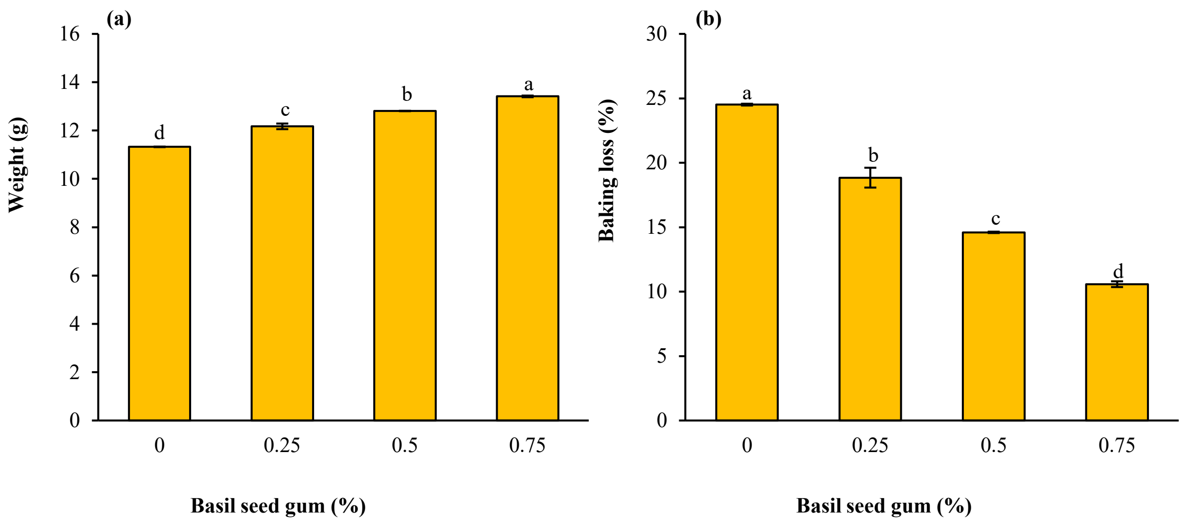


Fig. 5. Impact of basil seed gum concentration on the weight (a) and baking loss (b) of quinoa-based pancakes
Distinct letters above the columns denote statistically significant differences at the p<0.05 level.

3.6. Effect of BSG on pancake volume and density

Fig. 6. illustrates the effect of BSG concentration on the volume and density of pancakes made with quinoa powder. The volume of the baked pancakes increased with rising BSG concentrations (Fig. 6a.). The highest volume was recorded in the sample containing 0.75% BSG, which differed significantly from the control sample ($p< 0.05$).

As the concentration of BSG increased, the density of the baked pancakes decreased (Fig. 6b.), attributed to the corresponding increase in pancake volume. The lowest density was observed in the sample containing 0.75% BSG, which was significantly different from the control sample ($p < 0.05$). The pancake volumes observed in this study ranged from 11.8 to 17.1 cm^3, while the corresponding densities varied from 783.7 to 962.3 kg/m^3. Consistent with the findings of the present study, Asgari Verjani *et al.* [18] reported that increasing the concentration of BSG in chocolate cake formulations leads to a reduction in the product's density.

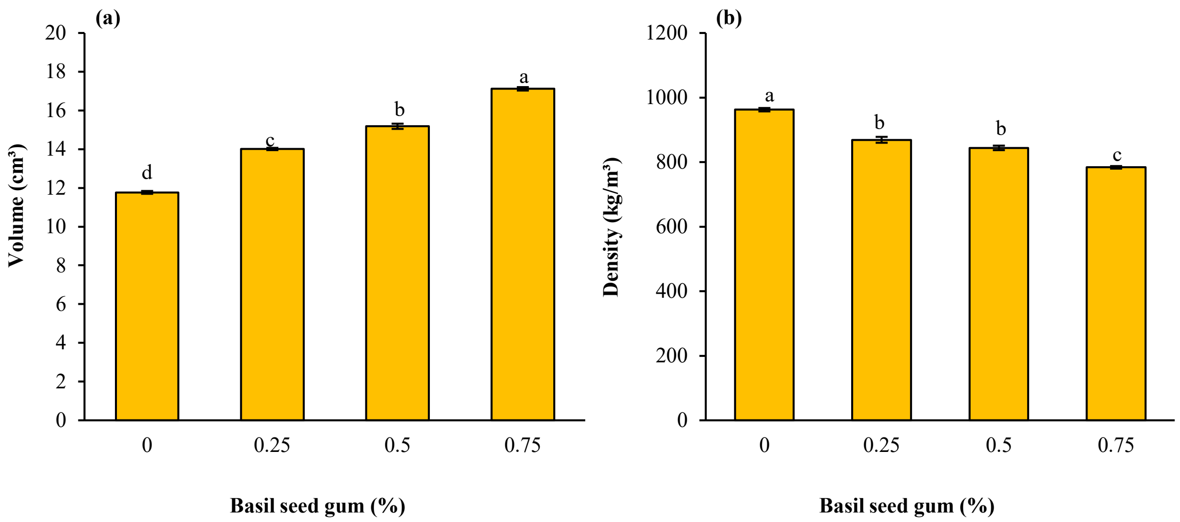


Fig. 6. Impact of basil seed gum concentration on the volume (a) and density (b) of quinoa-based pancakes
Distinct letters above the columns denote statistically significant differences at the $p<0.05$ level.

3.7. Effect of BSG on pancake crust hardness

The crust hardness of pancakes was significantly influenced by the level of BSG incorporated into the formulation ($p < 0.05$). As shown in Fig.7., increasing the concentration of BSG from 0% to 0.75% led to a progressive increase in crust hardness. The control sample exhibited the lowest hardness value (0.20 N), while the highest value (0.31 N) was observed for the 0.75% BSG level. These findings align with previous reports indicating that gums, due to their rheological properties, contribute to structural reinforcement and improved crust texture in gluten-free baked products [3]. Consistent with the findings of the present study, Peighambardoust *et al.* [19] reported that a higher proportion of BSG in cake formulations leads to an increase in the firmness of the product's texture. Ghaemi *et al.*'s [20] findings further demonstrated that increasing the concentration of BSG led to higher porosity and enhanced firmness in gluten-free cakes.

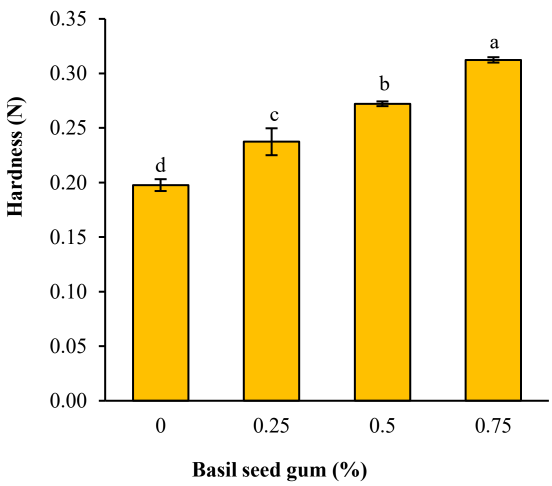


Fig. 7. Impact of basil seed gum concentration on the crust hardness of quinoa-based pancakes
Distinct letters above the columns denote statistically significant differences at the $p<0.05$ level.

3.8. Sensory evaluation of quinoa-based pancakes with BSG

The results presented in Table 3 indicate that BSG concentration had a significant influence ($p < 0.05$) on the sensorial attributes of quinoa-based pancakes. Appearance scores were highest at 0.25% gum addition (8.85), surpassing the control (7.90), and declined slightly at higher concentrations. Aroma acceptance remained relatively stable between the control (7.15) and 0.25% (7.25), but decreased markedly at 0.50% (6.10) and 0.75% (5.75). Flavor acceptance followed a similar pattern, peaking at 0.25% (7.65) and declining thereafter. Texture acceptance improved with gum incorporation (Fig.8.), with the highest scores observed at 0.75% (8.90), indicating a positive impact on mouthfeel and structural properties. Overall acceptance was highest at 0.25% (8.20), reflecting the combined effects of favorable appearance, aroma, flavor, and texture at this concentration. However, excessive gum addition (≥0.50%) reduced appearance, flavor and aroma scores, possibly due to alterations in crumb structure or mouth-coating effects. These findings suggest that moderate BSG levels (around 0.25%) optimize consumer acceptability, while higher concentrations may negatively affect sensory balance despite improving texture. Ghaemi *et al.* [20] reported that the incorporation of BSG enhances the sensory attributes of the product and recommended using 0.5–1% BSG for the preparation of gluten-free rice flour-based cakes containing soy protein isolate or whey protein concentrate, as a suitable alternative to conventional cakes for individuals with celiac disease.

Table 3. Effect of basil seed gum concentration on the sensorial attributes of quinoa-based pancakes

Basil seed gum (%)	Appearance acceptance	Aroma acceptance	Flavor acceptance	Texture acceptance	Overall acceptance
0.00%	7.90 ^{b}	7.15 ^{a}	7.40 ^{a}	7.10 ^{c}	7.60 ^{b}
0.25%	8.85 ^{a}	7.25 ^{a}	7.65 ^{a}	8.35 ^{b}	8.20 ^{a}
0.50%	8.25 ^{b}	6.10 ^{b}	6.35 ^{b}	8.85 ^{a}	7.15 ^{bc}
0.75%	8.25 ^{b}	5.75 ^{b}	5.90 ^{b}	8.90 ^{a}	6.80 ^{c}

Data are shown as mean ± standard deviation (N = 20). Distinct letters within the columns denote statistically significant differences at the p<0.05 level.

4. Conclusions

This study demonstrated that BSG is an effective hydrocolloid for improving the structural, textural, and certain sensory attributes of gluten-free quinoa-based pancakes. Its high molecular weight and water-binding capacity enhanced batter viscosity, reduced baking loss, and increased final product weight. The gum also contributed to greater pancake volume and reduced density, reflecting improved gas retention during baking. Additionally, BSG modified color attributes in both batter and baked products, likely through pigment dispersion and moisture retention effects, influencing the visual appeal of the pancakes.

From a sensory perspective, a clear trade-off emerged between structural improvements and flavor-related attributes. While higher BSG levels (0.75%) yielded superior texture scores and enhanced moisture retention, they also led to diminished aroma and flavor acceptance, possibly due to alterations in mouthfeel or matrix interactions affecting flavor release. The optimal sensory balance was observed at 0.25% BSG, which delivered the highest overall acceptance (8.20), combining appealing appearance, favorable flavor, and acceptable texture.
The findings confirm that controlled incorporation of BSG can address key quality challenges in gluten-free bakery products, particularly by enhancing texture, volume, and moisture retention. However, excessive use may negatively influence certain sensory attributes. Therefore, a formulation strategy targeting moderate BSG levels (around 0.25%) is recommended to maximize consumer satisfaction while leveraging its functional benefits. This research provides valuable insights into the application of natural seed gums in gluten-free product development and supports their potential as clean-label, functional ingredients for improving bakery product quality.

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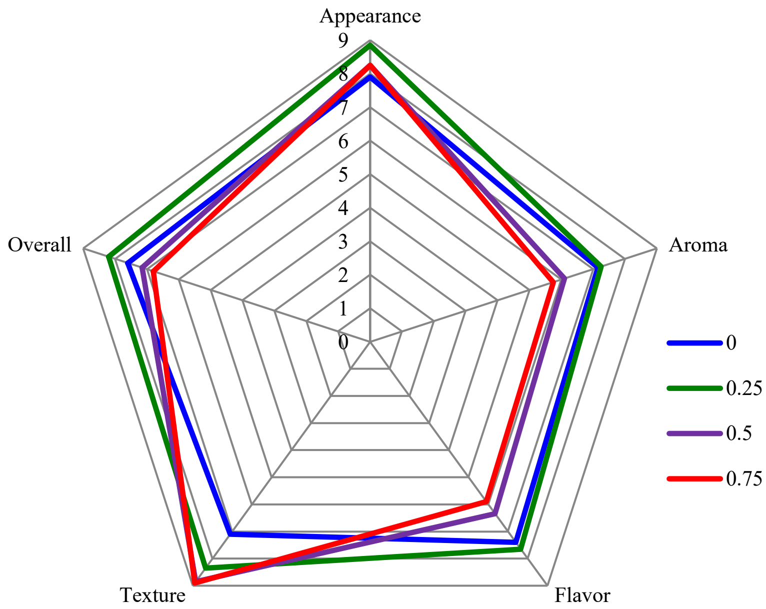

Fig. 8. Impact of basil seed gum concentration on the sensory properties of quinoa-based pancakes (Data are shown as mean, N = 20).

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