The effect of adding xanthan and carrageenan gum on improving the physicochemical and sensory properties of gluten-free biscuits prepared from almond powder

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Abstract

Almond powder, extracted from almonds, is a nutritional alternative rich in nutrients such as proteins, healthy fats, fiber, and minerals, as well as its high antioxidant content, making it a suitable option for improving the nutritional value of baked goods. Therefore, the research aimed to study the chemical and nutritional composition of almond powder and improve its rheological properties by adding xanthan gum and carrageenan gum at ratios of (1, 1.5, and 2%). The chemical composition results of protein, fat, moisture, ash, crude fiber, and carbohydrates were (22.6, 52.6, 6.25, 3.00, 8.15, and 7.4%), respectively. As for the chemical composition results of biscuits made from almond powder without and with the addition of xanthan gum, the protein percentage ranged between (20.23 - 21.23%), the fat percentage between (38.15 - 44.70%), the moisture percentage was (5.13 - 7.70%), the ash was (2.19 - 2.30%), the crude fiber was (2.15 - 2.99%), and the carbohydrates were (24.32 - 31.12%). The results of the chemical composition of biscuits made from almond powder without and with the addition of carrageenan gum indicate that the protein content was between (21.16-22.05%), fat was (40.20-44.70%), moisture was (5.13-8.15%), ash was between (2.15-2.50%), crude fiber was (2.41-3.33%), and carbohydrates were (24.11-25.67%). As for the results of the rheological properties of almond powder, the addition of gums improved the moisture absorption capacity and stability of almond powder. As for the sensory evaluation results, they showed an improvement in the sensory evaluation properties of biscuits made with the addition of xanthan gum and carrageenan.

Keywords: Chemical composition, gluten-free biscuits, xanthan gum, carrageenan, rheological properties, sensory evaluation.

The research is extracted from the master's thesis of the first researcher.

Introduction

The gluten-free product industry has seen significant growth in recent years, whether for health reasons related to gluten sensitivity or celiac disease (CD), or for reasons related to modern dietary trends. The “GF” label can be found on most health food products (9). The gluten-free food market is relatively new and limited to specialty grocery stores and health food stores. However, the past two decades have seen an increase in demand for gluten-free products. The main reason behind this market trend is attributed to several factors, most notably the growing belief that gluten poses long-term health risks, while others try a gluten-free diet to alleviate symptoms associated with asthma, attention deficit hyperactivity disorder (ADHD), irritable bowel syndrome (IBS), weight management, and more (28). This is further evidence that people with gluten sensitivity (CD) are not the only ones driving the gluten-free food market. Whatever the reason, the fact remains that the consumption of gluten-free foods and beverages is on the rise, and this trend is expected to continue in the future, presenting a unique challenge and an important opportunity for food product developers (24).

Celiac disease (CD) is a genetic intestinal disorder characterized by the inability to digest gluten proteins found in certain grains such as wheat, barley, and rye, and in secondary grains such as oats and triticale (20). Celiac disease (CD) is a chronic condition caused by alcohol-soluble prolamin molecules from gluten proteins (gliadin from wheat, hordein from barley, secalin from rye, and avenin from oats), leading to an autoimmune response that affects the villi of the small intestine, causing inflammation in affected individuals and a deterioration in overall health (19) The signs of celiac disease are generally divided into intestinal symptoms (abdominal pain, constipation, diarrhea, etc.) and extra intestinal symptoms (anemia, joint pain, bloating, weight loss, chronic fatigue, muscle cramps, etc.). There is no cure for this disease; however, patients can manage and eliminate the associated symptoms by following a strict gluten-free diet, which is easier said than done given the challenges involved in finding ingredients that meet the recommended daily nutritional intake (6). Non-celiac gluten sensitivity (NCGS) is not yet well understood in the medical field, especially with regard to its diagnosis, as it is similar to other common allergies, including mild symptoms (rash, hives, itching, swelling, etc.) and serious symptoms (difficulty breathing, wheezing, loss of consciousness). Like any other allergy, wheat allergy can be fatal. Due to the absence of proven biomarkers associated with this allergy, its treatment is the same—adherence to a strict gluten-free diet for life, which makes diagnosis and treatment more difficult.

Gluten is defined as a protein found in wheat, barley, rye, and some types of oats, as well as products made from these grains. It is a functional ingredient known for its sticky elasticity (such as the elastic properties in bread). It is derived from the Latin word gluten, which means glue, as it allows bread to rise and form air bubbles, resulting in a porous structure (11). Gluten-free foods have posed a challenge for product developers due to their lack of the elastic viscosity provided by gluten. However, several solutions have been explored to improve the sensory, functional, and nutritional properties to meet the growing demand for high-quality gluten-free products (19). Possible solutions to improve the physical and sensory properties of gluten-free products have included the use of functional ingredients (hydrocolloids, enzymes, starch, and protein), as well as technological advances (controlled instantaneous pressure reduction, extrusion, hot air roasting, etc.), or the use of food powders or gluten-free grain powders such as millet and buckwheat powder (6,9).

Baked goods are among the food products in which it is most difficult to eliminate gluten without affecting the sensory and physical properties of the final product. In this context, almond powder stands out as a promising option in the manufacture of gluten-free products, due to its high nutritional value. Hydrocolloids commonly referred to as gums are widely used as functional ingredients that mimic the structural role of gluten. These polysaccharides improve dough rheology, enhance water-holding capacity, stabilize air cells, and contribute to desirable crumb structure Among the most effective hydrocolloids are xanthan gum and carrageenan gum, which have attracted considerable attention in gluten-free formulations. Xanthan gum, produced by *Xanthomonas campestris* fermentation, is recognized for its high viscosity at low concentrations, shear-thinning behavior, and ability to synergistically interact with other polysaccharides and proteins. It is particularly effective in improving dough elasticity and volume, while delaying staling. On the other hand, carrageenan, a sulfated polysaccharide extracted from red seaweeds, provides strong gelling and stabilizing properties, contributing to crumb firmness and moisture retention. Its ability to interact with proteins and starch further enhances the texture and shelf-life of gluten-free baked goods (30,7) .This study aims to evaluate the effect of these additives in improving the physical and sensory properties of biscuits made from almond powder. It also highlights the promising potential of almond powder as a reliable alternative ingredient in the manufacture of healthy food products that comply with special dietary requirements.

Material and Methods

1- Prepare sample:

The American Sweet almond seeds under study were certified by the Ministry of Agriculture/Seed Inspection and Certification Department. Hydrocolloids, namely xanthan gum (of Chinese origin) and carrageenan (of Filipino origin), were used as binding agents for the almond powder with the other ingredients, namely granulated sugar, margarine, and glucose sugar, which are used in the manufacture of biscuit mixes. All ingredients were purchased from local markets in Baghdad, Iraq.

2- Preparation of the study model:

The method described in (11) was followed to prepare the almond seeds with some modifications. The seeds were soaked in hot water at a temperature of 70 °C for only 5 minutes. The shells were removed manually and discarded, followed by drying the purified seeds using a vacuum oven at a temperature of 50 °C until their moisture content reached 4-6%. The dried almond seeds were crushed using a Kenwood household food processor, intermittently for two minutes. The almond powder was sieved using a No. 60 sieve (with a mesh size of 250 micrometers) of American origin. The process was repeated on the coarse parts until a fine powder of uniform size was obtained. The final powder was mixed thoroughly and stored in sealed bags in a refrigerator (5±2 °C) until use.

3- Chemical tests for almond powder and biscuits:

All chemical components, including moisture, ash, protein (N×6.25) for almond , (N×6.25) for wheat powder , fat (Soxhlet), and fiber, were estimated according to the standard analytical method adopted by the Association of Official Analytical Chemists (AOAC) for 2005 and described by (22). The percentage of carbohydrates was calculated by subtracting all components from 100, as shown in the following equation:

Carbohydrates = 100- (moisture + ash + protein + fiber + fat) %.

4- Rheological test:

Rheological test (Farinograph test) was conducted at Ministry of Trade/General Company for Grain Industry. Water absorption capacity (WAC), dough development time (DDT), dough stability time (DST), mixing tolerance index (MTI), and powder consistency were determined using a Brabender farinograph (model 820603, Brabender OHG, Duisburg, Germany) at a temperature of 30 ± 0.2 °C, using a 300 g mixing bowl operating at a speed of 63 rpm, in accordance with the AACC method (2) 54-21. All primary and secondary readings for this test were recorded by a chart recorder (Farinogram) via an attached computer, from the moment the powder was added until the end of the test time after 20 minutes.

5- Manufacturing gluten-free laboratory biscuits:

5-1- Preparation of the biscuit mixture:

The method described by (10) was followed in the manufacture of gluten-free laboratory biscuits with some modifications, as shown in Table 1:

Table 1. Composition of Gluten-Free Almond Biscuit Blends with and without Xanthan and Carrageenan gum

Adding 2% of Xanthan / Carrageenan gum X3 / C3	Adding 1.5% of Xanthan / Carrageenan gum X2 / C2	Adding 1% of Xanthan / Carrageenan gum X1 / C1	Control group (Almond powder) X0 / C0	Raw materials (g)
225	225	225	225	Almond powder
130	130	130	130	sugar
64	64	64	64	Fat
2.0	2.0	2.0	2.0	salt
2.5	2.5	2.5	2.5	Soda
0	0	0	0	Water (ml)
20	20	20	20	Glucose solution (ml)
4.5	3.78	2.25	0	Xanthan / Carrageenan gum (g)

5-2-Manufacturing method:

The official method of the American Association of Cereal Chemists (A.A.C.C.) No. (10-50 B) was used, as followed by (10) in the preparation and manufacture of laboratory biscuits, with some modifications by adding xanthan gum and carrageenan separately, at a ratio of 1, 1.5, and 2% of the powder, as shown in Table 1, with two replicates for each mixture. The dry ingredients (sugar and fat) were mixed in a Kenwood mixer for only three minutes (creaming). Water and glucose solution were added, and the mixture was mixed for two minutes. Finally, the powder mixture mixed with salt, soda, and gum was added, and mixing continued for one additional minute. Small dough balls were rolled out on parchment paper between two 6 mm thick glass plates using a rolling pin. The dough was cut in the middle into 6 equal pieces using a 60 mm diameter cookie cutter. After removing the excess, they were baked in an electric oven at 200°C for 10 minutes. The biscuits were left to cool at room temperature and after 60 minutes, the spread coefficient of the biscuits was calculated by dividing the average width of the 6 pieces by the average thickness of the 6 pieces.

5-3- Measuring the color of the biscuits:

The color of the experimental biscuit pieces was measured using a laboratory colorimeter (the International Commission on Illumination colorimeter) according to the method described by (3,16). Color metrics (CIE), expressing color values as lightness (L*), red-green axis (a*), and yellow-blue axis (b*), were recorded directly from the colorimeter at a calibration rate. (Duplicate copy for each indicator).

5-4- Physical properties of biscuits:

The physical parameters, including diameter, thickness, and diffusion coefficient, of the laboratory biscuits were determined using the AACC procedure as described by (23). The width of the biscuits (W) was measured by placing six biscuits edge to edge and obtaining the average width in centimeters. The thickness of the biscuits (T) was measured by placing the same biscuits on top of each other and measuring them in centimeters. Spread ratio = average width of 6 biscuits (W) / average thickness of 6 biscuits (T).

5-5- Sensory evaluation of gluten-free biscuits:

Ten evaluators from the Food Science Department followed the evaluation model described by (10) to evaluate the sensory characteristics of laboratory-prepared gluten-free biscuits.

6- Statistical analysis:

The Statistical Analysis System (SAS) software (26) was used to analyze the data to determine the effect of various factors on the evaluated characteristics using a completely randomized design (CRD). Significant differences between means were compared using the least significant difference (LSD) test.

Results and Discussion

1- Chemical composition of almond powder

The results of the chemical analysis shown in Table (2) indicate that almond powder contains high levels of nutrients compared to the wheat powder under study, with a protein content of 22.6, fat content of 52.6, ash content of 3.00, and crude fiber content of 8.15. The high levels of these components are due to the low moisture content of 6.25% and carbohydrates of 7.4% compared to wheat powder. This rich nutritional composition of almond powder makes it an excellent choice for preparing healthy food products.

Most of the research on the composition of almonds worldwide has focused on fat and fatty acid components. The fat in almonds consists mainly of storage fats, which are found in the form of oil droplets inside the cells (with a diameter of about 1-3 micrometers), in the tissue of the kernel. (29). Found (5) that wheat has a lower protein and fat content than some field crops. Confirmed (13) that several Iraqi wheat cultivars had a maximum protein level of 11.13%, which is comparable to the wheat flour experiment's findings.

pointed (18) out the results of comparing raw almond powder with wheat flour, as almond powder contained a higher moisture content of 11.93% compared to wheat flour at 10.27%, and both results are higher than those estimated in this study. The protein content in raw almond powder (20.45%) and wheat flour (9.46%) was also lower than the results obtained in this study. This was expected because wheat is a grain, while almonds are oilseeds, and therefore, oilseeds contain more protein than grains. According to (14), that the moisture content of wheat flour should be between 11.5 and 15.2% because it plays a decisive role in determining its quality and shelf life during storage.

In a study conducted by (8), the average oil content during the two years (2009-2010) in two types of almond powder ranged from 47.75 to 60.95% and (47% to 56%). The results of this study were consistent with those of the study presented by (12), which found a higher percentage of fiber and protein in almond powder compared to wheat flour, in addition to noticeable differences in color and chemical content such as ash, total sugar, and reducing sugar. The recent study also indicated that gluten-free almond powder has been approved as a special substitute for the manufacture of gluten-free baked goods such as cookies, biscuits, and crackers for people with celiac disease or gluten sensitivity, who cannot consume products made from wheat flour or other grains that contain gluten, such as barley or oats.

Table 2. Chemical composition of wheat powder and almond powder

Almond powder (%)	**Wheat flour (%)**	**Ingredients**
22.60	10.03	Protein
52.60	0.96	Fat
6.25	10.12	Moisture
3.00	0.46	Ash
8.15	0.28	Fiber
7.40	78.15	Carbohydrates

2- **Chemical composition of biscuit samples prepared from almond powder fortified with hydrocolloids:**

The results of the chemical analysis described in Table (3) showed that the addition of xanthan gum and carrageenan to the manufactured biscuits led to noticeable changes in some chemical properties compared to the control sample. It can be seen from the table that the samples to which gums were added had a significantly higher moisture content, with the highest percentage in the carrageenan treatment (C3=8.15%), indicating the ability of both gums to retain water during mixing and baking. This enhances the texture of the final product and prolongs its shelf life, which is desirable in baked goods that tend to dry out quickly, such as cakes and pastries. Since carrageenan gum was more effective at increasing moisture, it may be more useful in products that require a moist and soft texture (such as cakes or muffins), especially since biscuits are considered long-life products due to their low moisture content (15, 25).

Table (3) shows that the protein content remained stable in all samples, with no significant differences, indicating that the addition of the two gums did not adversely affect the structural proteins of the dough (protein structure). Proteins play a pivotal role in maintaining the rise of the dough during fermentation, thereby preserving the final shape of the baked product (7,17). The fat content decreased in the treatments to which the two gums were added, especially in the xanthan group (X1=38.15%) compared to the control sample (44.70%), indicating the possibility of using these gums to reduce fat content without significantly affecting texture or flavor, which is a desirable feature in the production of low-fat baked goods, or perhaps due to the reduced ability of these gums to bind fat during baking. This point is important in the production of low-fat baked goods without significantly affecting taste or texture, especially with the use of carrageenan (25).

Table (3) shows the increase in fiber content in the treatments to which carrageenan was added. The highest value was in the carrageenan treatment (C1=3.33%), which enhances the nutritional value of baked goods and supports their use in healthy and functional products. Increasing fiber content is nutritionally beneficial, especially in the trend toward healthy baked goods, and carrageenan contributed best to increasing fiber (due to its chemical composition), making it suitable for use in functional baked goods or those for people with digestive problems (27). On the other hand, the carbohydrate content increased in the xanthan group compared to the control treatment, which may be related to the composition of the gum itself or a decrease in other components (such as fat). The decrease in carbohydrate content affects the glycemic index of baked goods, which is an important factor in products intended for diabetics.

Based on the above, it can be said that the introduction of xanthan gum and carrageenan in the bakery industry contributes to improving some of the technological and nutritional properties of the final product, particularly in terms of moisture, fiber, and fat, with a relative advantage for carrageenan in terms of increasing moisture and fiber.

Table 3. Chemical composition of biscuit samples made from almond powder with different proportions of xanthan gum and carrageenan added.

Carrageenan			**Xanthan gum**			**Control**	**Components**
C3	**C2**	**C1**	**X3**	**X2**	**X1**		
8.15	7.15	6.25	7.70	6.85	6.10	5.13	Moisture
21.16	21.36	22.05	21.15	20.52	20.23	21.23	Protein
41.75	40.56	40.20	39.15	39.50	38.15	44.70	Fat
2.15	2.39	2.50	2.19	2.30	2.25	2.21	Ash
2.68	3.12	3.33	2.99	2.88	2.15	2.41	Fiber
24.11	25.42	25.67	26.82	27.95	31.12	24.32	Carbohydrate

Control = Control group. X1= Control group with 1% xanthan gum. X2= Control group with 1.5% xanthan gum. X3= Control group with 2% xanthan gum. C1= Control group with 1% carrageenan gum. C2= Control group with 1.5% carrageenan gum. C3= Control group with 2% carrageenan gum.

3- Physical properties of biscuits:

Table (4) shows the physical properties of three groups of biscuit samples produced from almond powder (control and added xanthan gum and carrageenan separately) at ratios of (1, 1.5, 2%), represented by the thickness of 6 discs, their diameter, and their spread coefficient. The results show no significant differences between the values of the biscuit disc width, although the C3 sample with added carrageenan recorded the highest value. The same table indicates that only treatment X2 recorded a statistically significant difference ($P \leq 0.05$) in the thickness of the discs compared to the control group, as it was the thinnest among the treatments. The values of these two properties were reflected in the spread coefficient, with the highest values recorded in treatments X2 and C1, respectively, and only treatment C2 showing a significant difference compared to the other treatments.

Table (4) Thickness, width, and spread ability values of standard biscuits made from almond powder with added xanthan gum and carrageenan.

LSD.	Carrageenan gum			Xanthan gum			Control	Characteristic
	C3	C2	C1	X3	X2	X1		
1.372NS	42.96	42.23	42.60	41.86	41.80	42.10	42.60	Width
0.407 *	5.50^{ab}	5.60^{a}	5.20^{ab}	5.40^{ab}	5.10^{b}	5.20^{ab}	5.30^{ab}	Thickness
0.619 *	7.81^{ab}	7.54^{b}	8.19^{a}	7.75^{ab}	8.20^{a}	8.10^{ab}	8.04^{ab}	Spread factor
* (P<0.05).								

Control = Control group. X1= Control group with 1% xanthan gum. X2= Control group with 1.5% xanthan gum. X3= Control group with 2% xanthan gum. C1= Control group with 1% carrageenan gum. C2= Control group with 1.5% carrageenan gum. C3= Control group with 2% carrageenan gum.

4- Color properties of biscuits:

Table 5 shows the effect of adding xanthan gum and carrageenan on the color properties of biscuits made from almond powder compared to the control sample. Color properties were measured using the color system (L*, a*, b*), in addition to the *L*/b ratio, with significant differences between treatments determined using the LSD test. The table indicates significant differences in all color parameters under study between treatments. Table (4) shows a decrease in the brightness value (L*) of the biscuits after adding the hydrocolloids under study. The highest decrease was at an addition rate of 1.5% in both treatments X3 and C3, respectively. The same was true for the redness value (a*) in treatment X3 and the yellowness value (b*) in both treatments X3 and C3, respectively.

Higher brightness values indicate a lighter biscuit color, which was achieved in treatments (58.62) X3 and control treatment (57.98), respectively. The highest redness (a*) was recorded in the carrageenan treatments (13.81) C2 and (13.71) C3, respectively. The X1, C1, and X3 treatments recorded the lowest redness values, respectively. The C2 treatment (30.64) and the control treatment (30.07) recorded the highest yellow ness values, while the X3 (29.23) and C1 (27.58) treatments recorded the lowest values.

(L*/b*) refers to the ratio of brightness to yellowness, which is an additional indicator of overall color, and is the most important factor in baked goods as it determines the degree of brightness of the distinctive color of baked goods (shiny yellowish brown). Table (4) shows that treatment X3 (2.08) obtained the highest ratios (brightness relative to yellowness), while treatments C2 and C3 obtained the lowest ratios, as they were relatively darker in color. Although the differences between the L*/b* values were small, they were significant according to L.S.D. = 0.226 .

Table 5 Color values of biscuits produced from almond powder with the addition of xanthan gum and carrageenan according to the Lab colorimeter.

L.S.D.	Carrageenan gum			Xanthan gum			Control	Characteristic
	C3	C2	C1	X3	X2	X1		

3.257*	52.09 b	56.35 ab	57.15 ab	54.48 b	58.62 a	55.56 ab	57.98 a	L*
1.966*	13.71 a	13.81 a	10.82 b	10.30 b	10.40 b	12.43 a	11.45 b	a*
2.041*	28.61 ab	30.64 a	29.27 ab	27.58 b	28.23 b	29.16 ab	30.07 ab	b*
0.226*	1.83 b	1.84 b	1.96 ab	1.98 ab	2.08 a	1.91 ab	1.93 ab	**L*\b***
* (P<0.05).								

Control = Control group. X1= Control group with 1% xanthan gum. X2= Control group with 1.5% xanthan gum. X3= Control group with 2% xanthan gum. C1= Control group with 1% carrageenan gum. C2= Control group with 1.5% carrageenan gum. C3= Control group with 2% carrageenan gum.

5- Sensory evaluation of biscuits made from almond powder:

Table 6shows the results of the sensory evaluation of gluten-free biscuits made from almond powder, with and without the addition of xanthan gum and carrageenan separately. The evaluation was based on a set of external characteristics of the biscuits, namely spread ability, external appearance, surface cracking, and crust color. Internal characteristics included softness, crumb color, taste, and flavor. The results of the additives were compared with the control treatment based on statistical analysis using LSD to determine significant differences (P≤0.05).

Table (6) indicates that treatments X2 and C3 achieved the highest spread coefficient values, which represent the degree of product spread, at 30.00 and 29.99, respectively, while treatment C2 had the lowest spread coefficient at 27.60, with a significant difference from the other treatments. Table (6) shows that the best appearance and symmetry of the biscuit discs were in transactions C2, C3, and C1, with values of 19.01, 19.00, and 18.96, respectively, while transaction X2 showed the lowest value, with a significant difference from the other transactions, at 17.02 , which was considered less attractive in appearance.

The surface cracks were characterized by treatment X3 having the highest value (9.70), while treatment C2 had a value of 8.76, as the surface of the discs appeared blurred and the cracks were absent, indicating the high effect of carrageenan at this concentration in binding the components and not allowing them to expand and spread. There were no significant differences in the color characteristics of the crust, crumb, and pulp, as they were all at a similar level. Table (5) shows that the best evaluation of the aroma and taste characteristics was in treatment X3, reaching (18.13), while treatment C2 achieved the lowest values, with a significant difference from the rest of the values, as it was 18.01. Although the value of treatment C2 was lower than the other treatments, it was still very acceptable, and the minimum significant difference was low, not exceeding the threshold (*(LSD = 0.902).

Table (6) indicates that the total sensory evaluation scores, which represent the residents' acceptance of the gluten-free biscuit product under study, were highest for treatments X2, C1, and X3, reaching 95.51, 94.91, and 94.67, respectively. The lowest values were recorded in treatment C2, which achieved a significant difference from the other treatments, with a score of 90.34. It can be seen from the table that the lowest sensory acceptance limits for all characteristics under study were recorded for treatment C2, which negatively affected the total evaluation score for this treatment and made it the least acceptable. This reflects the negative impact of using carrageenan gum in the bakery industry, as it was the weakest in several aspects (appearance, softness, and overall evaluation) compared to xanthan gum, which yielded excellent sensory results.

Table 6. Sensory evaluation of standard biscuit samples made from almond powder with the addition of xanthan gum and carrageenan.

LSD.	Carrageenan gum			Xanthan gum			Control	Score	Characteristic
	C3	C2	C1	X3	X2	X1			
2.189 *	28.59^{ab}	27.60^{b}	29.96^{a}	28.37^{ab}	30.00^{a}	29.63^{ab}	29.42^{ab}	30	Spread factor
1.846 *	19.00^{a}	18.01^{ab}	19.01^{a}	18.96^{a}	18.63^{ab}	17.02^{b}	18.01^{ab}	20	Appearance
0.871 *	9.13^{ab}	8.76^{b}	9.02^{ab}	9.70^{a}	9.16^{ab}	9.11^{ab}	9.00^{ab}	10	Nature of surface
0.603NS	4.40	4.42	4.71	4.76	5.00	4.59	4.64	5	Crust color
0.667NS	9.59	9.00	9.01	9.13	9.03	8.96	9.09	10	Softness
0.902 *	18.58^{ab}	18.01^{b}	18.66^{ab}	19.07^{a}	19.13^{a}	19.05^{a}	19.00^{a}	20	Aroma and taste
0.412NS	4.69	4.54	4.51	4.68	4.56	4.70	4.76	5	Crumb color
4.926 *	93.98^{ab}	90.34^{b}	94.88^{ab}	94.67^{ab}	95.51^{a}	93.06^{ab}	93.92^{ab}	100	Total
* ($P<0.05$).									

Control = Control group. X1= Control group with 1% xanthan gum. X2= Control group with 1.5% xanthan gum. X3= Control group with 2% xanthan gum. C1= Control group with 1% carrageenan gum. C2= Control group with 1.5% carrageenan gum. C3= Control group with 2% carrageenan gum.

6- Rheological properties of almond powder

The table (7) shows the results of the Farinograph test, a device used to evaluate the kneading properties of powder and other powders by reflecting the interaction mechanism of the powder components and their reactions with water during dough formation through a detailed chart known as the Farinogram. The studied formulations (A, B, and C) represent almond powder compositions with the addition of xanthan gum and carrageenan separately at a rate of 2% each, and were evaluated based on five main properties.

Table 7. Rheological parameters (Farinogram) of native almond powder supplemented with 2% xanthan and carrageenan gum .

Farinograph quality number	Stability time (min)	Development time (min)	Arrival time (min)	Water absorption (%)	Treat.
116	16.1	6.4	6.20	10.7	A
143	9.5	14.2	6.40	13.1	B
200	13.6	20.0	6.20	10.1	C

A= Almond powder only. B= Almond powder + 2% xanthan gum. C= Almond powder +2% Carrageenan gum.

The percentage of water absorption refers to the amount of water needed to achieve a stable dough consistency, as determined by experiments conducted during the design of the device when the indicator reaches the 500 Brabender unit mark. The arrival time refers to the time in minutes it takes for the dough to reach its optimal kneading strength. A delay in reaching this point means that the gluten network is forming slowly, which may be related to the presence of non-traditional ingredients . The dough development time refers to the time in minutes required for the dough to form perfectly, and usually represents the highest point on the Farinogram curve. This part of the farinogram in traditional flour refers to the time it takes for the gluten network to be completed so that the dough has optimal viscosity and elasticity, with the network's ability to retain gas. It is also an indicator of the completion of gluten network formation and dough homogeneity, which requires the rearrangement of disulfide bonds (S-S) and other protein-binding bonds. The stability time refers to the period during which the dough retains its ideal consistency, and is measured from the moment the curve touches the 500 Brainerd line (arrival time) until it leaves this line (departure time). The length of this period indicates the viscosity and cohesion of the dough. The farinograph quality number is a composite number that reflects the overall quality of the dough. The higher the number, the better the quality of the dough (4,6) .

The results of the farinograph table show a clear difference between the three mixtures in terms of their rheological properties, reflecting the heterogeneity of the dough's behavior, unlike what is usually observed in traditional wheat flour, which is characterized by the presence of gluten proteins responsible for forming a flexible and cohesive network during kneading. This variation is attributed to the absence of gluten in the powder components used (almond powder), in addition to the limitations of the devices used to measure the rheological properties of non-gluten powder, as pointed out by (6,21) in his study on millet powder.

Treatment A showed the lowest relative quality among the treatments, recording low water absorption and the lowest quality index, despite recording the highest stability time (16.1 minutes), indicating a certain ability to resist disintegration during the kneading process, but insufficient to ensure complete rheological quality. In contrast, treatment B required the largest amount of water (13.1%), which may be attributed to its high protein or fiber content, or to the nature of the xanthan gum used, which is known for its high ability to bind and retain water through its functional groups. Although it recorded a good dough development time (14.2 minutes), its relative stability was low (9.5 minutes), which may reduce its efficiency during prolonged mixing operations. Treatment C outperformed all other treatments, recording the highest quality number (200) and the longest dough development time (20 minutes), with the lowest water absorption (10.1%), indicating its ability to form a strong and elastic dough that can withstand kneading and shaping better than the other treatments.

Based on these indicators, the treatments can be ranked according to rheological quality as follows: C, then B, then A, indicating the superiority of treatment C in the manufacture of baked products with improved dough properties.

Conclusion

The results showed that almond powder has a superior nutritional composition, with higher protein, fat and fiber content compared to wheat flour. The use of almond powder as a gluten-free alternative enhanced the nutritional value of the biscuit product, but the structural challenges required technical intervention to optimize the physical properties. According to the physical results, biscuit width was not significantly affected by the addition of the gum, while thickness and diffusion coefficient were significantly affected. The results showed that the use of hydrocolloids such as xanthan and carrageenan improved the texture of the biscuits and increased the willingness of residents to accept them as well as improving the rheological properties. The concentration (2%) of xanthan gum was the most suitable in terms of the balance between taste, texture and palatability. The addition of xanthan gum and carrageenan to the composition of biscuits made from almond powder not only improves the technological and nutritional properties of the baked goods, but also enhances consumer acceptance of the final product and represents an effective strategy to be able to direct their use according to the desired functional purpose of the final product.

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