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Formulation and quality analysis of gluten free cookies enriched with Pseudocereals

Pratiksha S Sukhadeve, Abhilasha B Shingote
School of Food Technology, MIT ADT University, Pune, Maharashtra, India
Corresponding Author: Abhilasha B Shingote

Abstract
Nutritious substitutes made with functional ingredients have been developed in response to the growing demand for gluten-free baked goods. The goal of the current study was to create gluten-free cookies with quinoa and amaranth flours, using flaxseed gel as a natural binding agent in place of gluten. Quinoa flour, amaranth flour, flaxseed gel, butter, sugar, and baking soda were used to make the cookies, and then their proximate composition was assessed. There were 55.02% carbohydrates, 23.92% crude fat, 10.50% crude protein, 6.20% crude fiber, 2.40% moisture, 1.98% ash, and 513 kcal/100 g of energy in the designed cookies. The addition of quinoa, amaranth, and flaxseed—all of which are known for having higher nutritional value than traditional gluten-free ingredients—is responsible for the comparatively high protein and fiber contents. The ash content shows the presence of important minerals, while the low moisture content suggests better storage stability. All things considered, the created gluten-free cookies showed a balanced nutritional profile with increased protein, dietary fiber, and energy content, making them a good substitute for those with celiac disease, gluten intolerance, or customers looking for healthier snack options. The study emphasizes flaxseed gel's potential as a natural binding agent that enhances the nutritional and functional qualities of gluten-free baked goods.

Keywords: Glute-free, amaranth, flaxseed gel, pseudocereals

Introduction

A gluten-free diet is the only treatment for celiac disease but can lead to other nutritional deficiencies because of its restrictive nature regarding gluten-containing cereals. Pseudocereals are valuable options for gluten-free diets because of their high nutritional value. They can improve the variety and nutritional quality of the celiac diet (Caeiro *et al*., 2022) [11].

Pseudocereals are non-grass plants that produce grains which are used in a similar way to true cereals. They are increasingly recognized for their nutritional value and potential health benefits (Kaur *et al.,* 2023) [12]. Unlike traditional cereals such as wheat, rice, and corn, pseudocereals are naturally gluten-free, making them valuable alternatives for individuals with celiac disease or gluten intolerance. Common examples of pseudocereals include amaranth, quinoa, and buckwheat.

The unique starch and protein compositions of pseudocereals play a crucial role in determining the texture of gluten-free cookies. Unlike gluten, which provides elasticity and structure to wheat-based dough, pseudocereal flours often require the addition of hydrocolloids or other binding agents to improve cohesion and prevent excessive crumbling. Research has shown that amaranth and navy bean flour blends can produce acceptable gluten-free cookies, with flavorings helping to mask any undesirable tastes *(*Liu et al., 2017).

The distinct starch and protein compositions of pseudocereals influence their functional properties in food applications *(*Schoenlechner, 2017 [13]*)*. Higher intake of pseudo-cereals can increase antioxidant content which can reduce oxidative load due to inhibition of free radical and oxidation chain reactions (Kaur *et al.,* 2023) [12].

Quinoa: Known for its balanced amino acid profile and high protein content (Kaur *et al.,* 2023) [12].

Amaranth: It contains a high amount of essential amino acids, including lysine *(*Langyan *et al., 2022).*

Buckwheat: It is rich in starch, fiber, proteins of high quality with a balanced essential amino acid composition, minerals (calcium, iron and zinc), vitamins, and phytochemicals (Kurčubić *et al.,* 2024) [15].

Pseudocereals contribute significantly to the human diet in certain regions and cultures. They are also potentially valuable for people with allergies to traditional cereals. Many can grow in poor soils and situations not suitable for other grain species. They are versatile ingredients that can be incorporated into various food products, including gluten-free baked goods, pasta, and cereals (Liu *et al*., 2017) [17].

Materials and Methods

Raw Materials: Amaranth flour, quinoa flour, flaxseed (for gel extraction), sugar, baking soda, oil, and vanilla essence were procured from the local market in Pune. Raw Materials Amaranth flour, quinoa flour, and flaxseed were procured from certified organic suppliers and stored in airtight containers at room temperature until use. All ingredients were sieved through 80-mesh sieve to ensure uniform particle size distribution. Flaxseed gel was prepared by mixing ground flaxseed with distilled water in a 1:3 ratio and allowing it to hydrate for 15 minutes at room temperature until a viscous gel formed.

Preparation of Flaxseed Gel: Flaxseed gel was prepared by boiling 1:15 (w/v) flaxseed: water ratio for 10 min, followed by filtration.

Raw Material Procurement

Amaranth seeds (*Amaranthus cruentus*) and quinoa seeds (*Chenopodium quinoa*) were procured from certified organic suppliers to ensure consistent quality and minimize contamination. Amaranth seeds were sourced from local agricultural cooperatives in Maharashtra, India, while quinoa seeds were obtained from certified importers specializing in South American quinoa varieties.

- Selection of other ingredients (sweeteners, fats, leavening agents)

Butter: Unsalted butter with minimum 80% fat content, stored at 4°C

Leavening Agents

Chemical leavening systems were evaluated for optimal gas production and stability:

- **Baking powder:** Double-acting baking powder containing sodium aluminum phosphate and sodium bicarbonate
- **Baking soda:** Food-grade sodium bicarbonate (99% purity)

Quality assessment of raw materials

Cookie Diameter and Thickness: Cookie diameter was measured using digital calipers at three different points across each cookie, and the average value was recorded. Thickness measurements were taken at the center and two edge points of each cookie using the same digital calipers. All measurements were performed in triplicate on freshly baked and cooled cookies.

Spread Ratio Calculation: Spread ratio was calculated using the formula: Spread Ratio = Cookie Diameter (mm) / Cookie Thickness (mm)

This parameter provides insight into dough spreading behavior during baking and the structural integrity of the final product.

Proximate analysis

The different chemical properties of the samples, such as the moisture, ash, fat, protein, and carbohydrate contents, were determined. For each test, three repetitions were carried out, and the mean result was taken.

Moisture content

The AOAC (2005) method was applied in measuring the moisture content. The loss in weight was Loss in weight.

$$\text{Moisture Content (\%)} = \frac{\text{Loss in weight}}{\text{Weight of sample}} \times 100$$

Fat

The amount of crude fat was determined using Soxhlet apparatus based on the AOAC (2005) method. The expression for calculating crude fat was

$$\text{Crude Fat (\%)} = \frac{\text{Weight of extracted fat}}{\text{Weight of sample}} \times 100$$

Protein

Determination of protein content was done using the AOAC (2005) method. The formula below was employed to estimate the percentage composition of protein and nitrogen:

$$\text{Nitrogen (\%)} = \frac{(T_s - T_b) \times N \times 0.014}{\text{Weight of sample}} \times 100$$

$$\text{Protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$

Where

- T_s= Titre value of sample
- T_b = Titre value of blank
- N= Normality of acid

Ash

Mixing of the sample under an electric heater and drying it up at 100ºC. The ash was subjected to heating at 550 degrees centigrade for five hours using a muffle furnace. The formula above was used to determine it.

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$$

Total carbohydrate

Total carbohydrate composition of the samples was estimated as total carbohydrate by difference, which is by subtracting the composition of protein, fat, ash, and moisture from 100.

$$\text{Carbohydrate (\%)} = 100 - (\text{Moisture} + \text{Protein} + \text{Fat} + \text{Ash})$$

Microbiological Analysis

Total Plate Count (TPC): Total viable count was determined using the pour plate method on Plate Count Agar (PCA). Serial dilutions of cookie samples were prepared in sterile peptone water, and appropriate dilutions were plated in duplicate. Plates were incubated at 37°C for 48 hours, and colonies were counted using a colony counter. Results were expressed as log CFU/g.

Yeast and Mold Count: Yeast and mold enumeration was performed using Potato Dextrose Agar (PDA) acidified with tartaric acid to pH 3.5. Sample dilutions were surface plated and incubated at 25°C for 5 days. Yeast and mold colonies were differentiated based on morphological characteristics and counted separately. Results were expressed as log CFU/g.

Cookie Formulation

Cookie formulations were developed using varying proportions of amaranth and quinoa flours with different concentrations of flaxseed gel incorporation. Control formulations and experimental variants were prepared according to standardized recipes with consistent mixing procedures and baking parameters to ensure reproducibility of results.

Processing Flowchart

Raw materials collection

↓

Weighing of ingredients

↓

Beating (Butter+Sugar)

↓

Mixing (Butter+Sugar+All Ingredients)

↓

Resting time in freezer (20 min)

↓

Sheeting

↓

Cutting

↓

Baking (180°C for 12 mins)

↓

Cooling and Packing

Chart 1: Processing flowchart of gluten-free cookies

The formulation of gluten-free cookies involved a progressive substitution of refined flour (T0) with varying proportions of quinoa flour and amaranth flour across treatments T1 to T4. Bryn, M., & Boye, J. I. (2018) [16] also have the similar formulation.

Table 1: Raw materials and ingredients

Ingredient	T0 (100 g)	T1 (100 g)	T2 (100 g)	T3 (100 g)	T4 (100 g)
Wheat flour	46.85	0	0	0	0
Quinoa flour	0	2.49	7.48	12.47	17.46
Amaranth flour	0	42.38	37.41	32.44	27.46
Flaxseed gel	0	4.99	4.99	4.99	4.99
Fat / Butter	13.35	24.94	24.94	24.94	24.94
Sugar	27.21	24.94	24.94	24.94	24.94
Baking soda	0.5	0.25	0.25	0.25	0.25
Water	12.09	0	0	0	0


T1 **T2**


T3 **T4**

Plate1: Developed gluten free cookies enriched with pseudo cereals

Result and Discussions

The physical dimensions of gluten free cookies were analysed.

Table 1: Physical dimensions of sample cookies

Treatment	Weight (g)	Diameter (mm)	Thickness (mm)	Spread ratio
T_c	6.98	41.03	4.20	9.76
T_1	7.11	41.21	4.81	8.56
T_2	7.00	40.48	4.27	9.48
T_3	6.69	40.79	4.67	8.73
T_4	7.23	41.13	4.92	8.35
Mean	7.00	40.86	4.57	8.97

The spread ratio of all samples was found in range of 8.35 – 9.76 in proportion to the average diameter and thickness of cookies. M. Suriya et. al., 2017 [17] found the spread ratio of cookies prepared using yam flour as 6.34 ± 0.27.

Water Absorption Capacity

Amaranth flour demonstrated superior water absorption capacity (156.2 ± 3.4%) compared to quinoa flour (142.8 ± 2.9%) and wheat flour control (124.5 ± 2.1%). This increased absorption capacity required adjustment of liquid ingredients to maintain proper dough consistency. The higher water absorption was attributed to the increased protein content and smaller starch granule size in amaranth flour, consistent with findings reported by Bender & Schönlechner (2021) [18].

Quinoa flour showed intermediate water absorption properties, requiring moderate adjustments to liquid formulations. The absorption characteristics varied depending on the quinoa variety and processing conditions, with darker varieties generally showing higher absorption rates due to increased fiber and protein content.

Sensory evaluation of formulated cookies

Sensory evaluation is a critical component of food product development and quality assessment, providing quantitative measures of consumer perception and acceptance. The hedonic scale approach, typically ranging from 1 to 9 (dislike extremely to like extremely), offers valuable insights into product attributes that drive consumer preference and purchasing decisions (Lawless & Heymann, 2010) [19]. This analysis examines sensory attributes across five treatment conditions (T0-T4) to understand the impact of processing conditions on consumer acceptability.

Table 2: Hedonic Scale Evaluation Sensory evaluation was conducted using a 9-point hedonic scale where:

Sample	Color & Appearance	Flavor	Mouthfeel	Texture	Overall Acceptability
T0	8.4	8.2	8	8	8.15
T1	7.5	7.8	7.7	7.8	7.7
T2	7.9	7.8	7.8	8	7.9
T3	8	8.2	7.9	8.1	8.05
T4	7.8	7.5	7.6	7.9	7.7

a. Color and Appearance (8.4 to 7.8)

Theoretical Background: Color and appearance represent the first sensory impression consumers encounter, significantly influencing initial acceptance and purchase intent. Visual attributes can account for up to 83% of initial product evaluation and create expectations for other sensory characteristics *(*Spence *et al.,* 2010 [20]*)*.

The color and appearance scores demonstrate a declining trend from T0 (8.4) to T4 (7.8), with the most pronounced decrease occurring between T0 and T1 (0.9 point reduction). This initial decline stabilizes in subsequent treatments, with T2 showing partial recovery (7.9) and T3 maintaining similar levels (8.0) before declining again at T4 (7.8).

b. Flavor (8.2 to 7.5)

Theoretical Framework: Flavor perception results from the complex interaction of taste (sweet, sour, bitter, salty, umami) and aroma compounds detected by olfactory receptors. Processing conditions significantly influence volatile compound profiles through thermal degradation, formation of new compounds, and release of bound flavors (Chakraborty & Chakraborty, 2023) [21].

Results Analysis: Flavor scores exhibit a pattern similar to color, with the most significant decline between T0 (8.2) and T1 (7.8), followed by stabilization in T2 (7.8) and recovery in T3 (8.2), before declining to the lowest level at T4 (7.5).

c. Mouthfeel (8.0 to 7.6)

Conceptual Background: Mouthfeel encompasses tactile sensations perceived during food consumption, including texture, temperature, and chemical sensations. These attributes significantly influence consumer satisfaction and are closely related to instrumental texture measurements (Ditschun *et.al.,* 2025) [22].

Results Interpretation: Mouthfeel scores demonstrate the most stable pattern among all attributes, with minimal variation (7.6-8.0) across treatments. The slight decline from T0 (8.0) to T1 (7.7) is followed by recovery in T2 (7.8) and T3 (7.9), with a final decline to T4 (7.6).

d. Texture (8.0 to 7.9)

Texture evaluation in sensory analysis differs from instrumental measurements by incorporating human perception, mastication effects, and individual sensitivity variations. The relationship between instrumental and sensory texture is complex and product-specific (Bodroža *et al.,* 2022) [23].

Texture scores show remarkable stability across treatments, ranging from 7.8 to 8.1. The pattern follows: T0 (8.0) → T1 (7.8) → T2 (8.0) → T3 (8.1) → T4 (7.9), suggesting successful maintenance of desirable textural properties despite significant instrumental changes. This may occur due to:

- Optimal Processing Window: Treatments may fall within an acceptable texture range for consumer perception
- Panelist Training: Well-trained panelists may show consistent evaluation patterns regardless of minor textural variations
- Product Characteristics: The specific food matrix may buffer extreme textural changes through structural compensation

e. Overall Acceptability (8.15 to 7.7)

The overall acceptability pattern closely mirrors individual attribute trends: T0 (8.15) → T1 (7.7) → T2 (7.9) → T3 (8.05) → T4 (7.7). This suggests:

- **Attribute Integration:** Consumers successfully integrate multiple sensory inputs into coherent preference judgments
- **Dominant Attribute Effects:** The decline in color and flavor significantly impacts overall perception
- **Compensatory Mechanisms:** Stable texture scores help maintain overall acceptability above 7.5

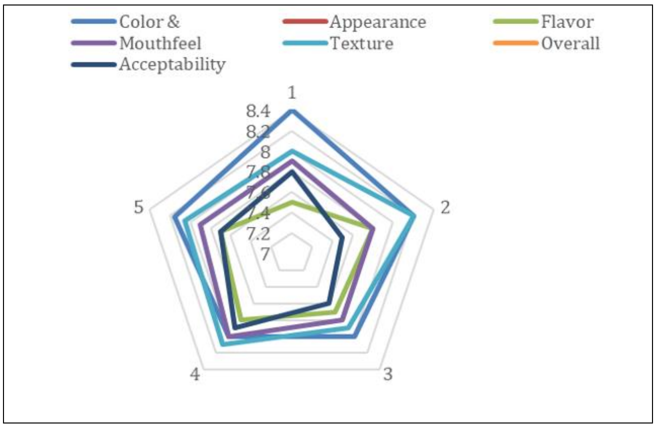

Fig 1: Sensory analysis graph

Proximate composition of Gluten Free cookie

Proximate composition	Results (%)
Carbohydrates	55.02
Crude fat	23.92
Crude protein	10.5
Crude fiber	6.20
Moisture	2.4
Ash	1.98
Energy (kcal)	513 kcal

Dowling, K. (2020) have the similar formulations Formulations with pseudocereals and flaxseed gel (especially T4) resulted in cookies with greater thickness and lower spread, indicating improved dough structure and reduced fragility. This implies enhanced product quality in terms of handling, packaging, and shelf life. The overall analysis suggests that T2 (highest thickness, protein, and fiber) is the most promising formulation among the samples. The use of quinoa, amaranth, and flaxseed gel improved the nutritional quality without compromising structural and sensory attributes, making it a potential market-ready gluten-free snack.

With an energy value of 513 kcal/100 g, the created gluten-free cookies' proximate composition showed a nutritionally balanced product (Table X). Quinoa and amaranth flours, which are high in complex carbs and offer long-lasting energy, made up the majority of the carbohydrate content (55.02%). Because nutrient-dense pseudocereals were included, the carbohydrate content was lower than that of many starch-based gluten-free cookies, suggesting a superior nutritional profile (Susman *et al*., 2021) [7]. The addition of butter and flaxseed gel, which enhance texture, mouthfeel, and energy value while also providing healthy unsaturated fatty acids, resulted in a very high crude fat content (23.92%). Similar findings of gluten-free cookies enhanced with flaxseed and other seed flours have been documented (Martínez *et al.,* 2021) [8].

Due to the excellent protein quality of quinoa and amaranth, which both provide balanced essential amino acids, the protein amount (10.50%) was higher than that of several commercially available gluten-free cookies (Susman *et al.,* 2021) [7]. Similarly, the addition of flaxseed gel and whole pseudocereal flours, which greatly increase dietary fiber intake and enhance the nutritional value of gluten-free bakery goods, resulted in a notably high crude fiber content (6.20%) (Martínez *et al.,* 2021) [8]. While the ash percentage (1.98%) shows the presence of vital minerals found naturally in quinoa, amaranth, and flaxseed, the low moisture content (2.40%) supports improved storage stability by restricting microbial development and minimizing spoiling (Giri & Sakhale, 2021) [9].

When compared to traditional gluten-free bakery goods, the produced cookies' improved nutritional quality is confirmed by the proximate composition. A promising functional food for people with celiac disease, gluten intolerance, and health-conscious consumers, the combination of quinoa flour, amaranth flour, and flaxseed gel produced cookies with improved protein, dietary fiber, mineral content, and desirable energy value (Susman *et al.,* 2021; Martínez *et al*., 2021) [7, 8].

Technoeconomic feasibility of selected sample

These calculations are done to check the market profitability of this prepared product. Total cost to produce 1 kg product is calculated to decide maximum retails price (MRP) of this product.

Table 5: 5.6 Techno-economic feasibility of selected sample

Ingredient	Quantity (g)	Cost (₹/kg)	Cost (₹)
Quinoa Flour	200	380	76.00
Amaranth Flour	200	299	59.80
Flaxseed Gel	100	160	16.00
Fat / Butter	80	200	16.00
Baking Soda	10	95	0.95
Sugar	100	45	4.50
Packaging Material	1 unit	₹10 /unit	10.00
Subtotal (Raw Materials)	-	-	₹196.75
Add: 10% Fluctuation	-	-	₹19.68
Adjusted Raw Cost	-	-	₹216.43
Add: 20% Overhead (Labour, Fuel, Electricity)	-	-	₹43.29
Total Production Cost	-	-	₹246.22
Add: 22% Profit Margin	-	-	₹54
Final Selling Price/kg	-	-	₹300

The techno-economical feasibility of gluten-free cookies was evaluated based on the cost of raw materials, production, processing, and packaging. The formulation included nutrient-rich pseudocereals such as quinoa flour, amaranth flour, and flaxseed gel, which were used as alternatives to refined wheat flour. Based on the calculations summarized in the above table, the total cost of production for 1 kg of gluten-free cookies was found to be approximately ₹246.22. By adding a 22% profit margin, the final selling price was estimated at ₹300 per kilogram. On average, around 80 cookies can be produced from 1 kg of dough, bringing the cost of a single cookie to approximately ₹3.75, which is comparatively economical compared to similar gluten-free cookies available in the market. In addition to cost-effectiveness, the product offers enhanced nutritional benefits due to the presence of high-quality proteins, dietary fiber, and essential fatty acids from the pseudocereals and flaxseed. (Ribeiro *et al.,* 2025 [24]***).*** Cost analysis of functional gluten-free bakery products: A case of sorghum and pseudocereal blends. Journal of Food Processing & Technology.

Conclusion

Using quinoa and amaranth flour and flaxseed gel as a natural binding agent to replace the functional qualities of gluten, the current study successfully developed gluten-free cookies. The use of flaxseed gel enhanced the cohesiveness of the dough and contributed to the cookies' desired texture, structure, and overall sensory acceptance. Quinoa and amaranth flours together improved the product's nutritional profile by adding high-quality protein, dietary fiber, vital minerals, and bioactive substances; flaxseed gel added soluble fiber and omega-3 fatty acids. These results suggest that the proposed formulation has a great deal of potential as a functional and nutritious bakery product that may be used by those who have gluten intolerance, celiac disease, or are looking for healthier options. Future studies should concentrate on formulation improvement using sophisticated optimization techniques to further enhance texture, sensory quality, and shelf life. It is also advised to do thorough nutritional profiling, glycemic index evaluation, storage stability studies under various packaging conditions, and microbiological testing. The quality and commercial value of the product may also be improved by adding additional useful substances and natural preservatives. To support industrial-scale production, extensive consumer acceptance tests and economic feasibility analyses are required. All things considered, this study offers a solid basis for the creation of gluten-free, clean-label baked goods with enhanced nutritional value and potential commercial uses.

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