

A Systematic Review on the Development of Gluten-Free Cookies: Formulation, Physicochemical, Nutritional and Sensory Properties

Marisa Zakiya Ulfa

Food Technology, Institut Teknologi dan Bisnis Muhammadiyah Bali, Jl. Bypass Ngurah Rai No.19, Sidakarya, Denpasar Selatan, 80224,
Bali, Indonesia

Corresponding author: marisazakiya@gmail.com; Tel.: +62-85710295062

ABSTRACT

Background: The awareness of celiac disease and other disease related gluten intolerance has driven customers to demand gluten free products. Though gluten free products have challenges to provide the consumer with the same quality attributes.

Purpose/Aim: The purpose of this study is to review the existing formulations which optimizes the ingredient functionality in gluten free cookies to improve the nutrition and sensory attributes.

Methods: Using the PRISMA guidelines and focusing on range of dates from 2016 - 2023, a literature review of peer reviewed articles has been completed. Starch, protein, and fiber breakdown and analysis, the review will also demonstrate quality and processing modifications.

Result: Evidence suggests the addition of legumes, pseudocereals, resistant starch and other dietary fibers to improve on protein, dietary fiber, and micronutrients. While also improving on other parameters including to water retention, texture, and matrix continuity. In balance though, additions have been noted to increase hardness, reduce spread ratio, and increase color. An optimal addition of 20 - 30% of most of the components is suggested to maintain or improve the other sensory attributes.

Conclusions: Integrated optimization approaches are clinically and commercially relevant to gluten free cookies for use as vehicle for functional and health benefitting ingredients. More focused approaches to demonstrate the ingredients for optimized variable will improve functional and health benefit.

ARTICLE INFO

Article history:

Received: Month 1st, Year

Revised: Month 1st, Year

Accepted: Month 1st, Year

Published: Month 1st, Year

Keywords: Cookies;
Composite flours; Nutritional
enhancement;
Physicochemical properties;
Sensory analysis

1. INTRODUCTION

Over the last decade, global demand for gluten-free food products has grown substantially, largely due to increased awareness of gluten-related health conditions such as celiac disease and non-celiac gluten sensitivity, as well as rising consumer belief in the health advantages associated with gluten-free diets (Makovicky et al., 2017). Within the bakery industry, cookies represent a prime candidate for gluten-free reformulation because of their extensive consumer appeal, convenience, prolonged shelf life, and diverse sensory characteristics (Goubgou et al., 2021). However, replicating the quality characteristics of conventional wheat-based cookies in gluten-free alternatives remains a major technological challenge, primarily due to the functional role of gluten (Belkacemi et al., 2025). The lack of gluten-forming proteins significantly modifies dough rheology and structural network development, frequently leading to gluten-free cookies that fall short of consumer expectations regarding texture, visual quality, and oral sensation (Ziobro et al., 2025).

Empirical evidence consistently demonstrates that gluten-free cookies frequently exhibit increased hardness or excessive brittleness in texture, altered spreading characteristics during baking, variations in color attributes, and generally, a reduced nutritional profile, including lower protein and dietary fiber content compared to wheat-based cookies (Huong et al., 2025). This challenge arises from the lack of gluten's

functional role in wheat-based formulations, where gluten proteins create a viscoelastic and cohesive matrix crucial for dough integrity, gas retention, and the ideal balance between crispness and tenderness in baked products (Ye et al., 2023). As a result, gluten-free formulations depend on alternative raw materials, including cereal and pseudo-cereal flours like rice, sorghum, millet, and quinoa, in addition to tuber-based flours, to mimic or approximate these functional qualities (Adewole et al., 2024).

A technological approach involves the utilization of hydrocolloids, including xanthan gum, guar gum, and hydroxypropyl methylcellulose, with protein isolates and modified starch (Lu et al., 2025). The choice and interplay of these components dictate significant physicochemical results, encompassing moisture content, water activity, dough and product rheology, spread ratio, color brightness, bulk density, and texture profile parameters such as hardness, breakability, and crispness (Azuan et al., 2020). The physicochemical characteristics will correlate with the shelf life, processing technique, and sensory acceptance of gluten-free cakes (Punfujinda et al., 2025).

Experimental studies indicate that the choice of ingredients and processing parameters influence these physicochemical properties, highlighting the necessity for systematic optimization, including mix design and response surface methodology, to reconcile conflicting quality attributes (Mulla et al., 2025). In addition to form and texture, the advancement of contemporary gluten-free cakes must also consider nutritional and functional attributes (Ferradji et al., 2024). Numerous studies have investigated enrichment strategies utilizing pseudocereals like quinoa and amaranth (Punia et al., 2022), legume flours and protein-dense ingredients (Ndovie et al., 2025), degreased grain flours (Flores et al., 2024), and by-products from fruits or vegetables (Gagnetten et al., 2023) to enhance protein and dietary fiber content (Cannas et al., 2020), also micronutrients and antioxidant capacity (Jan et al., 2018), as well as the modulation of glycemic responses and starch digestion via matrix and compositional impacts (Culetu et al., 2021).

Alterations in functional attributes can typically influence the physicochemical characteristics of a product. Augmenting fiber or protein levels typically increases water retention and bulk density. Nevertheless, if formulation and processing are inadequately calibrated, it may diminish the spread ratio and elevate hardness (Jan et al., 2018; Gagnetten et al., 2021). Evaluations of these factors suggest that multi-objective optimization, which simultaneously addresses texture, sensory acceptability, and nutritional improvement, is essential for creating commercially viable gluten-free cakes with enhanced health benefits (Ferradji et al., 2024). Investigations have examined the application of modified hydrocolloids and polysaccharides to replicate the functional characteristics of gluten (Culetu et al., 2021). A recent experimental study highlighted that hydrocolloids can significantly enhance water retention, dough viscosity, and the cohesiveness of the continuous phase, which are essential for achieving optimal textural results (Melini et al., 2019).

The efficacy of hydrocolloids is significantly influenced by their concentration, molecular interactions with starch and protein, and processing conditions; inappropriate application may result in undesired chewy or stale textures (Culetu et al., 2021). Consequently, while hydrocolloids are essential components in gluten-free formulations, their incorporation must rely on thorough physicochemical analysis and sensory evaluation (Hamdani et al., 2020). Despite significant progress, certain research gaps remain in the field of gluten-free baking development (Melini et al., 2017). Numerous published investigations are conducted at the laboratory scale and indicate enhancements in one or two quality metrics, although they do not comprehensively evaluate shelf life, industrial processing feasibility, or consumer acceptance among diverse populations (Cannas et al., 2020). Comparative analyses that comprehensively connect ingredient composition, dough rheology, and final product physicochemical parameters across various formulations remain few (Ferradji et al., 2024).

Further research is necessary to combine nutritional improvement with sensory enhancement and manufacturing efficiency in accordance with the physicochemical characteristics of gluten-free goods (Nakilcioğlu et al., 2022). To address this gap, it is necessary to develop marketable gluten-free pastry products that meet regulatory safety requirements for consumers with celiac disease as well as the sensory expectations of general consumers (Melini et al., 2019). Therefore, this systematic literature review aims to examine the development of gluten-free pastry products by synthesizing research published between 2016 and 2025, focusing on formulation strategies and their influence on physicochemical and functional

properties. To specifically identify the most frequently used ingredients and processing techniques, summarize their effects on key physicochemical parameters, assess the methodological approaches in contemporary studies, and identify research gaps and opportunities for innovation in the development of gluten-free products that effectively balance structural integrity, sensory acceptability, and nutritional quality.

2. METHODS

2.1 Research Design

This study uses a systematic literature review (SLR) methodology to thoroughly examine gluten-free cookie formulations, emphasizing formulation techniques and their effects on physicochemical and functional properties. This review sought to guarantee transparency, reproducibility, and scientific rigor by adhering to established principles for systematic reviews in food science research. The review process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, encompassing identification, screening, eligibility assessment, and inclusion of pertinent papers ([Haddaway et al., 2022](#)).

This review established specific research questions designed to critically assess the current state of knowledge on the formulation, processing strategies, and performance of gluten-free cookies, with particular emphasis on the relationships between ingredient selection, processing conditions, and their effects on physicochemical, functional, nutritional, and sensory properties.

3. **RQ1** : What formulation strategies have been applied in the development of gluten-free cookies, and which ingredients and processing variables are most frequently investigated?
4. **RQ2** : How do formulation strategies and processing conditions affect the physicochemical and functional properties of gluten-free cookies?
5. **RQ3** : What research gaps and future directions can be identified to support the development of gluten-free cookies that balance structural integrity, sensory quality, and nutritional value?

2.2. Strategy Screening for Literature Review

Accordingly, the following databases were analyzed from January 2016 to December 2025: Scopus, ScienceDirect (Elsevier), MDPI, Springer Link, Wiley Online Library, and NCBI/PMC. Academic papers were identified using the following string search: Abstract or title= "gluten-free cookies" OR "gluten-free biscuits" AND "formulation" OR "ingredient replacement" OR "enhancement" AND "physicochemical properties" OR "functional properties" AND "sensory" OR "hedonic". The papers must have been published in full form in the English language from 2016 onward. **Table 1.** Represent results collected from our preliminary database research records were subsequently evaluated based on the inclusion and exclusion criteria outlined in **Table 2.**

Table 1. . Lists articles including the author, publisher, references, and publication date.

Author(s)	Publisher / Journal	Publication Date
Adeola & Ohizua.	Wiley	2018
Nugraheni et al.	IOP Publishing	2019
Bolarinwa & Muhammad	Taylor & Francis	2019
Chervini et al.	Elsevier	2021

Author(s)	Publisher / Journal	Publication Date
Giri & Sakhale	Wiley	2021
Silav & Tacer	Croatian Sci. Publisher	2021
Martínez et al.	MDPI	2021
Mohammadi et al.	Wiley	2022
Dogruer et al.	MDPI	2023
Luque et al.	MDPI	2024
Silva et al.	Frontiers	2024
Thelma et al.	Springer Nature	2025
Punfujinda et al.	Wiley	2025
Huong et al.	Wiley	2025
Akram et al.	Frontiers	2025
Elisanti et al.	IOP Publishing	2025
Dadali et al.	Wiley	2025
Aini et al.	Elsevier	2025

Tabel 2 Inclusion and exclusion

Inclusion Criteria	Exclusion Criteria
Studies published between 2016 - 2025	Studies published before 2016 or after 2025
Research focusing on gluten-free cookies or pastry products	Studies not focused on gluten-free cookies/pastry
Studies reporting physicochemical and/or functional properties of gluten-free cookies/pastry	Studies that do not report physicochemical or functional properties
Studies providing sufficient methodological detail to allow assessment and reproducibility	Studies with insufficient methodological detail
Full-text reports successfully retrieved and accessible	Reports not retrieved or inaccessible
Non-duplicate records	Duplicate records
Studies that pass title, abstract, and full-text screening	Studies excluded during title/abstract screening or full-text eligibility assessment

2.3. Data Selection and Extraction Process

The study selection method followed to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method in order to ensure transparency, reproducibility, and scientific validity. **Figure 1** illustrates that the method had four sequential stages: identification, screening, eligibility assessment, and final inclusion. In the identification step, 138 records were obtained from the specified journal databases. Following the elimination of duplicate entries ($n = 2$), a total of 136 distinct works remained for further evaluation. During the screening phase, the titles and abstracts of the 136 publications were analyzed to assess their relevance to gluten-free cookie formulation and related physicochemical and functional characteristics. This stage led to the elimination of 96 records that were outside of the review parameters.

The remaining 40 articles received a thorough eligibility evaluation. Two studies were omitted, yielding 38 papers for comprehensive assessment based on predetermined inclusion and exclusion criteria. Articles were rejected for the following reasons: lack of focus on gluten-free cakes or similar items ($n = 9$), absence of physicochemical or functional parameters ($n = 6$), inadequate methodological quality ($n = 3$), or publication outside the designated period of 2016-2025 ($n = 2$). As a result, the conclusive systematic review comprised 18 articles that met all the inclusion eligibility criteria. This methodical, criteria-based approach ensured that only reliable and theoretically relevant material was incorporated into the synthesis, hence augmenting the validity and reliability of the review outcomes.

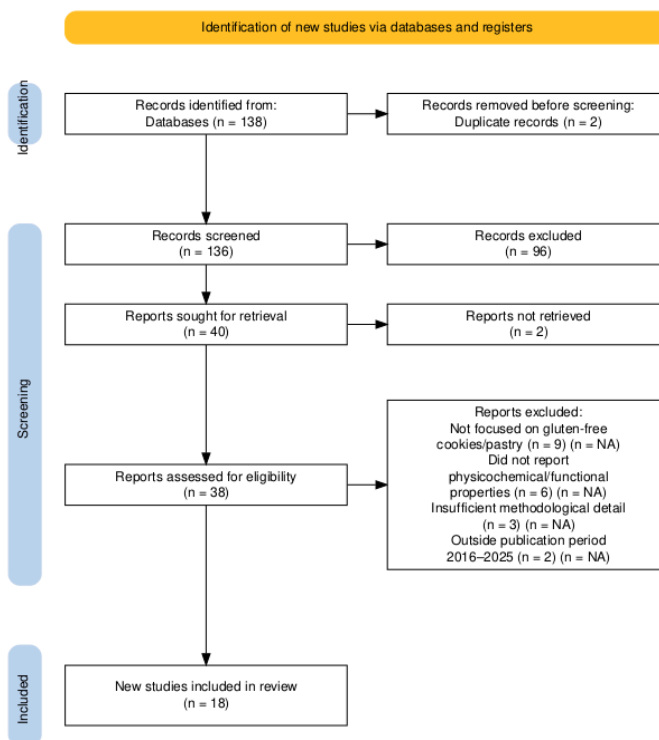


Figure 1. Representation of the inclusion and exclusion process.

3. RESULTS AND DISCUSSION

3.1 Strategies for Ingredients and Formulation

A starch-dominant basis, supplemented with other proteins and fibers, is utilized to replicate the structural and functional roles of gluten in the cake matrix (**Table 3**). Corn, rice, cassava, potato, sago, and millet starches function as the principal buffering agents, affecting the product's spread and dimensional stability during baking. This structural function is exemplified in formulations utilizing corn and tapioca starch, augmented with resistant starch type 3 and soy protein (Nugraheni et al., 2019). A cassava-amaranth composite system exhibiting starch-driven dimensional control, greater vitamin A potential, and improved

dough stability was described (Giri & Sakhale, 2021). The significance of sago and rice starch as essential matrix components has been recorded in cakes enhanced with soy and fiber, aimed at improving bonding and structural integrity (Elisanti et al., 2025). Proteins sourced from legumes and pseudograins (e.g., soybeans, chickpeas, lentils, cañihua, amaranth, and hazelnuts) have been employed to improve matrix cohesiveness via protein-starch and protein-water interactions. (Nugraheni et al., 2019) noted that soy protein improves water retention and increases elasticity in composite flour systems with resistant starch. An optimal ratio of chickpea, carob, and hazelnut flours exhibited an improvement in dough flavor and cohesiveness via a balanced protein-fat-fiber system (Dogruer et al., 2025). Moreover, in multi-flour formulations, the integration of high-protein legumes and pseudograins improved protein and mineral content while also decreasing crumb softness (Silva et al., 2024).

Key formulation strategy involve the deliberate inclusion of dietary fiber and resistant starch as beneficial structural elements. (Nugraheni et al., 2019) shown that retrograding resistant starch type 3 effectively inhibits the rapid swelling of starch granules and enhances moisture retention while maintaining the integrity of the formulation. Resistant starch from white sorghum, when integrated with fermentation and structural modification, improves soft mouthfeel and diminishes retrogradation, leading to decreased matrix roughness (Chervini et al., 2025). An enzyme-resistant starch system derived from mung bean optimizes the creation of a continuous matrix while regulating expansion during baking, hence decreasing the digestible starch fraction and glycemic response (Huong et al., 2025).

The integration of plant-based and indigenous fiber sources, such as sweet potato flour, date seed powder, artichoke bracts, and chia mucilage, seeks to augment antioxidant potential and enhance the product's water retention capacity. Each incremental substitution of the composite with purple sweet potato flour enhances the polyphenol and dietary fiber content of the composite. Nonetheless, the composite becomes denser and darker as a result of competing water binding and reduced gas cell growth (Punfujinda et al., 2025). The incorporation of date palm fiber, natural sugars from date paste, and, crucially, date palm powder enhances the viscosity of the dough, hence diminishing the spread of the composite and improving moisture retention and flavor (Akram et al., 2025). The incorporation of fiber from artichoke bracts, coupled with enzymatic binding, enhances the robustness of the protein network and optimizes the spread and strength of the matrix (Dadali et al., 2025).

The processing-oriented modification of finger millet during malting enhances its mineral and antioxidant content, augments textural stiffness, and boosts matrix density due to alterations in starch crystallinity and protein solubility (Thelma et al., 2025). The texture of resistant starch blends enhances and the recrystallization rate diminishes, attributed to a more random and porous structure resulting from the synergistic effects of fermentation and heating (Chervini et al., 2025). The incorporation of transglutaminase, functioning as an enzymatic binding agent, enhances water retention and the structural integrity of fiber-enriched matrices by fortifying protein-polysaccharide linkages and protein-protein structures (Dadali et al., 2025).

Table 3. Formulation Overview of Gluten-Free Cookies

Primary Starch Base	Protein Source	Fiber Source	Modification Strategy	Formulation Objective	Study (Author, Year)
Corn starch, tapioca, <i>M. arundinaceae</i> flour	Soy flour	RS3 (retrograded resistant starch)	Composite flour blending; thermal processing	Increase protein and dietary fiber while maintaining crispness and stable spread behavior	Nugraheni et al., 2019
Finger millet	Finger millet proteins	Native cereal fiber	Malting (24–72 h)	Improve mineral and antioxidant	Thelma et al., 2025

Primary Starch Base	Protein Source	Fiber Source	Modification Strategy	Formulation Objective	Study (Author, Year)
starch				profile while evaluating textural changes from starch modification	
Commercial GF flour mix	Sorghum protein (RSWS source)	RSWS (resistant starch from white sorghum)	Fermentation; annealing/structural starch modification	Enhance dietary fiber and reduce retrogradation while improving mouthfeel	Chervini et al., 2025
Rice flour	Chickpea flour	Date seed fiber; modified starch	Composite blending; hydrocolloid-assisted structuring	Improve moisture retention and dough viscosity for softer crumb	Mohammadi et al., 2022
Corn flour	Purple sweet potato protein fraction	Sweet potato fiber, polyphenols	Progressive flour substitution	Enhance antioxidant capacity while assessing hardness and color development	Punfujinda et al., 2025
Rice flour	Mung bean protein (HERS source)	HERS (high-amylose enzymatically modified resistant starch)	Enzymatic starch modification	Reduce digestible starch and glycemic response while preserving structure	Huong et al., 2025
Cassava starch	Amaranth protein	OFSP dietary fiber, carotenoids	Composite blending	Improve vitamin A potential and dough stability	Giri & Sakhale, 2021
Potato flour	Buckwheat, chestnut proteins	Chia mucilage and fiber	Hydrocolloid-assisted formulation	Enhance water absorption and crumb uniformity	Silav & Tacer, 2021
Potato starch	Germinated brown rice protein	Native cereal fiber	Germination	Improve nutrient bioavailability and softness	Bolarinwa & Muhammad, 2019
Potato starch	Cañihua protein, whey proteins	Native cereal fiber	Composite blending	Enhance protein quality and antioxidant capacity	Luque et al., 2024
Corn	Chickpea, carob,	Native legume	Ratio	Balance protein, fat, and fiber for	Dogruer et al.,

Primary Starch Base	Protein Source	Fiber Source	Modification Strategy	Formulation Objective	Study (Author, Year)
starch	hazelnut proteins	fiber	optimization	improved flavor and cohesiveness	2025
Wheat starch substitute	Defatted seed proteins (flax, sesame, chia, poppy)	Residual seed fiber and lipids	Flour replacement	Increase protein and PUFA content while evaluating fragility	Martínez et al., 2021
Sweet potato and banana starch	Pigeon pea protein	Native tuber fiber	Composite blending	Improve shape retention and carotenoid enrichment	Adeola & Ohizua, 2018
Rice flour	Date-derived protein traces	Date pit dietary fiber	Sweetener and fiber substitution	Increase dietary fiber and antioxidant content	Akram et al., 2025
Corn and pseudocereal starches	Lentil, chickpea, bean proteins	Native legume fiber	Multi-flour blending	Enhance protein density and mineral profile	Silva et al., 2024
Sago starch	Soy protein	Native cereal fiber	Ratio optimization	Increase calcium and protein while improving binding	Elisanti et al., 2025
Rice flour	Native cereal proteins	Artichoke bract fiber	Enzymatic crosslinking (transglutaminase)	Improve water-holding and matrix strength	Dadalı et al., 2025
Corn starch	Egg yolk protein	Coconut sugar minerals and fiber	Sweetener substitution	Modulate color development and crumb structure	Aini et al., 2025

3.2. Physicochemical Properties

As summarized in **Table 4**, the physicochemical properties of gluten-free cookies, as indicated in the examined research, were predominantly influenced by the interactions among starch, protein, dietary fiber, and functional additives, which collectively determined dough rheology, thermal characteristics, color formation, and the structure of the final product. Composite systems containing legume proteins and resistant starches consistently demonstrated improved water-holding capacity and matrix cohesion, leading to steady spreadability and moderate hardness. Soy and RS3 enriched formulations exhibited enhanced moisture retention and regulated lateral expansion during baking, indicative of a continuous protein-starch network that restricted fast starch swelling (Nugraheni et al., 2019).

Ingredient pre-treatments and structural alterations significantly influenced thermal and pasting properties. The malting of finger millet modified starch crystallinity and protein solubility, resulting in enhanced hardness, diminished lightness (L^*), and decreased spread ratios due to a more compact matrix and stronger Maillard processes (Thelma et al., 2025). Conversely, fermented systems enhanced with RSWS exhibited superior thermal stability and decreased retrogradation, resulting in softer textures and reduced grittiness due to the development of amorphous and porous starch domains that improved water absorption and restricted recrystallization during cooling and storage (Chervini et al., 2025).

A combination of chickpea and date seed flours markedly enhanced dough viscosity and moisture levels, leading to a softer crumb and delayed hardening. The phenomenon was attributed to hydroxyl-rich polysaccharides and protein fractions that enhance water retention and non-enzymatic browning, as indicated by elevated total color difference (ΔE) values (Mohammadi et al., 2022). In contrast, elevated inclusion levels of purple sweet potato starch and orange-fleshed sweet potato composites led to heightened hardness, decreased volume, and darker pigmentation, suggesting of restricted starch gelatinization and gas cell expansion owing to competition for available water and the presence of a fiber- and phenolic-rich matrix (Punfujinda et al., 2025; Giri & Sakhale, 2021).

Ingredients like hydrocolloids and high-amylose resistant starch additionally influence matrix continuity and spreading characteristics. Formulations containing Enzymatically Modified Resistant Starch with High Amylose Content (HERS) demonstrated improved biopolymer network formation, regulated lateral flow, and moderate hardness, aligning with the establishment of a continuous high-amylose phase that mitigates structural collapse during thermal expansion (Huong et al., 2025). Likewise, formulations using chia and chestnut enhanced water retention and enhanced crumb consistency, as mucilage-forming polysaccharides stabilize gas cells and phenolic components affect surface browning processes (Silav & Tacer, 2021).

The source of starch and the content of lipids significantly influence texture and visual characteristics. Combining sprouted brown rice with potato starch produced a softer texture and consistent water activity, as the enzymatic modification of macromolecules and the hydrocolloidal properties of potato starch enhanced dough elasticity and spreadability (Bolarinwa & Muhammad, 2019). In mixtures comprising cañihua and whey, protein-starch hydrogen bonding and sugar-mediated caramelization improve chewiness and promote color development at elevated inclusion levels (Luque et al., 2024). An optimal proportion of chickpea, carob, and hazelnut enhances cohesiveness and controlled spreadability via synergistic interactions among protein, fat, and fiber that govern gas retention and rheological properties (Dogruer et al., 2025).

The significance of residual lipids and enzymatic cross-linking is apparent in grain flours and enzyme-assisted systems. Lean grain flours enhance friability and modify distribution due to reduced dough cohesiveness linked to the residual oil fraction (Martínez et al., 2021), whereas transglutaminase-assisted artichoke formulations fortify the protein network and augment water-holding capacity, facilitating regulated hardness and ideal spreadability (Dadali et al., 2025). Sago-soy composites further demonstrated that soy proteins improved emulsification and binding, producing softer textures and structurally stable matrices (Elisanti et al., 2025).

Finally, sweetener selection significantly influenced crust color and crumb structure. Formulations using coconut sugar developed darker surfaces and more fragile crumbs relative to sucrose-based controls, reflecting intensified Maillard reactions and shifts in the amylose-amylopectin balance that affected starch recrystallization and light scattering within the crumb (Aini et al., 2025). Legume pseudocereal blends likewise showed that starch-protein ratios governed viscoelastic behavior and color modulation, leading to variable crumb softness and surface appearance across formulations (Silva et al., 2024).

Tabel 4. Physicochemical characteristics of gluten-free cookies in relation to formulation components and underlying mechanisms.

Key Ingredients	Physicochemical		Underlying Mechanism	Study (Author, Year)
	Parameters Observed	Direction of Effect		
Soy flour, RS3, composite starches	Moisture content, hardness, spread ratio, lipid/ash content	Moisture retention increased; hardness moderate; spread ratio stable	Protein-starch network improves water binding and matrix cohesion; RS3 limits rapid starch swelling	Nugraheni et al., 2019
Malted finger millet	Hardness, L*, ΔE, spread ratio	Hardness increased; lightness decreased; spread reduced	Malting alters starch crystallinity and protein solubility, increasing matrix density and Maillard browning	Thelma et al., 2025
RSWS (white sorghum RS), fermentation	Pasting temperature, swelling, retrogradation, hardness	Thermal stability increased; retrogradation reduced; softer texture	Amorphous/porous starch structure enhances water uptake and limits recrystallization	Chervini et al., 2025
Chickpea flour, date seed flour, modified starch	Dough viscosity, moisture, hardness, ΔE	Viscosity increased; crumb softer; darker color	Hydroxyl-rich polysaccharides and proteins enhance water binding and Maillard reactions	Mohammadi et al., 2022
Purple sweet potato flour	L*, a*, b*, hardness, volume, density	Darker color; hardness and density increased; volume reduced	High fiber and phenolics restrict starch gelatinization and gas cell expansion	Punfujinda et al., 2025
HERS (enzymatically modified RS)	Hardness, spread ratio, matrix continuity	Moderate hardness; improved continuity; controlled spread	High-amylose RS forms continuous biopolymer network, limiting collapse during baking	Huong et al., 2025
OFSP, amaranth, cassava starch	Gelatinization temperature, hardness, spread factor	Gelatinization temp increased; hardness increased; spread reduced	β-carotene-rich fibers compete for water, constraining starch swelling	Giri & Sakhale, 2021
Buckwheat, chestnut, chia	Water absorption, hardness, crumb uniformity, L*, a*	Water absorption increased; hardness modulated; color shifts	Mucilage polysaccharides and phenolics stabilize gas cells and modulate Maillard reactions	Silav & Tacer, 2021
Germinated brown rice, potato starch	Water activity, spread ratio, hardness	a_w stable; spread increased; softer texture	Germination modifies macromolecules; potato starch acts as hydrocolloid	Bolarinwa & Muhammad, 2019
Cañihua, whey,	Hardness, moisture, color	Optimized hardness; darker color at high	Protein–starch hydrogen bonding and whey sugars	Luque et al., 2024

Key Ingredients	Physicochemical		Underlying Mechanism	Study (Author, Year)
	Parameters Observed	Direction of Effect		
potato starch	(L*, a*, b*)	inclusion	intensify Maillard/caramelization	
Chickpea, carob, hazelnut	Spread factor, hardness, cohesiveness	Cohesiveness improved; controlled spread; softer texture	Protein–fat–fiber balance regulates rheology and gas retention	Dogruer et al., 2025
Defatted seed flours	Hardness, spread factor, moisture	Increased fragility; altered spread	Residual lipids reduce dough cohesiveness and weaken matrix	Martínez et al., 2021
Banana, pigeon pea, sweet potato	Thickness, spread ratio, fracturability	Shape retention improved; balanced spread	Protein–fiber network enhances structural stability	Adeola & Ohizua, 2018
Date paste, date pit powder	Moisture, spread ratio, hardness, color	Moisture increased; spread reduced; darker crust	Natural sugars and fibers enhance water binding and browning reactions	Akram et al., 2025
Legume & pseudocereal blends	Crumb softness, L*, ΔE, hardness	Texture varied; color modulated	Starch–protein ratios govern viscoelastic behavior and light scattering	Silva et al., 2024
Sago-soy blends	Binding, hardness, structure stability	Softer texture; stable matrix	Soy proteins improve emulsification and water-holding capacity	Elisanti et al., 2025
Artichoke bracts + transglutaminase	Hardness, water-holding, spread	WHC increased; hardness controlled; spread optimized	Enzyme-mediated protein crosslinking strengthens network; fiber binds water	Dadali et al., 2025
Corn flour, sucrose/coconut sugar	L*, crumb structure, hardness	Darker crust (coconut sugar); crumb more fragile	Sweetener composition drives Maillard reactions and amylose-amylopectin balance	Aini et al., 2025

3.3. Nutritional and Functional Characteristics of Gluten-Free Cookies

Formulations enhanced with legume derived components consistently demonstrated increased protein and dietary fiber levels, consequently enhancing the nutritional quality of gluten-free cookies compared to starch-dominant controls as summarized in **Table 5**. Composite systems containing soy flour, modified flour, and RS3 exhibited protein concentrations of approximately 16-18% and dietary fiber levels nearing 18.9%, alongside a decrease in total carbohydrates, while preserving *Maranta arundinaceae* consistent hardness and crispness with stable spread characteristics (Nugraheni et al., 2019). The addition of malted finger millet significantly enhanced micronutrient density, especially minerals like calcium, iron, magnesium, and zinc, while also augmenting antioxidant activity. Progressive malting durations correlated with enhanced product hardness, darker surface pigmentation, and decreasing spread ratios, suggesting a

densification of the cookie matrix and enhanced non-enzymatic browning during baking (Thelma et al., 2025).

Functional starch systems obtained from white sorghum (RSWS) enhanced dietary fiber content and altered protein availability without affecting fat levels. These solutions exhibited increased thermal stability and decreased starch retrogradation, resulting in softer textures and less grittiness, especially in fermented matrices, hence enhancing storage stability and consumer-perceived quality (Chervini et al., 2025). Mixtures of chickpea flour and date seed flour significantly elevated protein and dietary fiber content while improving water-binding capability. These modifications resulted in increased dough viscosity, softer crumbs, and postponed staling, illustrating the function of hydroxyl-rich polysaccharides and legume proteins in maintaining the biopolymer network (Mohammadi et al., 2022).

The incorporation of purple sweet potato flour resulted in significant enhancements in polyphenols, flavonoids, and dietary fiber, while simultaneously decreasing accessible carbs. Nonetheless, elevated replacement levels resulted in thicker and firmer textures, darker hues, and diminished volume, underscoring the necessity for optimum inclusion rates to reconcile nutritional benefits with technical efficacy (Punfujinda et al., 2025). Formulations enhanced with enzymatically modified high-amylose resistant starch (HERS) demonstrated elevated resistant starch fractions, less digestible starch, and lowered anticipated glycemic indices. The nutritional enhancements coincided with ongoing matrix development, regulated expansion during baking, and moderate hardness at optimal inclusion levels, suggesting beneficial interactions between high-amylose starch and the adjacent biopolymer network (Huong et al., 2025).

The incorporation of orange-fleshed sweet potato, amaranth, and cassava starch augmented β -carotene levels and enhanced micronutrient profiles. Nevertheless, greater levels of orange-fleshed sweet potato augmented product hardness and diminished spread, indicating competition for water between dietary fibers and starch granules during gelatinization (Giri & Sakhale, 2021). Formulations containing buckwheat, chestnut, and chia seeds exhibited elevated levels of protein, dietary fiber, phenolic compounds, and ω -3/ ω -6 lipid fractions. The compositional alterations enhanced water absorption, adjusted hardness, and improved crumb uniformity, indicating that mucilage-forming polysaccharides and lipid-protein interactions play a role in matrix stabilization and moisture retention (Silav & Tacer, 2021).

The combination of germinated brown rice flour and potato starch yielded elevated levels of protein, dietary fiber, and minerals, along with enhanced nutritional bioavailability. These formulations demonstrated enhanced softness, improved spreadability, and stable water activity, indicative of the hydrocolloid properties of potato starch and the enzymatic alterations of macromolecules during germination (Bolarinwa & Muhammad, 2019). Formulations containing cañihua flour, whey, and potato starch demonstrated improved protein quality along with increased phenolic and antioxidant concentrations. These cookies exhibited enhanced water retention and optimum hardness, with increased color development at elevated inclusion levels attributed to protein-starch hydrogen bonding and sugar-mediated browning processes (Luque et al., 2024).

The appropriate ratios of chickpea, carob, and hazelnut flours yielded cookies with elevated protein and fat levels, as well as enhanced resistant starch fractions. These mixtures enhanced matrix cohesiveness, regulated spread, and produced softer textures, emphasizing the synergistic function of protein, fat and fiber interactions in governing rheological properties and gas retention (Dogruer et al., 2025). Cookies made with defatted seed flours had elevated protein and dietary fiber levels, alongside PUFA-rich residual oils and diminished carbohydrate content. Increased fragility and altered spread behavior were noted at elevated lipid levels, signifying diminished dough cohesion and compromised structural integrity (Martínez et al., 2021).

Composite systems utilizing banana, pigeon pea, and sweet potato flours improved protein, fiber, carotenoid content, and magnesium levels, while preserving a beneficial low sodium-to-potassium ratio. These formulations exhibited enhanced shape retention and balanced fracturability, indicating the role of protein-fiber networks in maintaining structural integrity (Adeola & Ohizua, 2018). The addition of date paste and date pit powder significantly enhanced dietary fiber, mineral content, and antioxidant capacity. These formulations enhanced moisture retention and resulted in darker crusts with less spread, due to natural sugar-fiber interactions and amplified Maillard reactions (Akram et al., 2025). Legume and pseudocereal

mixtures regularly provided elevated levels of protein and fiber, along with improved mineral compositions. These systems adjusted crumb softness and texture by altering starch-rich components, illustrating that starch-protein ratios significantly affect viscoelastic properties and the mouthfeel of the final product (Silva et al., 2024).

Formulations that integrate sago and soy flours attained elevated calcium levels, enhanced protein and vitamin C contents, and reduced sodium concentrations. The nutritional advantages were augmented by improved binding, stable structural matrices, and increased softness, highlighting the emulsifying and water-retaining functions of soy proteins (Elisanti et al., 2025). The incorporation of artichoke bracts with transglutaminase augmented dietary fiber and phenolic compounds, simultaneously improving antioxidant activity. Enzyme-mediated protein crosslinking enhanced the biopolymer network's strength, increased water retention, and facilitated regulated dispersion and textural stability (Dadali et al., 2025). Ultimately, cookies made with corn flour and other sweeteners preserved carotenoids like lutein and zeaxanthin, maintained moderate dietary fiber content, and provided high calorie values. The incorporation of coconut sugar facilitated the development of a darker crust and a more delicate crumb structure compared to sucrose, indicating the impact of sweetener composition on Maillard reactions and the amylose-amylopectin ratio within the starch matrix (Aini et al., 2025).

Table 5. Nutritional and functional characteristics of gluten-free cookies

Key Ingredients	Nutritional Characteristics	Functional Characteristics	Study (Author, Year)
Soy flour, corn starch, M. arundinaceae, tapioca, RS3	High protein ($\approx 16\text{--}18\%$); high dietary fiber ($\leq 18.9\%$); resistant starch ($\leq 2.8\%$); reduced carbohydrates	Increased moisture retention; balanced hardness and crispness; stable spread ratio	Nugraheni et al., 2019
Malted finger millet	Increased protein, crude fiber, ash, minerals (Ca, Fe, Mg, Zn); improved antioxidant activity	Hardness increases with malting time; darker color; reduced spread ratio	Thelma et al., 2025
RSWS in GF flour mix	Higher dietary fiber; modified protein availability; stable fat content	Improved thermal stability; reduced retrogradation; softer, less gritty texture (fermented systems)	Chervini et al., 2025
Chickpea flour, date seed flour, modified starch	Increased protein and dietary fiber; enhanced water-binding capacity	Higher dough viscosity; softer crumb; delayed staling	Mohammadi et al., 2022
Purple sweet potato flour	Increased polyphenols, flavonoids, dietary fiber; reduced carbohydrates	Increased hardness and density at high levels; darker color; reduced volume	Punfujinda et al., 2025
HERS (enzymatically modified RS)	Higher resistant starch; lower digestible starch; reduced glycemic index	Continuous matrix formation; controlled expansion; moderate hardness at optimal level	Huong et al., 2025
OFSP, amaranth, cassava starch	β -carotene enrichment; improved micronutrient profile	Increased hardness at high OFSP; improved dough stability; reduced spread	Giri & Sakhale, 2021

Key Ingredients	Nutritional Characteristics	Functional Characteristics	Study (Author, Year)
Buckwheat, chestnut, chia	Increased protein, fiber, phenolics, ω -3/ ω -6 lipids	Improved water absorption; modulated hardness; enhanced crumb uniformity	Silav & Tacer, 2021
Germinated brown rice, potato starch	Increased protein, fiber, minerals; improved nutrient bioavailability	Improved softness; increased spread; stable water activity	Bolarinwa & Muhammad, 2019
Cañihua, whey, potato starch	Higher protein quality; increased phenolics and antioxidants	Improved water retention; optimized hardness and color development	Luque et al., 2024
Chickpea, carob, hazelnut	High protein and fat; increased resistant starch fractions	Improved cohesiveness; controlled spread; softer texture at balanced ratios	Dogruer et al., 2025
Defatted seed flours	High protein, fiber, PUFA-rich residual oils; lower carbohydrates	Increased fragility at high fat; modified spread and hardness	Martínez et al., 2021
Banana, pigeon pea, sweet potato	Increased protein, fiber, carotenoids, Mg; low Na/K ratio	Improved shape retention; balanced spread and fracturability	Adeola & Ohizua, 2018
Date paste and pit powder	High dietary fiber; increased minerals; antioxidant enrichment	Increased moisture retention; reduced spread; darker crust	Akram et al., 2025
Legume & pseudocereal blends	High protein and fiber; mineral enrichment	Texture modulation via starch-rich blends; varied crumb softness	Silva et al., 2024
Sago–soy flour blends	High calcium; increased protein and vitamin C; low sodium	Improved binding; stable structure; enhanced softness	Elisanti et al., 2025
Artichoke bracts + transglutaminase	Increased fiber and phenolics; enhanced antioxidant capacity	Improved protein network; higher water-holding; controlled spread	Dadali et al., 2025
Corn flour with sucrose/coconut sugar	Carotenoids (lutein, zeaxanthin); moderate fiber; high energy value	Sweetener-driven browning; crumb modulation via amylose/amylopectin balance	Aini et al., 2025

3.4 Sensory Assessment

As summarized in **Table 6**, the sensory acceptance of gluten-free cookies in the examined experiments was predominantly influenced by the interplay of formulation content, processing circumstances, and matrix structure. Composite systems enhanced with protein and fiber-rich components consistently attained elevated hedonic ratings when substitution levels were kept within an ideal range.

Formulations utilizing soy flour, modified *Maranta arundinaceae* flour, tapioca, and RS3 achieved the highest overall acceptability (7.6/9), indicating an advantageous blend of balanced crispness and subtle nutty aroma linked to enhanced protein and starch network formation (Nugraheni et al., 2019).

The processing of treatments and functional starch systems significantly affected visual and textural perception. Biscuits made from 24-hour malted finger millet, especially light-brown types, demonstrated enhanced appearance, aroma, and overall preference, while extended malting durations resulted in increased hardness and diminished flavor acceptance due to matrix densification and intensified browning reactions (Thelma et al., 2025). Cookies containing 30% RSWS or 30% HERS were assessed as equivalent to wheat-based controls regarding appearance, texture, and overall preference, whereas higher substitution levels led to diminished visual appeal and heightened firmness associated with reduced matrix porosity (Chervini et al., 2025; Huong et al., 2025).

Root and tuber based enrichment schemes underscored the significance of regulated inclusion levels. Cookies composed of 30% purple sweet potato flour and 70% orange-fleshed sweet potato attained superior sensory evaluations in terms of appearance, taste, and texture; however, excessive inclusion resulted in darker coloration and heightened hardness, adversely affecting consumer preference (Punfujinda et al., 2025; Giri & Sakhale, 2021). Simultaneously, formulations with chia-enriched buckwheat and chestnut were preferred for their enhanced scent and crumb softness, but cookies made just from buckwheat received lower ratings due to bitterness linked to phenolic compounds (Silav & Tacer, 2021).

Blends derived from legumes and seeds exhibited varied sensory results influenced by flavor complexity and matrix cohesion. Formulations comprising chickpea, carob, and hazelnut had the greatest acceptance by improving scent and mouthfeel, while systems consisting only of chickpea were less favored due to the emergence of off-flavors (Dogruer et al., 2025). Defatted seed flour cookies demonstrated that sesame and flax versions exhibited performance similar to wheat controls, however chia and poppy formulations were adversely affected by their darker look and bitter sensory characteristics (Martínez et al., 2021). Composites of banana, pigeon pea, and sweet potato, optimized at 21.7% UBF, 21.7% PPF, and 56.7% SPF, demonstrated enhanced shape retention and crunchiness, highlighting the significance of protein-starch equilibrium in preserving sensory quality (Adeola & Ohizua, 2018).

The choice of sweeteners and the enhancement of fiber significantly influenced consumer impression. Cookies made with date paste and pit powder exhibited incremental enhancements in flavor and texture with increased inclusion levels, while maintaining acceptability across treatments (Akram et al., 2025). Conversely, sucrose-based maize cookies were consistently favored over those made with coconut sugar, which resulted in a gritty mouthfeel and a bitter aftertaste due to heightened caramelization and mineral content (Aini et al., 2025). Enzyme-assisted systems utilizing artichoke bracts and transglutaminase achieved best acceptability with a 15–30% substitute; nonetheless, excessive fiber augmented hardness and diminished overall preference (Dadali et al., 2025). Ultimately, legume pseudocereal mixtures demonstrated that cookies made from corn and chickpeas garnered the greatest consumer approval, whereas formulations containing common beans were the least favored due to their bitter flavor characteristics (Silva et al., 2024).

Table 6. Sensory evaluation outcomes of gluten-free cookies across 18 studies (synthesized from reviewed literature).

Gluten-Free Composition	Sensory Attributes Evaluated	Overall Acceptability	Study (Author, Year)
Soy flour (≈42%), corn starch, <i>M. arundinaceae</i> flour, tapioca, RS3	Color, aroma, taste, crispness, overall liking (9-point scale)	Highest overall acceptability (≈7.6/9) at composite formulation with high protein and fiber; balanced crispness and mild nutty flavor	Nugraheni et al., 2019
Malted finger millet (24–72	Appearance, color, aroma,	24 h malted light-brown biscuits	Thelma et al.,

Gluten-Free Composition	Sensory Attributes Evaluated	Overall Acceptability	Study (Author, Year)
h; light vs dark brown)	taste, texture	achieved highest acceptance; prolonged malting reduced aroma/taste and increased hardness	2025
RSWS substitution (0–45%) in GF mix	Texture, mouthfeel, aftertaste, aroma, flavor, overall liking	30% RSWS comparable to wheat cookies; fermented matrix preferred over non-fermented due to reduced grittiness	Chervini et al., 2025
Chickpea flour, date seed flour, modified starch blends	Flavor, chewing ability, firmness, overall liking	Darker color did not reduce acceptance; optimal blends (T6) showed highest overall acceptability with softer texture	Mohammadi et al., 2022
Purple sweet potato flour (0–50%)	Appearance, color, aroma, taste, texture, overall liking	PSPF30 achieved highest scores across attributes; low and high substitutions reduced preference	Punfujinda et al., 2025
HERS resistant starch (15–45%)	Appearance, texture, flavor, overall liking	30% HERS comparable to wheat–sugar control (>7/9); higher levels decreased visual and textural acceptance	Huong et al., 2025
OFSP (40–100%) + amaranth + cassava starch	Appearance, taste, texture, overall liking	Optimal at 70% OFSP; highest overall acceptability (~9/9); excessive OFSP increased hardness	Giri & Sakhale, 2021
Buckwheat/chestnut with chia	Appearance, aroma, texture, overall liking	Chia-containing formulations rated highest; buckwheat-only cookies lower due to phenolic bitterness	Silav & Tacer, 2021
Germinated brown rice flour + potato starch	Appearance, aroma, taste, texture, overall liking	Best acceptance at 75% GBRF : 25% potato starch; improved softness and flavor	Bolarinwa & Muhammad, 2019
Cañihua flour + whey + potato starch	Odor, texture, overall liking (102 consumers)	Balanced formulation (F12) “liked a lot”; high cañihua levels caused off-odor and reduced liking	Luque et al., 2024
Chickpea, carob, hazelnut flours	Flavor, taste, texture, overall liking	Highest acceptance at 30% chickpea : 30% carob : 30% hazelnut; 100% chickpea lowest	Dogruer et al., 2025
Defatted seed flours (flax,	Color, odor, taste, texture,	Sesame and flax comparable to	Martínez et al.,

Gluten-Free Composition	Sensory Attributes Evaluated	Overall Acceptability	Study (Author, Year)
sesame, chia, poppy)	overall liking	wheat; chia/poppy darker and more bitter, lower scores	2021
Banana–pigeon pea–sweet potato blends	Appearance, mouthfeel, taste, crunchiness	Optimal at 21.7% UBF : 21.7% PPF : 56.7% SPF; best shape and crunch	Adeola & Ohizua, 2018
Date paste/pit powder substitution	Color, taste, texture, overall liking	Higher date inclusion improved flavor and texture; all formulations acceptable	Akram et al., 2025
Legume and pseudocereal blends	Texture, aroma, overall liking (CATA)	Corn and chickpea cookies highest acceptance; common bean lowest (bitter notes)	Silva et al., 2024
Sago-soy flour ratios	Taste, texture, aroma, color (hedonic)	Best acceptance at high soy ratio (3:7 sago:soy); improved flavor and aroma	Elisanti et al., 2025
Artichoke bracts + transglutaminase	Appearance, texture, overall liking	Optimal at 15–30% artichoke with enzyme; excessive fiber increased hardness and reduced liking	Dadali et al., 2025
Corn flour with sucrose vs coconut sugar	Aroma, taste, mouthfeel, overall liking	Sucrose-based cookies preferred; coconut sugar cookies scored lower due to gritty mouthfeel and bitter aftertaste	Aini et al., 2025

CONCLUSIONS

According to reviewed studies, making an effective formulation of a gluten-free cake involves making a cake structure and GL sensory profile of a gluten containing cake by balancing the networks of carbohydrate, protein, and fiber. Composite flours with legumes and pseudo-cereals along with resistant starch and fruit or vegetable fiber improve the micro-nutritional profile by augmenting protein, dietary fiber, bioactive compounds and mineral bioavailability and also may affect the physico-chemical properties such as water holding capacity, hardness, spread ratio and color development. 20-30% composite flours is a critical level to achieve a good balance between nutritional improvement and sensory attributes. Formulations within this span have better cohesiveness and less staleness, coupled with a good, laminar cell structure, thus leading to products that are comparable to or better than wheat products in terms of texture, look and overall acceptability. The findings are that gluten-free cookies have fused their functional and nutritional purposes, especially for consumers with celiac disease, and for those seeking healthier snacks. There is a need for future work to focus on the development of a standardized set of evaluation criteria, as well as shelf-life and digestion studies, and the application of new processing methods such as the banks of enzymes and fermentations less than controlled, to improve in product value, bioaccessibility of nutrients, and the production on an industrial scale. The main conclusion of the study may be presented in a short Conclusions section, which can stand alone. It should avoid repeating the Results and instead focus on highlighting the

significant findings and contributions of the study.

REFERENCES

- Adeola, A. A., & Ohizua, E. R. (2018). Physical, chemical, and sensory properties of biscuits prepared from flour blends of unripe cooking banana, pigeon pea, and sweet potato. *Food Science & Nutrition*, 6(3), 532–540. <https://doi.org/10.1002/fsn3.590>
- Adewole, O. A., Jolayemi, O. S., Ayo-Omogie, H. N., & Badejo, A. A. (2024). Development and techno-functional characterization of gluten-free flour from rice, Cardaba banana, and pigeon pea. *Journal of Future Foods*, 6(2), 266–278. <https://doi.org/10.1016/j.ifutfo.2024.04.011>
- Aini, N., Sustriawan, B., Olivia, N. A., & Mela, E. (2025). Sensory profile, preference and nutritional value of gluten-free cookies made from corn flour, sweetened with sucrose and coconut crystal sugar. *Food Research*, 9(3), 292–302. [https://doi.org/10.26656/fr.2017.9\(3\).163](https://doi.org/10.26656/fr.2017.9(3).163)
- Akram, S., Chatha, A., Abid, J., Farooq, U., & Ahmad, A. M. R. (2025). Development and quality assessment of gluten-free cookies using rice flour and date fruit. *Frontiers in Nutrition*, 12, 1645063. <https://doi.org/10.3389/fnut.2025.1645063>
- Azuan, A. A., Mohd Zin, Z., Hasmadi, M., Rusli, N. D., & Zainol, M. K. (2020). Physicochemical, antioxidant and sensory characteristics of cookies supplemented with different levels of spent coffee ground extract. *Food Research*, 4(4), 1181–1190. [https://doi.org/10.26656/fr.2017.4\(4\).058](https://doi.org/10.26656/fr.2017.4(4).058)
- Belkacemi, L., Ozgolet, M., & Arici, M. (2025). Enhancing the nutritional and textural properties of gluten-free shortbread biscuits: The potential of white-fleshed sweet potato flour blended with corn starch. *Journal of Food Science*, 90, e70123. <https://doi.org/10.1111/1750-3841.70123>
- Bolarinwa, I. F., Lim, P. T., & Muhammad, K. (2019). Quality of gluten-free cookies from germinated brown rice flour. *Food Research*, 3(3), 199–207. [https://doi.org/10.26656/fr.2017.3\(3\).228](https://doi.org/10.26656/fr.2017.3(3).228)
- Cannas, M., Pulina, S., Conte, P., Del Caro, A., Urgeghe, P. P., Piga, A., & Fadda, C. (2020). Effect of substitution of rice flour with quinoa flour on the chemical-physical, nutritional, volatile and sensory parameters of gluten-free ladyfinger biscuits. *Foods*, 9(6), 808. <https://doi.org/10.3390/foods9060808>
- Cervini, M., Frustace, A., Garrido, G. D., Rocchetti, G., & Giuberti, G. (2021). Nutritional, physical and sensory characteristics of gluten-free biscuits incorporated with a novel resistant starch ingredient. *Heliyon*, 7(3), e06562. <https://doi.org/10.1016/j.heliyon.2021.e06562>
- Culetu, A., Duta, D. E., Papageorgiou, M., & Varzakas, T. (2021). The role of hydrocolloids in gluten-free bread and pasta: Rheology, characteristics, staling and glycemic index. *Foods*, 10(12), 3121. <https://doi.org/10.3390/foods10123121>
- Dadali, C., Özcan, Y., & Ensari, İ. C. (2025). Multifactorial optimization of gluten-free cookie with artichoke bracts as rice flour substitute and transglutaminase. *Food Science & Nutrition*, 13, e70420. <https://doi.org/10.1002/fsn3.70420>
- Dogruer, I., Baser, F., Gulec, S., Tokatli, F., & Ozen, B. (2023). Formulation of gluten-free cookies utilizing chickpea, carob, and hazelnut flours through mixture design. *Foods*, 12(19), 3689. <https://doi.org/10.3390/foods12193689>
- El Khoury, D., Balfour-Ducharme, S., & Joye, I. J. (2018). A review on the gluten-free diet: Technological and nutritional challenges. *Nutrients*, 10(10), 1410. <https://doi.org/10.3390/nu10101410>
- Elisanti, A. D., Rindiani, R., Purnasari, G., Amareta, D. I., & Permadi, M. R. (2025). Nutritional content of gluten-free cookies as an alternative snack for undernourished children. *IOP Conference Series: Earth and Environmental Science*, 1446, 012029. <https://doi.org/10.1088/1755-1315/1446/1/012029>
- Ferradji, S., Bourekoua, H., Djeghim, F., Ayad, R., Krajewska, M., & Różyło, R. (2024). Development of a novel gluten-free cookie premix enriched with natural flours using an extreme vertices design: Physical,

- sensory, rheological, and antioxidant characteristics. *Applied Sciences*, 14(22), 10391. <https://doi.org/10.3390/app142210391>
- Flores-Jiménez, N. T., Ulloa, J. A., & Urías-Silvas, J. E. (2024). Assessment of the physicochemical, functional and structural characteristics of a defatted flour from guamuchil (*Pithecellobium dulce* (Roxb.)) seeds. *Future Foods*, 9, 100351. <https://doi.org/10.1016/j.fufo.2024.100351>
- Gagnetten, M., Pieniazek, F., Archaina, D., et al. (2023). Texture study of gluten-free cookies added with fibre by instrumental, image and sensory analysis. *Food Measure*, 17, 4034–4044. <https://doi.org/10.1007/s11694-023-01943-3>
- Giri, N. A., & Sakhale, B. K. (2021). Effects of incorporation of orange-fleshed sweet potato flour on physicochemical, nutritional, functional, microbial, and sensory characteristics of gluten-free cookies. *Journal of Food Processing and Preservation*, 45, e15324. <https://doi.org/10.1111/jfpp.15324>
- Goubgou, M., Songré-Ouattara, L. T., Bationo, F., et al. (2021). Biscuits: A systematic review and meta-analysis of improving the nutritional quality and health benefits. *Food Production, Processing and Nutrition*, 3, 26. <https://doi.org/10.1186/s43014-021-00071-z>
- Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams. *Campbell Systematic Reviews*, 18, e1230. <https://doi.org/10.1002/cl2.1230>
- Hamdani, A. M., Wani, I. A., & Bhat, N. A. (2021). Pasting, rheology, antioxidant and texture profile of gluten-free cookies with added seed gum hydrocolloids. *Food Science and Technology International*, 27(7), 649–659. <https://doi.org/10.1177/1082013220980594>
- Huong, N. T. M., Tien, N. N. T., Phi, N. T. L., Hoa, P. N., & Van Hung, P. (2025). Quality and digestibility of gluten-free cookies made from rice flour substituted with highly enzyme-resistant mung bean starch. *International Journal of Food Science*, 2025, 7689819. <https://doi.org/10.1155/ijfo/7689819>
- Jan, K. N., Panesar, P. S., & Singh, S. (2018). Optimization of antioxidant activity, textural and sensory characteristics of gluten-free cookies made from whole Indian quinoa flour. *LWT – Food Science and Technology*, 93, 573–582. <https://doi.org/10.1016/j.lwt.2018.04.013>
- Lonescu, V. A., Ciontu, A. E., Ianuş, G. I., et al. (2025). Celiac disease: Diagnostic advances, differential challenges, and interface with non-celiac gluten sensitivity. *Gastrointestinal Disorders*, 7(4), 79. <https://doi.org/10.3390/gidisord7040079>
- Lu, X., Kraithong, S., Theppawong, A., et al. (2025). The multifunctional role of hydrocolloids in modulating retrogradation, starch hydrolysis, and the gut microbiota. *Food Chemistry*, 489, 144974. <https://doi.org/10.1016/j.foodchem.2025.144974>
- Luque-Vilca, O. M., Paredes-Erquinigo, J. Y., Quille-Quille, L., et al. (2024). Utilization of sustainable ingredients (cañihua flour, whey, and potato starch) in gluten-free cookie development: Analysis of technological and sensorial attributes. *Foods*, 13(10), 1491. <https://doi.org/10.3390/foods13101491>
- Makovicky, P., Makovicky, P., Caja, F., et al. (2020). Celiac disease and gluten-free diet: Past, present, and future. *Gastroenterology and Hepatology from Bed to Bench*, 13(1), 1–7.
- Martínez, E., García-Martínez, R., Álvarez-Ortí, M., et al. (2021). Elaboration of gluten-free cookies with defatted seed flours: Effects on technological, nutritional, and consumer aspects. *Foods*, 10(6), 1213. <https://doi.org/10.3390/foods10061213>
- Melini, V., & Melini, F. (2019). Gluten-free diet: Gaps and needs for a healthier diet. *Nutrients*, 11(1), 170. <https://doi.org/10.3390/nu11010170>
- Mohammadi, M., Khorshidian, N., Yousefi, M., & Khaneghah, A. M. (2022). Physicochemical, rheological, and sensory properties of gluten-free cookie produced by flour of chestnut, date seed, and modified starch. *Journal of Food Quality*, 2022, 5159084. <https://doi.org/10.1155/2022/5159084>

- Mulla, M. F. Z., Mullins, E., Lynch, R., & Gallagher, E. (2025). A mixture design approach to investigate the impact of raw and processed chickpea flour on the techno-functional properties in a bakery application. *LWT – Food Science and Technology*, 229, 118206. <https://doi.org/10.1016/j.lwt.2025.118206>
- Nakilcioğlu, E., & Ötleş, S. (2022). Multiresponse optimization of physical, chemical, and sensory properties of the gluten-free cake made with whole white quinoa flour. *Journal of Food Science and Technology*, 59(10), 3836–3847. <https://doi.org/10.1007/s13197-022-05406-3>
- Ndovie, P., Nkhata, S. G., Geresomo, N., et al. (2025). Nutritional, functional, and microbial qualities of legume-based flour blends processed by SMEs in Zambia and Malawi compared to standard corn-soy blend plus (CSB+): A cross-sectional study. *BMC Nutrition*, 11(1), 49. <https://doi.org/10.1186/s40795-025-01034-0>
- Nugraheni, M., Sutopo, Purwanti, S., & Handayani, T. H. W. (2019). Nutritional, physical and sensory properties of high protein gluten and egg-free cookies made with resistant starch type 3 *Maranta arundinaceae* flour and flaxseed. *Food Research*, 3(6), 658–663. [https://doi.org/10.26656/fr.2017.3\(6\).145](https://doi.org/10.26656/fr.2017.3(6).145)
- Punia Bangar, S., Sharma, N., Singh, A., Phimolsiripol, Y., & Brennan, C. S. (2022). Glycaemic response of pseudocereal-based gluten-free food products: A review. *International Journal of Food Science & Technology*, 57, 4936–4944. <https://doi.org/10.1111/ijfs.15890>
- Punfujinda, C., Pattarathitawat, P., Chombhuphan, R., et al. (2025). Physical and chemical properties of gluten-free biscuits incorporated with purple sweet potato flour. *International Journal of Food Science*, 2025, 9955286. <https://doi.org/10.1155/ijfo/9955286>
- Silav-Tuzlu, G., & Tacer-Caba, Z. (2021). Influence of chia seed, buckwheat and chestnut flour addition on the overall quality and shelf life of gluten-free biscuits. *Food Technology and Biotechnology*, 59(4), 463–474. <https://doi.org/10.17113/ftb.59.04.21.7204>
- Silva-Paz, R. J., Silva-Lizárraga, R. R., Jamanca-Gonzales, N. C., & Eccoña-Sota, A. (2024). Evaluation of the physicochemical and sensory characteristics of gluten-free cookies. *Frontiers in Nutrition*, 10, 1304117. <https://doi.org/10.3389/fnut.2023.1304117>
- Stoin, D., Poiana, M.-A., Alexa, E., et al. (2025). Current trends in gluten-free biscuit formulation using rice flour enriched with chestnut flour and fruit powders. *Foods*, 14(23), 4074. <https://doi.org/10.3390/foods14234074>
- Thelma, K., Shonisani, M., Ramashia, E., & Edward, M. (2025). Nutritional composition, antioxidant, and sensory characteristics of gluten-free biscuits produced from malted finger millet (*Eleusine coracana*) flours. *Discover Food*. <https://doi.org/10.1007/s44187-025-00408-4>
- Ye, L., Zheng, W., Li, X., et al. (2023). The role of gluten in food products and dietary restriction: Exploring the potential for restoring immune tolerance. *Foods*, 12(22), 4179. <https://doi.org/10.3390/foods12224179>
- Ziobro, R., Juszczak, L., Witczak, M., & Korus, J. (2016). Non-gluten proteins as structure forming agents in gluten-free bread. *Journal of Food Science and Technology*, 53(1), 571–580. <https://doi.org/10.1007/s13197-015-2043-5>