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Effect of guar gum on batter viscosity and the physical, textural, and sensory properties of gluten-free pancakes based on Quinoa powder

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ABSTRACT

Quinoa, a nutrient-rich and naturally gluten-free pseudocereal, offers great potential for developing healthier bakery products. Incorporating hydrocolloids like guar gum can enhance their volume, texture, and sensory attributes. Accordingly, this study aimed to evaluate the effect of incorporating different levels of guar gum (0.00%, 0.25%, 0.50%, and 0.75%) on the physical, structural, and sensory properties of gluten-free pancakes made from quinoa powder. The apparent viscosity of the pancake batter increased significantly with higher guar gum concentrations, reaching its peak at 0.75% gum, while still exhibiting pseudoplastic behavior across all shear rates. Moisture content of the baked pancakes improved from 32.05 ± 1.06% in the control to 36.42 ± 1.58% in the 0.75% sample. A concurrent increase in pancake volume (from 11.12 to 13.52 cm^3) and a decrease in density (from 994.30 to 815.87 kg/m^3) were also observed. Color measurements showed a reduction in crust lightness from 54.06 (control) to 41.52 (0.75%), while crumb lightness increased from 58.58 to 69.81. Crust hardness rose steadily with guar gum level, from 0.20 N in the control to 0.31 N at 0.75%. Sensory evaluation revealed that moderate levels of guar gum (0.25%) improved appearance (score of 7.9) and maintained favorable scores for texture (7.9) and overall acceptance (7.6), while higher levels (0.75%) led to significant reductions in flavor (6.2) and texture (5.6) acceptances. Overall, guar gum positively influenced batter rheology, moisture retention, and appearance, but excessive concentrations compromised sensory quality. The optimal level was determined to be 0.25%, balancing technological enhancements with consumer acceptance.

Keywords: Apparent viscosity; Hardness; Lightness; Moisture content; Overall acceptance.

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1. Introduction

Pancakes are starch-based food products typically prepared by pouring a semi-liquid batter onto a preheated flat surface and cooking until the structure sets and solidifies (Messaoudi & Fahloul, 2018). Pancakes are quick-to-prepare, flat bakery products traditionally made from wheat flour. High-quality pancakes are characterized by desirable volume and texture, which are often achieved using freshly prepared batter. Typically served as a convenient breakfast option, pancake formulations commonly include flour, milk, eggs, sugar, and a leavening agent such as baking powder, and are cooked on a hot griddle or pan (Chen et al., 2022; Marta et al., 2023).

Gluten intolerance, associated with celiac disease and related health disorders, has emerged as a global concern, thereby increasing interest in gluten-free products among researchers and consumers alike (Cappelli et al., 2020; Ren et al., 2020). Despite the increasing popularity of gluten-free products, many of them still exhibit unsatisfactory sensory attributes. Consequently, numerous studies have focused on developing improved gluten-free pancake formulations to enhance their sensory and functional qualities (Akshata et al., 2019; Marta et al., 2023; Samary et al., 2025; Vejdanivahid & Salehi, 2025).

Quinoa (*Chenopodium quinoa* Willd.), a pseudocereal native to ancient Andean civilizations, is valued for its high-quality protein containing all nine essential amino acids. Its naturally gluten-free composition, along with a rich profile of vitamins and minerals,

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makes it a suitable ingredient for individuals with celiac disease or gluten intolerance (Filho et al., 2017). Quinoa seeds can be utilized as a nutritious ingredient in the formulation of various gluten-free bakery products, including pancakes (Nalbandian et al., 2025; Vejdanivahid & Salehi, 2025). Vejdanivahid and Salehi (2025) evaluated the physicochemical and sensory characteristics of pancakes made with sprouted quinoa flour. Their findings demonstrated significant improvements in total phenolic content and antioxidant capacity, suggesting enhanced nutritional value. Due to its favorable taste, texture, and nutrient profile, sprouted quinoa flour was recommended for use in gluten-free formulations.

Hydrocolloids are hydrophilic biopolymers that interact with water to form viscous solutions or gels. Due to their high molecular weight and extended polymer chains, they exhibit strong water-holding capacity and swelling behavior under specific conditions. As food-grade additives, hydrocolloids are valued for their natural origin, safety, and ability to stabilize food structures by regulating water distribution and forming cohesive gel networks (Salehi, 2019b; Huang et al., 2025).

Guar gum, a galactomannan-rich polysaccharide derived from leguminous seeds, has garnered considerable attention as a dietary supplement, particularly for its potential benefits in managing diabetes and hyperlipidemia (Ellis et al., 2001). This gum is a high molecular weight polymer comprising of $(1 \rightarrow 4)$ linked β-D mannopyranosyl units having single $(1 \rightarrow 6)$ linked α-D-galactopyranosyl units (Wu et al., 2009). In the food industry, guar gum is commonly utilized at low concentrations as an effective thickening and stabilizing agent, and it also serves as a valuable source of dietary fiber (Ellis et al., 2001). Although guar gum enhances viscosity, its use at higher concentrations can negatively impact food palatability and texture. To overcome these limitations and enable its application as a dietary fiber at elevated levels, partial hydrolysis of guar gum is recommended (Cui et al., 2007). Dangi et al. (2019) evaluated the effects of guar gum and its hydrolysate (at 1% and 2% w/w) on the physicochemical, pasting, thermal, rheological, and textural properties of pearl millet starch. Their results demonstrated that both additives significantly enhanced the hydration characteristics of the starch, indicating their potential to improve functional properties in starch-based food systems. Ayoubi et al. (2008) investigated the effects of whey protein concentrate (WPC), guar gum, and xanthan gum on the quality and physicochemical properties of muffin cakes. Their findings indicated that although WPC alone was not a suitable replacement for egg white, its combination with guar gum (0.3%) or xanthan gum (0.15%) at substitution levels of 25% and 50% effectively maintained sensory attributes and improved most physicochemical properties of the muffins, making it a viable alternative to egg white.

Producing high-quality gluten-free batters and baked products presents greater challenges compared to those made with wheat flour, primarily due to the absence of gluten, which plays a crucial role in determining batter rheology and overall product characteristics (Cappelli et al., 2020). Therefore, the objective of this study was to investigate the impact of different levels of guar gum (0.00%, 0.25%, 0.50%, and 0.75%) on the physical, textural, color, and sensory attributes of gluten-free pancakes formulated from quinoa powder. Particular attention was given to batter viscosity behavior, product moisture, volume, and consumer acceptance to determine the optimal guar gum concentration that balances technological performance with sensory quality.

2. Materials and Methods

2.1. Materials

Quinoa seeds, vanilla, baking powder, sugar, pasteurized full fat milk, fresh eggs, and oil (Table 1) 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). Guar gum powder (food grade) was purchased from Abdullabhai abdul kader Co. (India).

Table 1. Composition and quantities of ingredients used in the control pancake formulation.

Ingredient	Quantity (g)	Quantity (%)	Company	Country
Quinoa powder	70	26.62	OAB	Iran
Vanilla	1	0.38	Golha	Iran
Baking powder	4	1.52	Golestan	Iran
Sugar	25	9.51	Mojeze	Iran
Pasteurized full fat milk (3.4% fat)	100	38.02	Damdaran	Iran
Fresh egg	57	21.67	Telavang	Iran
Oil	6	2.28	Famila	Iran
Guar gum	0	0	Abdullabhai abdul kader Co.	India
Sum	263	100	-	-

2.2. Pancake preparation

First, the dry ingredients were mixed and sieved. 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. Guar gum was used to replace oil at four levels (0.0%, 0.25%, 0.5%, and 0.75%) on a percentage basis (Table 2), ensuring that the proportions of the other ingredients remained constant across all formulations.

Table 2. Gluten-free pancake formulations containing different levels of guar gum.

Ingredient	Formula 1 (%)	Formula 2 (%)	Formula 3 (%)	Formula 4 (%)
Quinoa powder	26.62	26.62	26.62	26.62
Vanilla	0.38	0.38	0.38	0.38
Baking powder	1.52	1.52	1.52	1.52
Sugar	9.51	9.51	9.51	9.51
Milk	38.02	38.02	38.02	38.02
Fresh egg	21.67	21.67	21.67	21.67
Oil	**2.28**	**2.03**	**1.78**	**1.53**
Guar gum	**0**	**0.25**	**0.50**	**0.75**

2.3. Evaluation of pancake batter viscosity

The apparent viscosity of the pancake batter was measured as a function of spindle rotation speed (5, 10, and 15 RPM) and time (0–120 s) using a rotational viscometer (Brookfield DV2T, RV model, USA) equipped with spindle RV-06. All measurements were conducted at a temperature of 25 °C.

2.4. Moisture content determination

The moisture content of the pancake samples was determined using a digital moisture analyzer (Model DBS60-3, Kern, Germany). Prior to analysis, each sample was carefully weighed with a precision balance integrated into the analyzer. The measurement procedure was conducted under controlled heating conditions, whereby the instrument applied a predefined thermal program to gradually remove moisture from the sample. The reduction in sample weight during heating was continuously monitored, and the percentage of moisture was automatically calculated by the device based on the total weight loss. The final values were expressed as the moisture content (% wet basis) of the samples.

2.5. Volume and density determination

The volume of the baked pancakes was determined using the canola seed displacement method, in which the volume of canola seeds displaced by the pancake sample was measured in a graduated container. The density of the baked pancakes was determined following the method described by Amin Ekhlas et al. (2023).

2.6. Color parameters determination

Image processing techniques were employed to evaluate the color parameters of the pancake crust (outer layer) and crumb (inner portion) (Fig. 1). For image acquisition, the samples were placed inside a photographic chamber under standardized and constant lighting conditions. The distance between the camera and the samples was kept fixed to minimize variations caused by changes in angle or light intensity. Photographs of the pancake samples were captured using a high-resolution 48-megapixel camera (iPhone 15 Pro Max, Apple Inc., China). The captured images were subsequently processed to extract color-related data. Specifically, the raw images in the RGB color space were converted into the CIE Lab* color space, which is widely recognized as a reliable system for describing and quantifying color attributes in food products. This conversion and subsequent analysis were carried out using ImageJ software (version 1.42e, USA) equipped with a dedicated color analysis plugin. The values of L^* (lightness), a^* (green to red axis), and b^* (blue to yellow axis) were obtained separately for the crust and crumb portions of each sample (Salehi, 2019a).

2.7. Puncture test

The crust hardness of the pancake samples was measured using a puncture test conducted with a texture analyzer (Santam, STM-5, Iran). A cylindrical probe with a diameter of 0.5 cm was employed, operating at a constant speed of 0.1 cm/s to a penetration depth of 1 cm.

Fig. 1. Crust (surface) and crumb (cross-sectional) appearances of quinoa-based pancake containing 0.25% guar gum.

2.8. Sensorial evaluation of pancake

The sensory analysis was conducted in the Laboratory of New Technologies at Bu-Ali Sina University. A panel of 20 individuals from diverse age groups was selected to assess the sensory attributes of the pancake samples. The evaluation criteria included appearance, aroma, flavor, texture, and overall acceptability.

2.9. Statistical analysis

All measurements were conducted in triplicate, and the results were expressed as mean ± standard deviation. Statistical analysis was carried out using one-way analysis of variance (ANOVA) with SPSS software (version 21, SPSS Inc., Chicago, IL, USA). Duncan's multiple range test was applied for post hoc comparisons, with statistical significance set at $p < 0.05$.

3. Results and Discussion

3.1. Viscosity of pancake batter

The absence of gluten in gluten-free products significantly alters both dough rheology and the quality of the final baked goods. Unlike wheat-based dough, gluten-free dough typically exhibits inferior consistency, reduced elasticity, and weaker gas retention capacity, which can negatively affect texture and volume (Cappelli et al., 2020; Marta et al., 2023). Fig. 2 illustrates the influence of spindle rotation speed (ranging from 5 to 15 RPM) and mixing time on the apparent viscosity of pancakes batter made with quinoa powder. 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 characteristic of many non-Newtonian food systems. Notably, this rheological trend was consistent across all formulations, regardless of guar gum concentration. This indicates that while guar gum enhances batter viscosity, it does not fundamentally alter the batter's flow behavior, maintaining its pseudoplastic properties across varying shear conditions.

As shown in Fig. 2, the apparent viscosity of the pancake batter exhibits a clear time-dependent behavior, particularly at a spindle rotation speed of 5 RPM. At this low shear rate, a gradual decrease in viscosity over time is observed for all guar gum concentrations, indicating a thixotropic behavior. This time-dependent decrease is more pronounced at higher guar gum concentrations, suggesting that

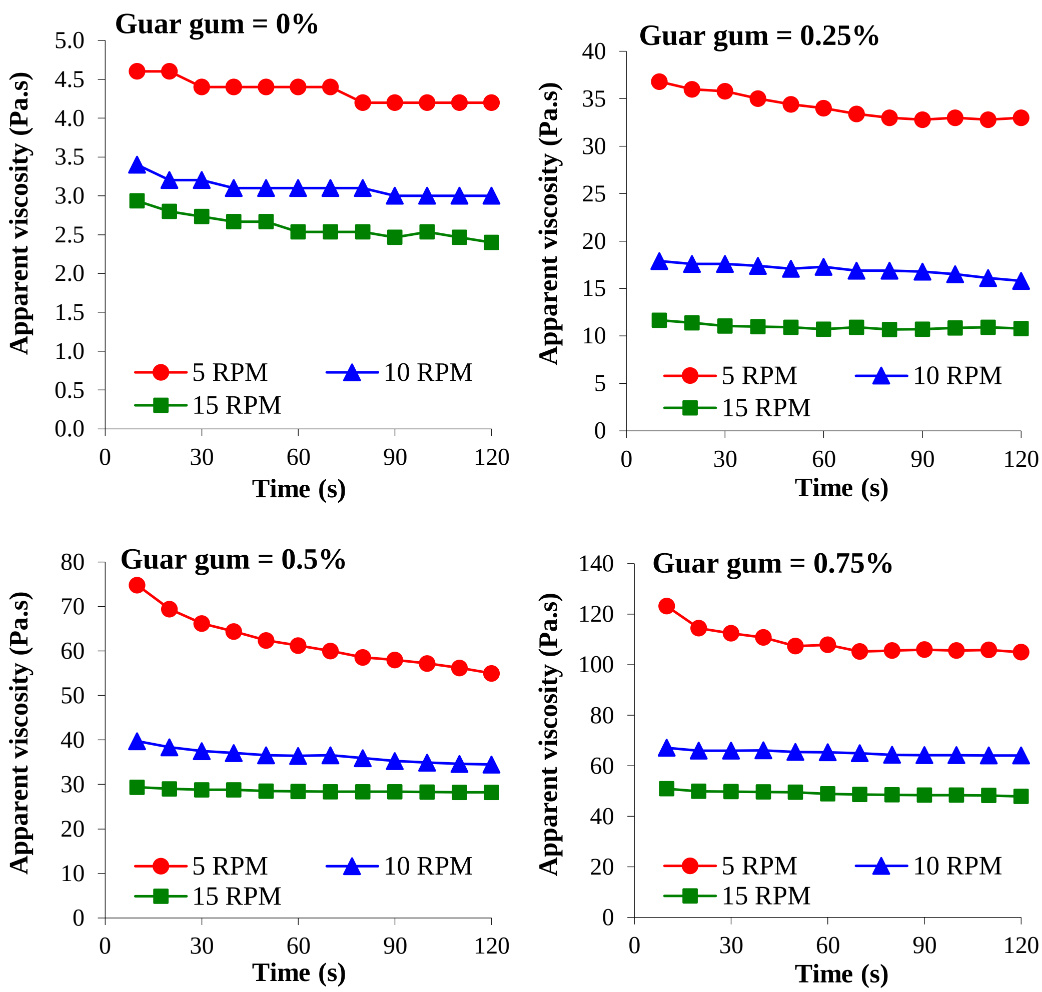

Fig. 2. Influence of spindle rotation speed and time on the apparent viscosity of pancakes batter.

the structural network formed by the hydrocolloid undergoes progressive alignment or breakdown under sustained shear. In contrast, at higher rotation speeds (10 and 15 RPM), the apparent viscosity remains relatively stable over time, indicating that the time-dependent effects are mitigated at higher shear rates. These observations highlight the critical influence of both shear rate and hydrocolloid concentration on the rheological stability and processing behavior of pancake batters.

Fig. 3 shows the impact of guar gum concentration on the apparent viscosity of pancake batter. The figure shows that increasing the guar gum level led to a proportional increase in the batter's apparent viscosity. This increase in viscosity can be attributed to guar gum's high molecular weight and its ability to form a stable polysaccharide network, which enhances the water-holding capacity and viscosity of the batter system. The higher viscosity may also contribute to improved air entrapment and gas retention during mixing, thereby potentially supporting better pancake structure and volume in the final baked product. Moreover, at all levels of guar gum substitution, an increase in spindle speed resulted in decreased batter viscosity, confirming its pseudoplastic (shear-thinning) behavior. This is characteristic of hydrocolloid-containing systems, where polymer chain alignment under shear reduces flow resistance. Although guar gum elevated the overall viscosity, it did not modify the non-Newtonian flow nature of the batter.

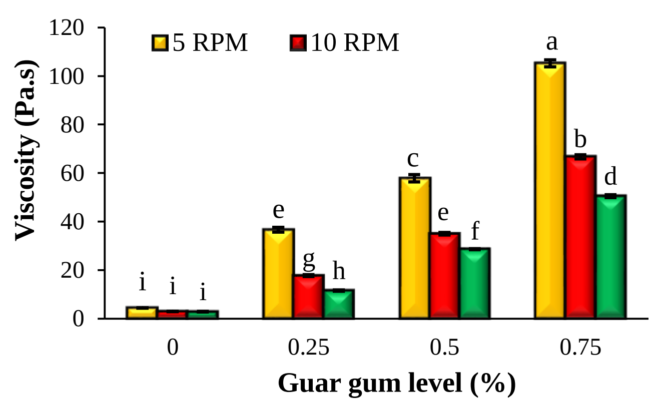

Fig. 3. Effect of guar gum level on the apparent viscosity of pancakes batter as a function of spindle rotation speed. Different superscript letters indicate significant differences ($p < 0.05$).

3.2. Moisture content of pancakes

Fig. 4 shows the effect of different concentrations of guar gum on the moisture content of pancakes prepared with quinoa powder. The results show that the incorporation of guar gum led to a gradual increase in moisture content compared to the control sample (0% guar gum). The control sample exhibited the lowest moisture content, while the highest value (36.4%) was observed at 0.75% guar gum addition. Statistical analysis ($p < 0.05$) revealed that the control group differed significantly from the 0.75% guar gum treatment, indicating that higher concentrations of guar gum significantly enhanced the water retention capacity of the pancakes. However, the intermediate concentrations (0.25% and 0.5%) did not differ significantly from either the control or the highest concentration, as reflected by the shared superscript letters. These findings suggest that guar gum, owing to its hydrocolloidal properties, contributes to improved moisture retention in quinoa-based pancakes. The ability of guar gum to bind water likely results in reduced moisture loss during baking. Consistent with the findings of the current study, Ayoubi et al. (2008) reported that the incorporation of guar gum into muffin cake formulations led to an increase in product moisture content. Obinna-Echem et al. (2024) reported that pancakes prepared using wheat flour contained approximately 35% moisture, which is closely comparable to the moisture content observed in the present study. Additionally, Chen et al. (2022) reported that sodium alginate and soluble soybean polysaccharide were effective in retaining the moisture content of Chinese pancakes during storage, thereby contributing to improved shelf-life and texture stability.

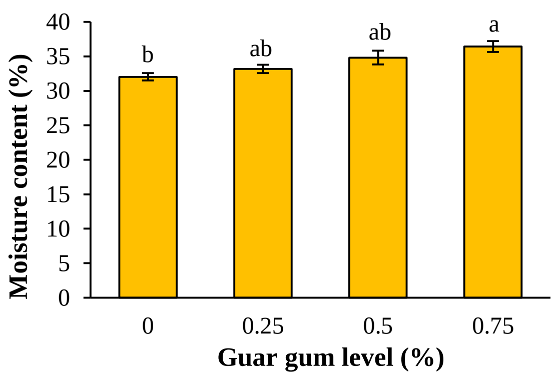

Fig. 4. Effect of guar gum concentration on the moisture content of pancakes made with quinoa powder. Different superscript letters indicate significant differences ($p < 0.05$).

3.3. Volume and density of pancakes

Fig. 5 presents the influence of guar gum concentration on the physical properties of quinoa-based pancakes, specifically their volume (a) and density (b). The results indicate that increasing the level of guar gum significantly affected both parameters ($p < 0.05$).

As shown in Fig. 5a, the pancake volume exhibited a progressive increase with the addition of guar gum. The lowest volume (11.12 cm^3) was recorded in the control sample (0%), while the highest volume (13.52 cm^3) was observed at 0.75% guar gum. Each incremental increase in guar gum concentration resulted in a statistically significant enhancement of volume, suggesting that guar gum contributes to improved gas retention and expansion during batter baking. Comparable to the outcomes observed in this study, Chen et al. (2022) reported that the addition of sodium alginate, soluble soybean polysaccharide, and xanthan gum to Chinese pancake formulations significantly enhanced the specific volume of the final product.

Conversely, Fig. 5b demonstrates an inverse trend for density. The control sample exhibited the highest density (994.3 kg/m^3), whereas the lowest density (815.9 kg/m^3) was observed in pancakes containing 0.75% guar gum. Intermediate concentrations (0.25% and 0.5%) showed a gradual and statistically significant reduction in density relative to the control. This reduction is consistent with the observed increase in volume, as lower density values are typically associated with lighter and more aerated structures. Overall, these findings highlight the functional role of guar gum as a hydrocolloid in modifying the structural characteristics of quinoa-based pancakes. Its ability to enhance water binding and stabilize gas cells during cooking likely contributes to increased volume and reduced density, thereby improving the textural and sensory qualities of the final product. In agreement with the results of this study, Ayoubi et al. (2008) reported that the incorporation of guar gum into muffin cake formulations led to a decrease in product density. Furthermore, Akshata et al. (2019) reported that incorporating xanthan gum, sodium stearoyl-2-lactylate, and psyllium husk at concentrations of 0.2% and 0.5% into gluten-free eggless pancake formulations significantly reduced batter density.

3.4. Color attributes of pancakes

As shown in Table 3, the level of guar gum significantly influenced the color attributes, lightness (L*), redness (a*), and yellowness (b*), of both the crust and crumb of pancakes made with quinoa powder ($p < 0.05$).

Lightness: Increasing the guar gum level resulted in a progressive decrease in crust lightness, with the highest value observed in the control sample (54.06) and the lowest in the 0.75% guar gum sample (41.52). The crumb lightness, however, increased significantly with higher levels of guar gum, ranging from 58.58 in the control to 69.81 in the 0.75% sample.

Redness: Crust redness values fluctuated slightly with guar gum level but did not follow a consistent trend, although the 0.50% sample recorded the highest a* value (9.86). In contrast, crumb redness was significantly affected, with the most negative a* value (–2.33) observed at 0.50% guar gum, indicating a shift towards a greener tone, whereas the least negative value (–1.39) was seen in the 0.25% treatment.

Yellowness: A notable decline in crust yellowness was observed with increasing guar gum content, from 41.11 in the control to 35.10 in the 0.75% sample. Conversely, the crumb yellowness increased, peaking at 41.40 in the 0.75% sample.

Overall, the use of guar gum altered the visual appearance of the pancakes, likely due to its impact on water distribution, baking temperature uniformity, and browning reactions. The increase in crumb lightness and yellowness may be desirable from a consumer perspective, whereas excessive darkening of the crust at higher guar levels could be less favorable.

3.5. Crust hardness of pancakes

The crust hardness of pancakes was significantly influenced by the level of guar gum incorporated into the formulation ($p < 0.05$). As shown in Fig. 6, increasing the concentration of guar gum 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

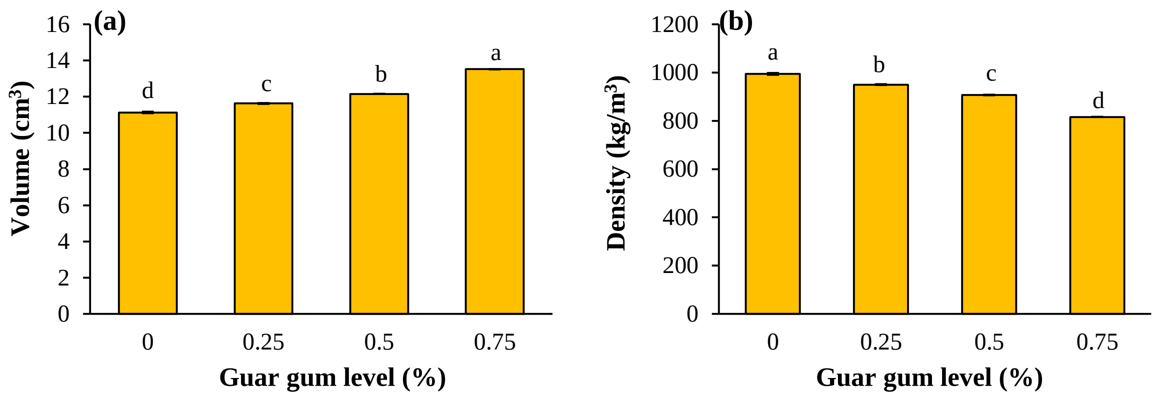

Fig. 5. Effect of guar gum concentration on the volume (a) and density (b) of pancakes made with quinoa powder. Different superscript letters indicate significant differences ($p < 0.05$).

Table 3. Effect of guar gum level on the lightness, redness, and yellowness of pancakes made with quinoa powder.

Guar gum level (%)	**Lightness**		**Redness**		**Yellowness**	
	Crust	**Crumb**	**Crust**	**Crumb**	**Crust**	**Crumb**
0.00%	54.06 ± 1.22 ^{a}	58.58 ± 0.78 ^{d}	9.71 ± 0.81 ^{a}	-1.15 ± 0.35 ^{a}	41.11 ± 0.38 ^{a}	37.56 ± 1.06 ^{c}
0.25%	47.11 ± 1.70 ^{ab}	62.22 ± 0.83 ^{c}	7.68 ± 0.52 ^{b}	-1.39 ± 0.22 ^{a}	38.81 ± 0.88 ^{b}	39.21 ± 0.31 ^{b}
0.50%	45.62 ± 0.19 ^{ab}	66.24 ± 0.04 ^{b}	9.86 ± 0.37 ^{a}	-2.33 ± 0.14 ^{b}	35.49 ± 0.41 ^{c}	40.72 ± 0.52 ^{ab}
0.75%	41.52 ± 0.31 ^{b}	69.8 1± 2.76 ^{a}	8.45 ± 0.18 ^{b}	-1.78 ± 0.46 ^{ab}	35.10 ± 0.90 ^{c}	41.04 ± 0.67 ^{a}

Values represent mean ± standard deviation ($n = 3$). Different superscript letters indicate significant differences at $p < 0.05$.

the highest value (0.31 N) was observed for the 0.75% guar gum 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 goods (Salehi, 2019b).

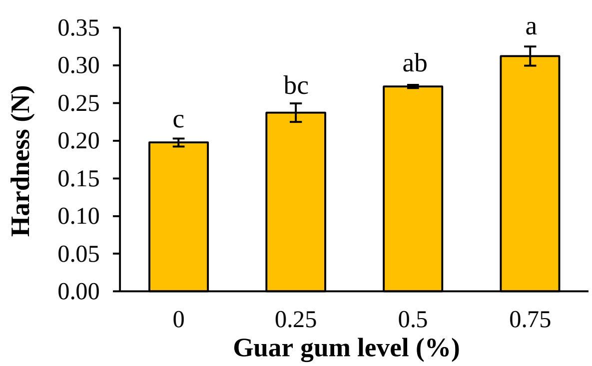

Fig. 6. Effect of guar gum concentration on the crust hardness of pancakes made with quinoa powder. Different superscript letters indicate significant differences ($p < 0.05$).

3.6. Sensory evaluation

As illustrated in Table 4, the addition of guar gum at various levels had a significant impact on the sensorial attributes of quinoa-based pancakes, including appearance, aroma, flavor, texture, and overall acceptance ($p < 0.05$).

Appearance acceptance: Appearance scores increased significantly with increasing guar gum levels. The highest score (8.1) was recorded at 0.75% guar gum, while the control sample (0.00%) had the lowest score (6.9). This suggests that guar gum improved surface uniformity and visual appeal, likely due to its effect on batter stability and spreadability.

Aroma acceptance: No statistically significant differences were observed among samples regarding aroma. Scores remained relatively consistent, ranging from 7.1 to 7.6, indicating that guar gum had little or no influence on the aromatic profile of the pancakes.

Flavor acceptance: The highest flavor score (7.8) was observed in the control, with values declining at higher guar gum levels, particularly in the 0.75% sample (6.2). Although not statistically different between the control and 0.25% groups, the significant reduction in flavor acceptance at 0.50% and 0.75% suggests that excess guar gum may negatively affect taste perception, possibly due to its interaction with flavor compounds or mouthfeel alterations.

Texture acceptance: A significant decline in texture acceptance was observed with increasing guar gum content. While the control and 0.25% samples scored above 7.7, the 0.75% sample scored significantly lower (5.6), indicating a less desirable texture at higher gum levels. This could be attributed to excessive gel formation or a gummy mouthfeel introduced by guar gum at higher concentrations.

Overall acceptance: Overall liking mirrored trends in flavor and texture scores. The control (7.7) and 0.25% (7.6) samples showed the highest acceptance, while the 0.75% sample (5.9) received the lowest score. These results suggest that moderate levels of guar gum (up to 0.25%) can maintain or slightly improve consumer acceptability, but higher levels may lead to sensory rejection due to undesirable texture and flavor changes.

In summary, while guar gum can enhance visual properties, excessive amounts (> 0.25%) may compromise key sensory

Table 4. Effect of guar gum level on the sensorial attributes of pancakes made with quinoa powder.

Guar gum level (%)	Appearance acceptance	Aroma acceptance	Flavor acceptance	Texture acceptance	Overall acceptance
0.00%	6.90 ± 0.99 [b]	7.60 ± 0.73 [a]	7.80 ± 0.81 [a]	7.70 ± 0.64 [a]	7.70 ± 0.84 [a]
0.25%	7.95 ± 0.96 [a]	7.60 ± 0.86 [a]	7.45 ± 0.80 [a]	7.90 ± 0.83 [a]	7.60 ± 0.73 [a]
0.50%	7.90 ± 1.18 [a]	7.10 ± 0.89 [a]	6.60 ± 0.66 [b]	6.50 ± 0.87 [b]	6.45 ± 1.02 [b]
0.75%	8.11 ± 0.97 [a]	7.10 ± 0.70 [a]	6.15 ± 0.91 [b]	5.55 ± 0.86 [c]	5.90 ± 0.89 [b]

Values represent mean ± standard deviation (n = 20). Different superscript letters indicate significant differences at $p < 0.05$.

attributes. Therefore, 0.25% guar gum appears to be the optimal level for balancing textural enhancement without adversely affecting overall consumer acceptance. Comparable to the outcomes observed in this study, Ren et al. (2020) demonstrated that an improper balance between water and hydrocolloid content can adversely affect product quality, that leading to issues such as low dough stability, overexpansion, and weak crumb structure at excessive water levels, or conversely, high dough rigidity, excessive air entrapment during mixing, and restricted gas cell expansion when high hydrocolloid levels are combined with insufficient water.

4. Conclusion

The incorporation of guar gum into quinoa-based gluten-free pancake formulations significantly affected a range of quality parameters, including viscosity, moisture retention, volume, color, texture, and sensory attributes. From a rheological perspective, guar gum increased batter viscosity while maintaining shear-thinning behavior, consistent with non-Newtonian pseudoplastic systems. This elevated viscosity contributed to greater gas retention during baking, enhancing pancake volume and reducing density. Guar gum also influenced moisture content positively, likely due to its water-binding capacity, which can contribute to improved softness and shelf life. In terms of appearance, higher gum levels darkened the crust but lightened and brightened the crumb, enhancing internal visual quality. Crust hardness increased with gum addition, indicating a firmer exterior, which may be desirable depending on consumer preference. Sensory results emphasized the importance of optimizing hydrocolloid concentration. While visual appeal improved across all treatments, excessive guar gum (≥ 0.50%) adversely affected flavor and texture perception, potentially due to excessive gel formation or altered mouthfeel. Therefore, maintaining guar gum at 0.25% ensures a favorable balance between functional improvements and consumer acceptance. In conclusion, guar gum is a promising clean-label ingredient for improving the structure and appearance of gluten-free baked products. However, its level must be carefully controlled to prevent negative impacts on flavor and mouthfeel. Future studies could explore interactions with other hydrocolloids or protein sources to further enhance the sensory and textural properties of gluten-free pancake formulations.

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Conflict of interest

The authors declare that there is no conflict of interest.

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