Journal of Food Science

ORIGINAL ARTICLE OPEN ACCESS

Sensory and Consumer Sciences

Comparison Analyses of Consumer Acceptance, Evoked Emotions, and Purchase Intent Between Gluten-Containing Versus Gluten-Free Chocolate Chip Cookie Products

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Received: 17 December 2024 | **Revised:** 10 April 2025 | **Accepted:** 30 April 2025

Funding: This study was based upon work that is supported, in part, by the University of Arkansas Honors College Research Grant to S.F. and the United States Department of Agriculture National Institute of Food and Agriculture Hatch Act funding (7001030) to H.-S.S.

Keywords: cookie | emotion | gluten | gluten-free | sensory

ABSTRACT

The demand for gluten-free products has increased significantly over the past few decades. This study aimed to determine differences in consumer acceptance, emotional responses, and purchase intent between gluten-containing versus gluten-free chocolate chip cookies. Twelve commercially available chocolate chip cookie products from 11 brands were evaluated, including 7 gluten-free and 5 gluten-containing options. Eighty-nine participants without celiac disease took part in this 2-day study, evaluating six cookies per day. Participants rated sensory acceptance (appearance, flavor, texture, and overall liking) using a 9-point hedonic scale and evaluated specific sensory attributes (chocolate flavor, sweetness, chewiness, and hardness) using a 5-point just-about-right (JAR) scale. Emotional responses were measured using a circumplex-inspired emotion questionnaire, and purchase intent was rated on a 9-point scale. Results showed that gluten-free cookies received significantly lower hedonic ratings for flavor, texture, and overall impression compared to gluten-containing cookies ($p < 0.05$). Among gluten-free samples, 44.14%, 34.03%, 21.99%, and 43.02% of participants rated chocolate flavor, sweetness, hardness, and chewiness, respectively, as "too little," whereas 38.04% rated hardness as "too much." These deviations from ideal intensities significantly reduced overall liking for the gluten-free cookies samples ($p < 0.05$). Additionally, gluten-free cookies more frequently elicited negative valence-related emotions, such as "blue/uninspired," "unhappy/dissatisfied," "tense/bothered," and "jittery/nervous," and were associated with lower purchase intent scores ($p < 0.05$). In conclusion, our findings indicate that most gluten-free cookies evaluated in this study remain less favored than their gluten-containing counterparts in terms of consumer acceptance, evoked emotions, and purchase intent.

Practical Applications: These findings provide valuable guidance for product developers and sensory professionals aiming to enhance the quality of gluten-free cookies. Improving key sensory attributes, especially flavor and texture (chocolate flavor, sweetness, hardness, and chewiness), has the potential to significantly increase consumer acceptance and emotional satisfaction. Enhancing the sensory and emotional appeal of gluten-free products can elevate both the diversity and quality of options available on the market, ultimately benefiting consumers who require gluten-free diets by offering a wider selection of enjoyable and emotionally satisfying products.

1 | Introduction

The need for gluten-free products has grown over the last decade. It is largely due to a rise in the diagnosis of celiac disease, wheat allergies, and gluten intolerance, as well as the increased awareness of gluten-related disorders (Fasano and Catassi 2012; Shewry 2019). Celiac disease is a genetic disorder that damages the small intestine upon gluten ingestion, affecting as many as 1 in 133 Americans (Demirkesen and Ozkaya 2020). The treatment for celiac disease, wheat allergies, and gluten intolerance is total avoidance of gluten in diet. However, as gluten, the protein that is found in wheat, rye, barley, and triticale, plays an important role in holding food components together and keeping food shape (Delcour et al. 2012; Jnawali et al. 2016; El Khoury et al. 2018), it is included in a wide spectrum of food and beverages. Therefore, maintaining a total avoidance of food and beverages, including gluten, can be challenging in daily life. Gluten-free food products tend to be less nutritious, less tasty, more expensive, less available, and have quality issues, which would be another cause of poor adherence for people needing to follow a gluten-free diet (Demirkesen and Ozkaya 2020; Alencar et al. 2021).

With the growing number of individuals adopting a gluten-free diet, the demand for gluten-free products has increased significantly. In 2019, the global market was valued at \$21.61 billion and is projected to reach approximately \$24 billion by 2027 (Aguiar et al. 2021). Despite the rise in product availability driven by this demand, gluten-free foods are still frequently reported to lack diversity and desirable sensory attributes (Alencar et al. 2021; Eastlake 2024). Gluten-free food samples are frequently characterized as being smaller, more crumbly, lighter in color, blander in flavor, and denser compared to their gluten-containing counterparts (O'Shea et al. 2014; Alencar et al. 2021). According to Laureati et al. (2012), the acceptance of gluten-free bread is positively associated with sweet taste, porosity, and softness, whereas negatively associated with salty taste, rubberiness, and adhesiveness in both celiac and non-celiac participants. In another study, Iwamura et al. (2022) identified sweet taste, salty taste, and softness as key sensory drivers of liking for gluten-free bread made with sorghum, teff, and/or yacon flours. A recent study by Alencar et al. (2021) found that among 205 Brazilian consumers with celiac disease, 32% and 30% cited the taste and texture, respectively, as the most significant shortcomings of gluten-free food products. These concerns were followed by issues related to price (19%), limited product variety and availability in retail locations (15%), and the absence of gluten-free alternatives for specific food items, such as pizza and bread rolls (12%). Together, these factors contribute to celiac consumers' dissatisfaction with the current offerings in the gluten-free market (Alencar et al. 2021).

As wheat flour cannot be used in gluten-free products, alternative ingredients must be employed. Consequently, numerous studies have explored how these substitutes, along with processing methods, can improve the physicochemical properties, sensory qualities, and nutritional aspects of gluten-free foods (Jnawali et al. 2016; El Khoury et al. 2018; Jamieson et al. 2018; Taetzsch et al. 2018; Ho et al. 2023; Kaur et al. 2024). Flours derived from potatoes, rice, maize, and sorghum are commonly used in gluten-free foods due to their mild flavors and neutral baking properties (O'Shea et al. 2014; Jnawali et al. 2016; Gao et al. 2017; Iwamura et al. 2022). The choice of flour typically depends on the specific product being developed; for example, rice flour is the most commonly used base for gluten-free cookies (Xu et al. 2020). Although these flours share a relatively bland flavor profile, they vary in the textures they contribute to the final product (Jnawali et al. 2016; El Khoury et al. 2018). Furthermore, previous research has shown that gluten-free processed foods often contain higher fat levels and lower amounts of essential nutrients, such as protein, compared to their gluten-containing counterparts (Jamieson et al. 2018; Roman et al. 2019).

Over the past decade, research on gluten-free foods has expanded significantly, accompanied by a notable rise in published studies incorporating sensory analysis (Capriles et al. 2023). The number of such publications increased from 17 in 2012 to 105 in 2022 (Capriles et al. 2023). Despite this growing body of literature, critical knowledge gaps remain. First, as highlighted by Capriles et al. (2023) in their recent review, few studies have investigated the sensory characteristics and consumer purchasing behaviors associated with commercially available gluten-free products. Although previous research has examined sensory attributes, it has largely focused on variations in sensory quality stemming from ingredient composition and processing techniques under controlled laboratory conditions (Capriles et al. 2023). However, Roman et al. (2019) emphasized a significant disconnect between laboratory-based findings and the realities of commercial gluten-free products. For example, ingredients and processing methods commonly explored in academic research are often not used in commercially produced items (Roman et al. 2019). This highlights the importance of examining the sensory drivers and characteristics of gluten-free products currently available on the market. Second, little attention has been paid to the emotional responses elicited by gluten-free food samples (Aguiar et al. 2022; Capriles et al. 2023). Given the influence of emotional responses on product acceptance and purchasing behavior (Seo et al. 2009; Samant and Seo 2020; Gurdian et al. 2022), understanding how gluten-free products evoke emotions, especially in comparison to their gluten-containing counterparts, is crucial. Although some studies have addressed emotional responses, they have typically focused on specific variables, such as flour blend ratios in bread (Aguiar et al. 2022) or sweetener types in muffins (Wardy et al. 2018). Research specifically examining the emotional impact of commercially available gluten-free products remains scarce. Additionally, among gluten-free products, bread has been the most extensively studied and serves as the primary reference point in sensory research (Aguiar et al. 2021; Alencar et al. 2021). However, cookies are also a widely consumed option among individuals with celiac disease (Alencar et al. 2021). Therefore, this study focused on the sensory and emotional responses to commercially available gluten-free chocolate chip cookies.

This study aimed to compare commercially available gluten-containing and gluten-free chocolate chip cookies with respect to sensory acceptance, sensory intensity, emotional responses, and purchase intent. The research was guided by the following three research questions (RQs):

RQ 1: What specific sensory attributes differ between gluten-containing and gluten-free chocolate chip cookie products in terms of consumer perception and acceptance?

RQ 2: What specific emotional attributes are elicited by gluten-containing versus gluten-free chocolate chip cookie products?

RQ 3: How do gluten-containing and gluten-free chocolate chip cookie products differ in terms of consumer purchase intent?

2 | Materials and Methods

2.1 | Participants

A total of 89 participants (60 females and 29 males) ranging from age 21 to 70 years (mean age ± standard deviation [SD] = 40 ± 14 years) participated in this study. They were recruited using the consumer profile database of the University of Arkansas Sensory Science Center (Fayetteville, AR, USA) and self-reported no diseases or conditions that would impact their sensory functions. Participants also self-reported no allergies related to food ingredients. Participants reported consuming cookie products at least once a month. As participants were required to consume both gluten-containing and gluten-free food samples, individuals with celiac disease were excluded from this study. Table S1 represents demographic profiles of the participants in this study.

This study was conducted following the Declaration of Helsinki for human-based studies. The protocol (2311502798) used in this study was approved by the University of Arkansas' Institutional Review Board (IRB) in Fayetteville, AR, USA. Prior to participation, each participant provided voluntary written informed consent.

2.2 | Chocolate Chip Cookie Samples

Across 11 brands, 12 products, including 5 gluten-containing and 7 gluten-free products, were used for this study. The test products were chosen to ensure a wide range of sensory attributes on the basis of a preliminary test at the University of Arkansas Sensory Science Center. Four sensory professionals sampled over 20 different chocolate chip cookie products and selected 12 ones on the basis of their sensory and ingredient characteristics, as shown in Table 1. All samples used in this study were acquired from markets within the United States.

The color attributes and textural properties of the chocolate chip cookie samples were measured using a portable colorimeter (MiniScan XE Plus, HunterLab, Reston, VA, USA) and a texture analyzer (TA-XT2i, Stable Micro Systems, Godalming, UK), respectively. On the basis of the CIE L^*, a^*, and b^* system, L^* (brightness) ranging from 0 (black) to 100 (white), a^* for redness (+) or greenness (−), and b^* for yellowness (+) or blueness (−) were measured. For each sample, five cookie subsamples were measured in duplicate. In addition, hardness of the test cookie samples was assessed by a compression test using a spherical probe (6.25 mm diameter), with pre-test, test, and post-test speeds set at 1.0, 0.5, and 1.0 mm/s, respectively. A strain of 70% was applied to compress the cookies to a set distance, simulating the force required for a human to bite a cookie. This process measured the force needed to penetrate the surface of the cookie, providing insights into its hardness (Gagneten et al. 2023).

2.3 | Procedure of Sensory Evaluation

Each participant evaluated 12 cookie samples over 2 separate days, with a minimum interval of 1 week between sessions. On each day, participants were presented with six cookie samples, labeled with three-digit codes and served in a randomized order. Due to logistical constraints, the same six cookie samples were presented to participants on each testing day: for example, three gluten-containing and three gluten-free on Day 1 (or Day 2), and two gluten-containing and four gluten-free on Day 2 (or Day 1). Participants were asked to refrain from cigarette smoking, eating, and drinking (except water) for at least 2 h before their participation (Cho et al. 2017).

Using a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely), participants rated sensory acceptance on the basis of appearance, texture, flavor, and overall liking. Participants also provided comments on what they liked or what they disliked for each cookie sample. Additionally, a 5-point just-about-right scale (JAR) was utilized to determine the JAR ratings with respect to chocolate flavor, sweetness, chewiness, and hardness. Emotional responses were assessed using the Circumplex-inspired Emotion Questionnaire (CEQ) developed by Jaeger et al. (2020). The CEQ was selected for its balanced representation of both pleasant and unpleasant emotion terms, as well as its comprehensive coverage of the valence and arousal dimensions (Jaeger et al. 2021; Seo et al. 2023). The CEQ has been widely used to assess emotional responses to a variety of food and beverage items, including beer (Jaeger et al. 2022), crackers (Jaeger et al. 2022), kiwifruit (Jaeger et al. 2021), potato chips (Jaeger et al. 2021), salted snacks (Jaeger et al. 2022), and yogurt (Jaeger et al. 2021). It includes 12 emotion terms: "active/alert," "energetic/excited," "enthusiastic/inspired," "happy/satisfied," "secure/at ease," "relaxed/calm," "passive/quiet," "dull/bored," "blue/uninspired," "unhappy/dissatisfied," "tense/bothered," and "jittery/nervous" (Jaeger et al. 2020). Consistent with previous studies (Jaeger et al. 2021; Seo et al. 2023), the multiple-choice layout variant of the CEQ was employed in this study. Finally, participants also rated their purchase intent for each cookie sample on a 9-point category scale ranging from 1 (definitely would not buy) to 9 (definitely would buy). A 1-min break was given between sample presentations. During each break, spring water (Clear Mountain Spring Water, Taylor Distributing, Herber Springs, AR, USA) and unsalted crackers (Nabisco Premium Unsalted Tops Saltine Crackers, Mondelēz Global LLC, East Hanover, NJ, USA) were provided as palate cleansers.

2.4 | Data Analysis

Data collection of sensory testing was performed using Compusense Cloud (Compusense Inc., Guelph, ON, Canada). Data were analyzed using JMP Pro (version 17, SAS Institute Inc., Cary, NC, USA) and XLSTAT (Addinsoft, New York, NY, USA). To determine whether 12 cookie samples could differ in terms of color parameters or texture property, a one-way analysis of variance (ANOVA), treating "cookie sample" (12 samples) or "gluten presence" (gluten-containing vs. gluten-free) as a fixed effect, was conducted. Post hoc tests were conducted using Tukey's honest significant difference (HSD) tests.

TABLE 1 | Characteristics and ingredients of the gluten-containing (GC) and gluten-free (GF) chocolate chip cookie samples used in this study.

Code	Characteristics				Type of flour
	CR	CW	TH	NS	
GC_A	○	×	×	×	Unbleached enriched flour (wheat flour, niacin, reduced iron, thiamine mononitrate, riboflavin, folic acid).
GC_B	×	○	×	×	Enriched bleached flour (wheat flour, niacin, reduced iron, thiamine mononitrate, riboflavin, folic acid).
GC_C	○	×	×	○	Enriched flour (wheat flour, niacin, reduced iron, thiamine mononitrate, riboflavin, folic acid).
GC_D	○	×	×	×	Enriched flour (wheat flour, niacin, reduced iron, thiamine mononitrate, riboflavin, folic acid).
GC_E	×	○	×	×	Enriched flour (wheat flour, niacin, iron, thiamin, riboflavin, folic acid).
GF_F	×	○	×	×	Gluten-free flour blend (organic light buckwheat flour, gluten-free oat flour, cassava flour, tapioca flour)
GF_G	×	○	×	×	Gluten-free flour blend (white rice flour, potato starch, tapioca starch, xanthan gum)
GF_H	○	×	×	×	Tapioca starch, resistant corn starch, rice flour
GF_I	○	×	×	×	Gluten-free flour blend (organic light buckwheat flour, gluten-free oat flour, cassava flour, tapioca flour)
GF_J	×	○	×	×	Gluten-free flour blend (white rice flour, corn starch, brown rice flour, tapioca starch, oat flour, potato starch, coconut milk powder, xanthan gum), rice starch
GF_K	○	×	×	×	Nut & seed flour blend (almonds, organic coconut, flaxseeds), tapioca starch
GF_L	○	×	○	×	Gluten-free flour blend (oat flour, potato starch, oat hull fiber, tapioca starch)

Abbreviations: CR = crunchy; CW = chewy; TH = thin; NS = no sugar; ○ = yes; × = no.

For sensory data, a two-way mixed model, treating "cookie sample" (12 samples) or "gluten presence" (gluten-containing vs. gluten-free) as a fixed effect and "participant" as a random effect, was performed. Post hoc tests were conducted using Tukey's HSD tests. To visualize associations between hedonic impressions (i.e., attribute and overall liking) and cookie samples, principal component analysis (PCA) was performed using the covariance matrix. As recommended by Borgognone et al. (2001), PCA based on the covariance matrix is more appropriate than using the correlation matrix in most sensory studies, especially when identical sensory scales (9-point hedonic scale in this study) are applied across all attributes. Additionally, Partial Least Squares Regression (PLSR) analysis was conducted to model overall liking (Y-matrix) using independent variables (X-matrix), including appearance liking, flavor liking, and texture liking. Both X and Y matrices were centered and scaled. Leave-One-Out cross-validation was applied to identify the minimal number of factors needed to minimize the root mean PRESS statistics (RM-PRESS) and maximize the explained variance for Y (Cox and Gaudard 2013; Samant and Seo 2020). The importance of the independent variables in the model was determined using variable influence on projection (VIP) values and model coefficients. Variables with VIP values greater than 0.8 were considered significant in modeling overall liking (Samant and Seo 2020). For the JAR data, a penalty analysis was performed to determine the positive and negative drivers of overall liking for cookie samples. Finally, participant feedback regarding attributes they liked or disliked about the gluten-containing and gluten-free samples was analyzed using chi-square tests and z-tests. The data were also visually represented through word cloud analysis.

For CATA data of evoked emotions, Cochran's Q-test was conducted to test whether 12 cookie samples differed in terms of the proportions of selection of individual terms of the CEQ emotions. For each emotion term, multiple pairwise comparisons were conducted using the critical difference (Sheskin) procedure. A correspondence analysis (CA) was also conducted to visualize associations between cookie samples and evoked emotions. Additionally, z-tests were performed to compare the proportions of each emotion term cited by participants for gluten-containing versus gluten-free cookies.

For purchase intent data, a two-way mixed model, treating "cookie sample" (12 samples) or "gluten presence" (gluten-containing vs. gluten-free) as a fixed effect and "participant" as a random effect, was performed. Post hoc tests were conducted using Tukey's HSD tests. A statistical difference was defined when $p < 0.05$.

3 | Results

3.1 | Color and Textural Properties of Cookie Samples

When analyzing the effect of gluten presence (gluten-containing vs. gluten-free) on the color properties of chocolate chip cookies, the gluten-containing samples exhibited higher L^*, a^*, and b^* values (Table 2). This indicates that, on average, they are lighter in color, as well as redder and more yellow, compared to the gluten-free samples: L^* ($F = 11.98$, $p = 0.001$), a^* ($F = 6.12$, $p = 0.02$),

TABLE 2 | Mean (± standard deviation) comparisons between gluten-containing and gluten-free cookie samples in terms of color attributes and texture property (maximum force).

Category	Subcategory	Gluten-containing	Gluten-free	*F*-ratio (*p* value)
Color	L^*	56.67a (±4.16)	53.34b (±5.35)	11.98 (0.001)
	a^*	10.37a (±1.41)	9.72b (±1.41)	6.12 (0.02)
	b^*	31.72a (±3.34)	28.52b (±2.66)	34.17 (<0.001)
Texture	Maximum force (g)	3031.03a (±1464.70)	2832.50a (±2176.89)	0.13 (0.73)

Note: Means with different letters within a row indicate a significant difference at $p < 0.05$.

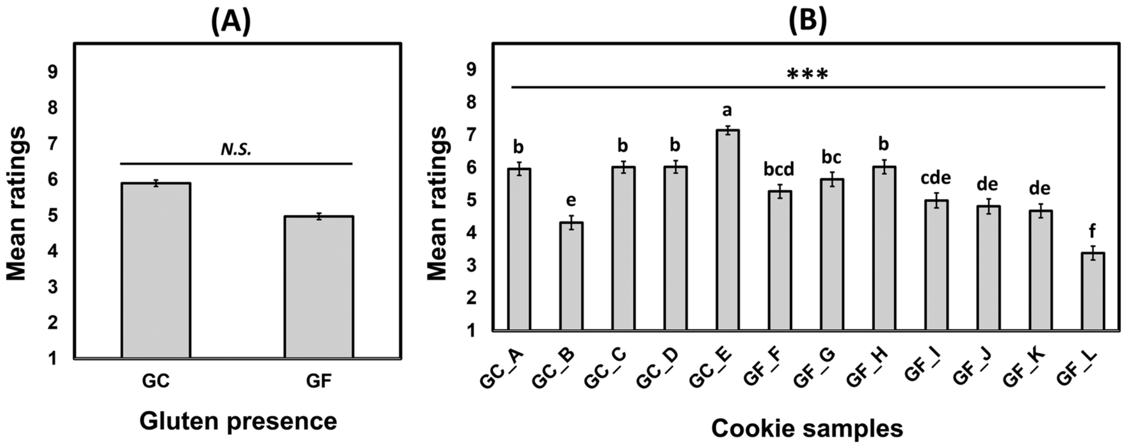

FIGURE 1 | **Mean comparisons (with error bars representing the standard error of the means) of appearance liking with respect to (A) gluten presence and (B) cookie samples**. GC and GF indicate gluten-containing and gluten-free, respectively. N.S. represents no significant difference at $p < 0.05$. *** Represents a significance at $p < 0.001$. Mean ratings with different letters indicate a significant difference at $p < 0.05$.

and b^* ($F = 34.17$, $p < 0.001$). Table S2 shows that the three color parameters, L^*, a^*, and b^*, differed significantly among the 12 cookie samples (for all, $p < 0.001$).

When examining the effect of gluten presence on the textural property (hardness) of chocolate chip cookies, no significant difference was observed between the gluten-containing and gluten-free samples in terms of maximum force ($F = 0.13$, $p = 0.73$), as shown in Table 2. Table S3 presents variations in the maximum force (hardness) among the 12 cookie samples.

3.2 | Sensory Properties of Cookie Samples

3.2.1 | Hedonic Impression

The presence of gluten (gluten-containing vs. gluten-free) had no significant effect on participants' appearance liking of the cookie samples ($F = 2.95$, $p = 0.12$). However, as shown in Figure 1, appearance liking varied significantly across the 12 cookie samples ($F = 31.33$, $p < 0.001$). Sample GC_E received the highest mean ratings for appearance, indicating it was the most visually appealing, whereas sample GF_L received the lowest.

As illustrated in Figure 2, participants significantly liked the flavor of gluten-containing cookies significantly more than that of gluten-free ones ($F = 12.91$, $p = 0.005$). Among the 12 samples, sample GC_D received significantly higher flavor ratings compared to samples GC_B, GF_F, GF_G, GF_I, GF_J, GF_K, and GF_L ($F = 22.81$, $p < 0.001$).

Similarly, texture liking ratings were significantly higher for gluten-containing cookies than for gluten-free cookies ($F = 27.32$, $p = 0.004$), as shown in Figure 3. Sample GC_E was rated significantly higher in texture liking than all gluten-free samples, and it differed significantly from one gluten-containing sample, GC_C ($F = 15.58$, $p < 0.001$).

In terms of overall liking, gluten-containing cookies gain outperformed gluten-free cookies, receiving significantly higher ratings from participants ($F = 18.90$, $p < 0.001$), as shown in Figure 4. Samples GC_D and GC_E received the highest overall liking ratings and were rated significantly higher than all gluten-free samples, except GF_H ($F = 20.59$, $p < 0.001$). Notably, when comparing each participant's ratings of gluten-containing versus gluten-free cookies, none of the 89 participants liked the gluten-free group more than the gluten-containing group. In contrast, 23 participants rated the gluten-containing cookie group significantly higher in overall liking than the gluten-free group.

PCA of hedonic ratings (appearance, flavor, texture, and overall liking) accounted for 95.49% of the total variance. The biplot (Figure 5) clearly separated the samples into two distinct clusters along the first principal component (F1), which explained 80.99% of the variance. All gluten-containing samples, along with one gluten-free sample (GF_H), clustered together, whereas the remaining gluten-free samples formed a separate cluster.

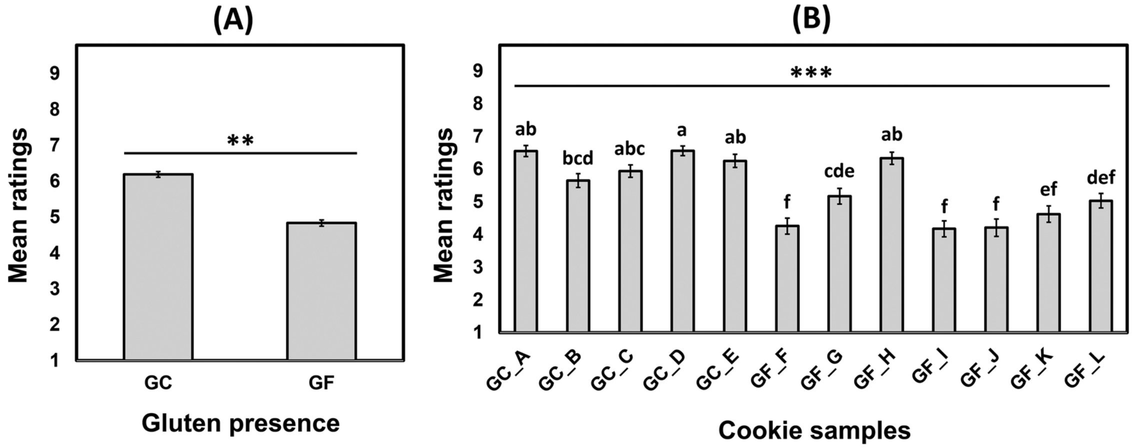

FIGURE 2 | **Mean comparisons (with error bars representing the standard error of the means) of flavor liking with respect to (A) gluten presence and (B) cookie samples**. GC and GF indicate gluten-containing and gluten-free, respectively. ** and *** represent a significance at $p < 0.01$ and $p < 0.001$, respectively. Mean ratings with different letters indicate a significant difference at $p < 0.05$.

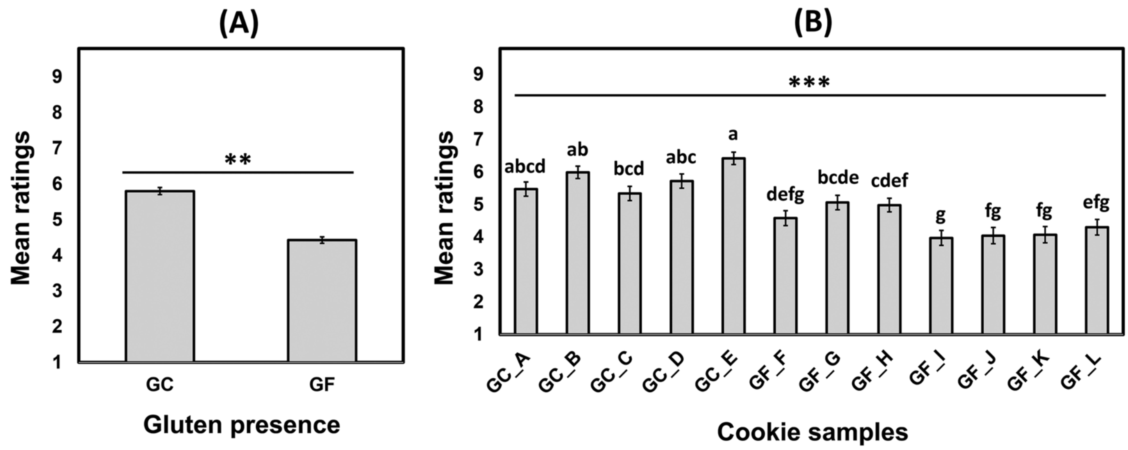

FIGURE 3 | **Mean comparisons (with error bars representing the standard error of the means) of texture liking with respect to (A) gluten presence and (B) cookie samples**. GC and GF indicate gluten-containing and gluten-free, respectively. ** and *** represent a significance at $p < 0.01$ and $p < 0.001$, respectively. Mean ratings with different letters indicate a significant difference at $p < 0.05$.

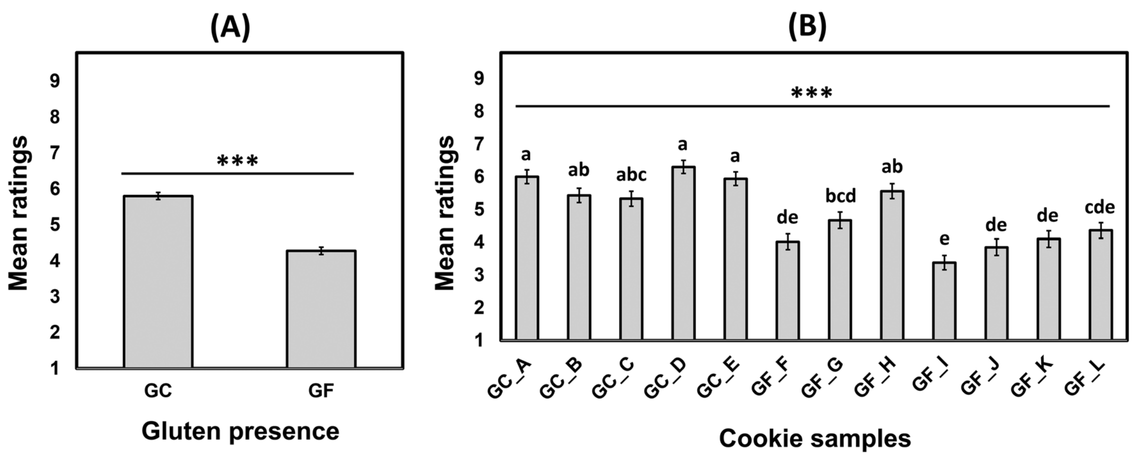

FIGURE 4 | **Mean comparisons (with error bars representing the standard error of the means) of overall liking with respect to (A) gluten presence and (B) cookie samples**. GC and GF indicate gluten-containing and gluten-free, respectively. *** Represents a significance at $p < 0.001$. Mean ratings with different letters indicate a significant difference at $p < 0.05$.

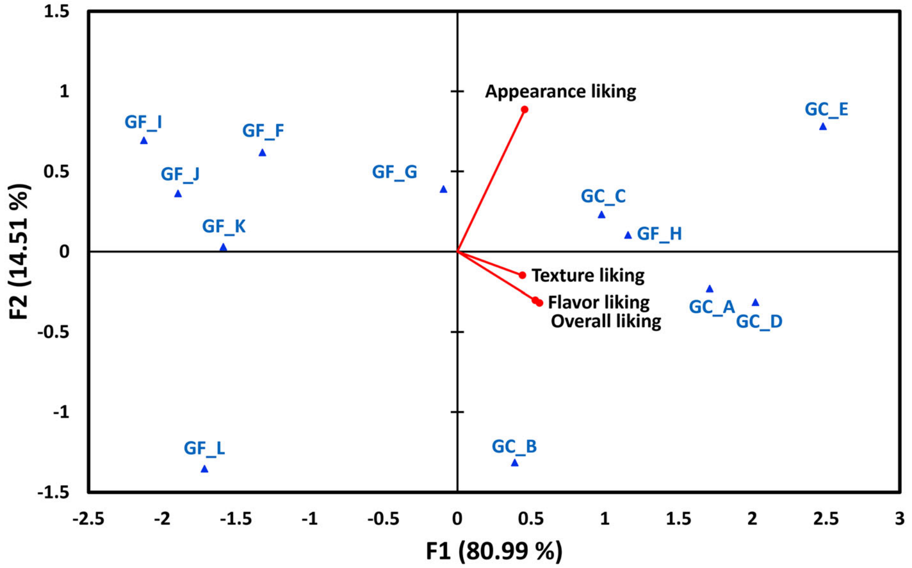

FIGURE 5 | **A biplot of principal component analysis (PCA) based on attribute and overall liking ratings across twelve cookie samples**. GC and GF indicate gluten-containing and gluten-free, respectively.

TABLE 3 | Variable influence on projection (VIP) values and standard coefficients of the partial least squares regression (PLSR) models in gluten-containing and gluten-free cookie samples.

	Gluten-containing cookies		Gluten-free cookies	
Category	**VIP**	**Standard coefficient**	**VIP**	**Standard coefficient**
Appearance liking	0.70	0.04	0.71	0.04
Flavor liking	1.19	0.58	1.17	0.60
Texture liking	1.05	0.40	1.06	0.38

Interestingly, appearance liking was not associated with flavor, texture, or overall liking ratings.

For gluten-containing cookies, the PLSR model with three factors and the lowest RM-PRESS value (0.47) accounted for 100% of the variance in the independent variables (appearance, flavor, and texture liking) and 78.38% of the variance in the dependent variable (overall liking). Among the predictors, flavor liking had the highest VIP value (1.19), followed by texture liking (1.05) and appearance liking (0.70), highlighting the dominant role of flavor and texture in influencing overall liking. Notably, flavor liking exerted the strongest impact (+0.58), compared to texture (+0.40) and appearance (+0.04) liking (Table 3). Similarly, for gluten-free cookies, the PLSR model with three factors and the lowest RM-PRESS value (0.44) explained 100% of the variance in the independent variables and 81.10% of the variance in overall liking. As with the gluten-containing cookies, flavor liking emerged as the most influential predictor (VIP value = 1.17), followed by texture liking (1.06) and appearance liking (0.71). Flavor liking also had the greatest impact on overall liking (+0.60), compared to texture (+0.38) and appearance (+0.04) liking (Table 3).

3.2.2 | JAR Attributes

As shown in Figure 6, for the gluten-containing cookies, 36.18%, 22.92%, and 30.34% of the 89 participants rated chocolate flavor, sweetness, and chewiness, respectively, as deviating from the ideal intensity. These deviations led to significant reductions in overall liking ratings by 1.93, 1.99, and 1.68 points, respectively. In addition, 29.21% of participants rated the hardness of the gluten-containing cookies as “too much,” which decreased overall liking by 1.80 points.

Among the gluten-free samples, 44.14%, 34.03%, 21.99%, and 43.02% of participants rated chocolate flavor, sweetness, hardness, and chewiness, respectively, as “too little,” resulting in declines in overall liking by 2.17, 2.74, 2.39, and 1.86 points. Furthermore, 38.04% of participants rated the hardness of the gluten-free cookies as “too much,” leading to a drop in overall liking by 1.93 points ($p < 0.05$).

3.2.3 | Comments on What Participants Liked or Disliked

The participant comments regarding attributes they liked or disliked about the gluten-containing and gluten-free samples were analyzed. Tables S4–S7 provides a comprehensive list of keywords mentioned by participants across the 12 cookie samples. Across both cookie types, “flavor” emerged as the most frequently mentioned attribute, both for likes and dislikes (Figure 7).

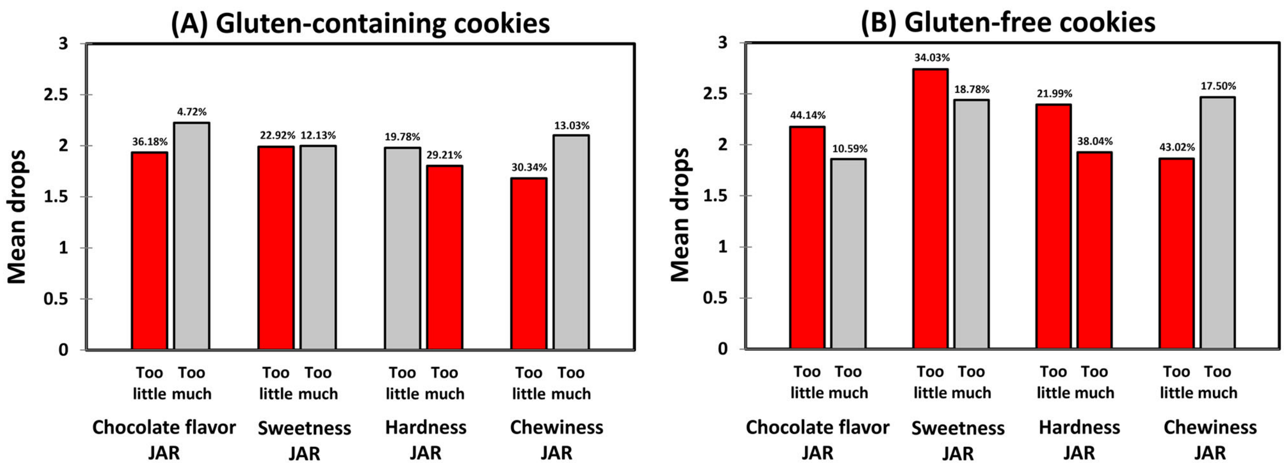

FIGURE 6 | Mean drops in overall liking associated with deviations from the just-about-right (JAR) levels for the attributes of chocolate flavor, sweetness, hardness, and chewiness with respect to (A) gluten-containing cookies and (B) gluten-free cookies. The percentage value above each “too little” bar represents the proportion of the 89 participants who rated the attribute as either “too little” or “much too little.” Similarly, the percentage value above each “too much” bar indicates the proportion who rated the attribute as either “too much” or “much too much.” Red bars denote statistically significant differences ($p < 0.05$), whereas gray bars indicate that the statistical test was not conducted due to an insufficient number of responses (i.e., less than 20%).

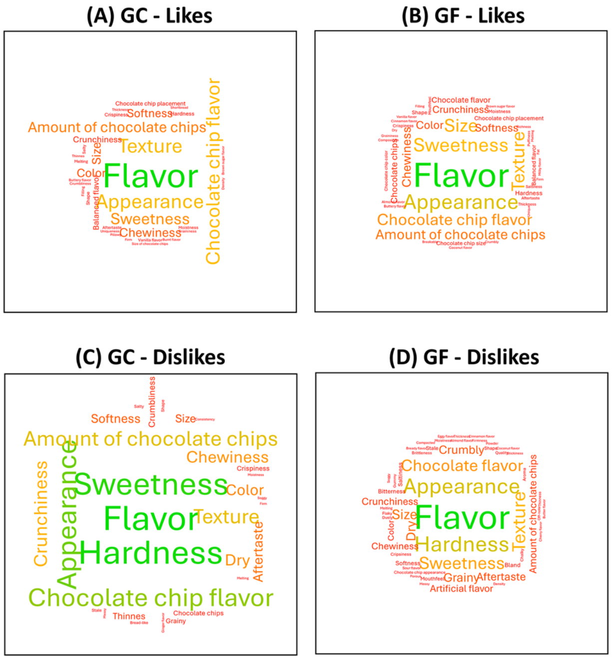

FIGURE 7 | Visualizations (word cloud) of participant comments on what they liked or disliked about the chocolate chip cookie samples: (A) their likes in gluten-containing cookies, (B) their likes in gluten-free cookies, (C) their dislikes in gluten-containing cookies, and (D) their dislikes in gluten-free cookies. The size of a keyword in each figure is proportional to the number of keywords captured from participants’ feedback.

For gluten-containing cookies, the top five keywords cited for what participants liked were “flavor” (n = 158), followed by “appearance” (n = 83), “texture” (n = 83), “chocolate chip flavor” (n = 81), and “sweetness” (n = 64). When grouped into broader categories, appearance, flavor, taste, texture, and others, attributes related to flavor, appearance, and texture were mentioned more frequently than those associated with taste or others ($p < 0.001$) (Table S8). For gluten-free cookies, the most liked attributes were “flavor” (n = 150), “appearance” (n = 85), “sweetness” (n = 76), “texture” (n = 73), and “size” (n = 72). When classified into the same five categories, participants reported attributes related to appearance as their likes more frequently than those related to texture, taste, or others ($p < 0.001$) (Table S8).

Regarding dislikes, the top five attributes mentioned for gluten-containing cookies were “flavor” (n = 78), “hardness” (n = 74), “sweetness” (n = 70), “appearance” (n = 60), and “chocolate chip flavor” (n = 55). For gluten-free cookies, participants cited “flavor” (n = 203), “hardness” (n = 119), “appearance” (n = 117), “texture” (n = 99), and “sweetness” (n = 91) as the most disliked attributes. When classified into the five categories, participants most frequently cited texture-related attributes as their likes in both gluten-containing and gluten-free cookie samples (Table S8).

When comparing groups (i.e., gluten-containing vs. gluten-free cookies), participants more frequently cited attributes related to flavor and texture from gluten-containing cookies as their likes compared to those from gluten-free cookies (Table 4). In contrast, when assessing their dislikes, attributes related to appearance, flavor, taste, and texture from gluten-free cookies were cited more often than those from gluten-containing cookies (Table 4).

3.3 | Evoked Emotions

Cochran’s Q-test revealed significant differences among the 12 cookie samples across most emotional attributes, with the exception of “dull/bored” and “blue/uninspired” ($p < 0.05$) (Table S9). Post hoc testing further confirmed no significant differences for “relaxed/calm,” “passive/quiet,” as well as “dull/bored” or “blue/uninspired” ($p > 0.05$). A biplot generated from **CA**, which explained 89.55% of the total variance, showed

TABLE 4 | Group comparisons between gluten-containing ($n = 5$) and gluten-free cookie samples ($n = 7$) for each category, based on the proportions[a] of citations by 89 participants, focusing on their likes or dislikes.

	What participants liked			What participants disliked		
Category	**Gluten-containing**	**Gluten-free**	**z value (p value)**	**Gluten-containing**	**Gluten-free**	**z value (p value)**
Appearance	0.56	0.50	1.92 (0.06)	0.37	0.44	−2.08 (0.04)
Flavor	0.60	0.41	6.12 (<0.001)	0.30	0.58	−9.46 (<0.001)
Taste	0.16	0.13	1.30 (0.19)	0.22	0.28	−2.06 (0.04)
Texture	0.53	0.36	5.54 (<0.001)	0.67	0.89	−8.66 (<0.001)
Others	0.005	0.003	0.00 (1.00)	0.01	0.03	−1.72 (0.09)

[a]The proportions represent the frequency of citations as a fraction of the total number of cases, with 445 cases for gluten-containing cookies and 623 cases for gluten-free cookies.

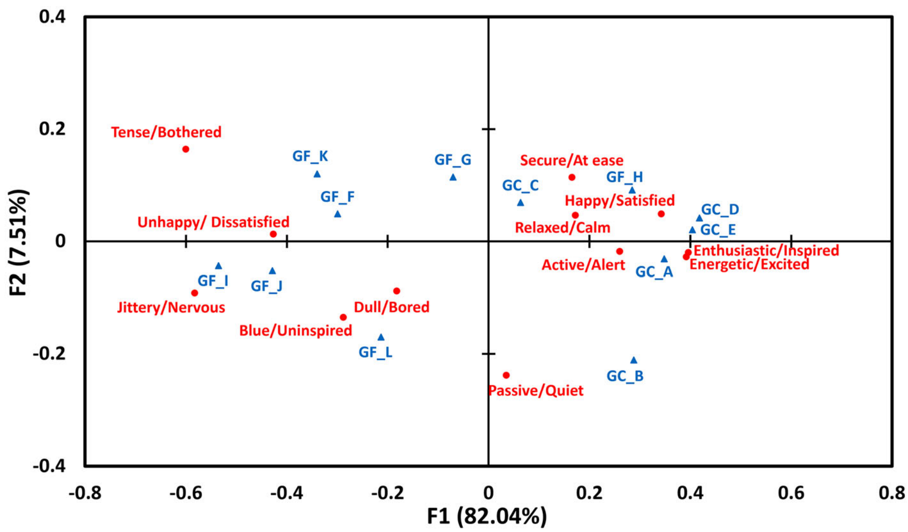

FIGURE 8 | **A biplot of correspondence analysis (CA) based on the 12 emotion terms from the circumplex-inspired emotion questionnaire (CEQ) across 12 cookie samples**. GC and GF indicate gluten-containing and gluten-free, respectively.

that all gluten-containing samples were associated with positive emotional responses (Figure 8). In contrast, the gluten-free samples, except for GF_H, were more strongly associated with negative emotions. Notably, sample GF_H did not differ significantly from the gluten-containing cookie samples in any of the 12 emotional attributes evaluated (Table S9).

When comparing broader groups (i.e., gluten-containing vs. gluten-free cookies), participants more frequently associated gluten-containing cookies with emotion terms reflecting positive valence and activation, such as "active/alert," "energetic/excited," "enthusiastic/inspired," "happy/satisfied," "secure/at ease," and "relaxed/calm (Table 5)". In contrast, emotion terms related to negative valence, such as "blue/uninspired," "unhappy/dissatisfied," "tense/bothered," and "jittery/nervous," were more frequently linked to gluten-free cookies than to gluten-containing ones ($p < 0.05$).

3.4 | Purchase Intent

When examining the purchase intent of the cookie samples, the gluten-containing group received higher ratings overall compared to the gluten-free group ($F = 17.75$, $p = 0.002$) (Figure 9). Among the 12 samples, GC_A, GC_D, and GC_E had higher purchase intent ratings than all gluten-free samples, with the exception of GF_H ($F = 17.91$, $p < 0.001$) (Figure 9).

4 | Discussion

This study aimed to investigate consumer perception and acceptance of gluten-free cookie products available in the market (Roman et al. 2019; Capriles et al. 2023), as well as emotional responses to gluten-containing versus gluten-free foods. Specifically, it compared gluten-containing and gluten-free chocolate chip cookies in terms of consumer perception and acceptance, evoked emotions, and purchase intent. We discussed the study's results that provided answers to the three RQs.

4.1 | Consumer Perception and Acceptance Differed Between Gluten-Containing and Gluten-Free Cookie Products

Across the 12 products examined, gluten-containing cookie samples were consistently favored over their gluten-free counterparts

TABLE 5 | Group comparisons between gluten-containing ($n = 5$) and gluten-free cookie samples ($n = 7$) for each emotion attribute, based on the proportions[a] of citations by 89 participants.

Emotion attributes	Gluten-containing	Gluten-free	z value (p value)
Active/Alert	0.24	0.16	3.25 (0.001)
Energetic/Excited	0.17	0.09	3.56 (<0.001)
Enthusiastic/Inspired	0.17	0.10	3.16 (0.002)
Happy/Satisfied	0.48	0.27	6.97 (<0.001)
Secure/At ease	0.33	0.24	3.04 (0.002)
Relaxed/Calm	0.35	0.25	3.58 (<0.001)
Passive/Quiet	0.21	0.18	1.42 (0.16)
Dull/Bored	0.19	0.22	−0.95 (0.34)
Blue/Uninspired	0.11	0.16	−2.18 (0.03)
Unhappy/Dissatisfied	0.21	0.45	−8.72 (<0.001)
Tense/Bothered	0.08	0.27	−8.70 (<0.001)
Jittery/Nervous	0.03	0.09	−3.51 (<0.001)

[a]The proportions represent the frequency of citations as a fraction of the total number of cases, with 445 cases for gluten-containing cookies and 623 cases for gluten-free cookies.

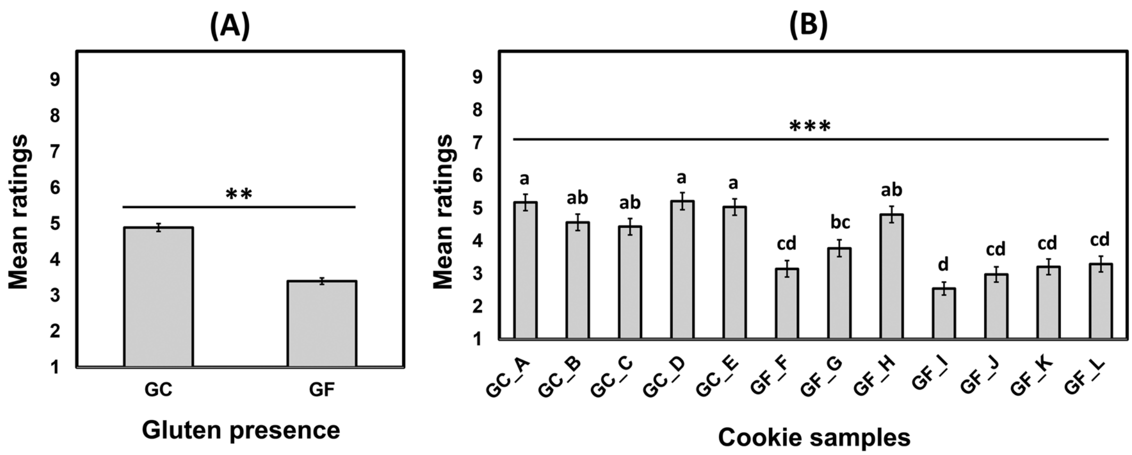

FIGURE 9 | **Mean comparisons (with error bars representing the standard error of the means) of purchase intent ratings with respect to (A) gluten presence and (B) cookie samples**. GC and GF indicate gluten-containing and gluten-free, respectively. ** and *** represent a significance at $p < 0.01$ and $p < 0.001$, respectively. Mean ratings with different letters indicate a significant difference at $p < 0.05$.

in terms of flavor, texture, and overall likings (Figures 2–4). Notably, none of the 89 participants liked the gluten-free cookie group more than the gluten-containing group evaluated in this study. This aligns with prior research indicating that gluten-free options generally exhibit inferior sensory qualities and consumer acceptance, particularly in baked food items (Drabińska et al. 2016). This study corroborates the prevailing view that gluten-free products are less sensory appealing by evaluating commercially available items. However, whereas most gluten-free samples scored lower on flavor, texture, and overall liking, one exception, sample GF_H, made with tapioca starch, resistant corn starch, and rice flour (Table 1), matched the gluten-containing samples in terms of flavor and overall likings (Figure 5). This indicates that high-quality gluten-free products can compete with their gluten-containing counterparts, though further research is needed to enhance the sensory aspects of many gluten-free cookies.

Color properties measured by a colorimeter (L^*, a^*, and b^*) revealed significant differences, with gluten-containing cookies displaying lighter, redder, and yellower hues compared to the gluten-free samples. Nonetheless, no significant difference was observed in the appearance liking ratings of gluten-containing and gluten-free cookies across the 12 commercial products. This contracts earlier studies that reported lower appearance ratings for gluten-free products (Schober et al. 2003), potentially due to differences in experimental settings. Unlike prior studies that assessed appearance likings of gluten-free samples varying in specific ingredients or processing technologies in a controlled laboratory environment, this study compared commercially available products with a wider range of variation, leading to no significant impact of gluten on appearance ratings. In addition, the PLSR analysis suggested that flavor likely had a more significant impact on consumer acceptance than appearance or texture in both cookie types. Notably, the appearance did not significantly influence overall liking in either cookie type, which aligns with the minimal effect of gluten presence on appearance liking ratings shown in Figure 1. Furthermore, the CA biplot demonstrated that the pattern of appearance likings diverged from those of flavor and texture, which were closely associated with overall liking.

Another notable finding is the grater discrepancies in JAR attribute ratings for the gluten-free cookies, particularly in terms of chocolate flavor, sweetness, hardness, and chewiness, highlighting a wider gap between expected and perceived intensities of these sensory attributes compared to the gluten-containing cookies (Figure 6). These discrepancies contributed to more pronounced declines in overall liking for the gluten-free samples. Given that participants evaluated both cookie types under the blind conditions with respect to gluten content, the results suggest that gluten-free cookies generally fell short of consumer expectations for chocolate chip cookies. This mismatch between expectation and sensory perception likely hindered consumer acceptance of the gluten-free products, consistent with the "assimilation-contrast" theory (Hovland et al. 1957; Sherif et al. 1958), which posits that deviations from expectations can negatively affect sample evaluation (Seo et al. 2008). The JAR findings were further supported by open-ended participant feedback, which frequently cited texture-related issues in the gluten-free cookies. These were described as too hard, dry, grainy, crumbly, crunchy, chewy, or soft. Interestingly, although excessive hardness was the main deriver of reduced liking for the gluten-containing cookies, both excessive hardness and insufficient hardness negatively impacted overall liking of the gluten-free cookies. This finding reinforces previous research emphasizing the unique textural challenges of gluten-free baked goods, particularly in terms of hardness.

Notably, instrumental texture analysis revealed no significant difference in breaking force between the gluten-containing and gluten-free cookies (see also Matos and Rosell 2012). This discrepancy suggests that consumer perceptions of texture may be more nuanced and sensitive than what is captured by instrumental methods, highlighting the complexity of texture as a sensory attribute in cookie evaluation (Choi and Seo 2023). For example, as the instrumental analysis assessed only one textural parameter, that is, maximum force for hardness, it may have overlooked other perceptual dimensions reported by consumers, such as dryness, graininess, crumbliness, crunchiness, chewiness, or softness.

4.2 | Consumers' Evoked Emotions Differed Between Gluten-Containing and Gluten-Free Cookie Products

Emotional responses have been shown to significantly affect consumer acceptance, experience, and purchasing decisions regarding food products (Seo et al. 2009; Samant and Seo 2019; Gurdian et al. 2022). In line with the observed sensory differences, the emotions elicited by the cookie samples varied according to gluten condition (i.e., gluten-containing vs. gluten-free). Specifically, gluten-containing cookies tended to evoke emotions associated with positive valence and activation, whereas gluten-free cookies more often triggered emotions characterized by negative valence and deactivation. These emotional patterns likely stem from the sensory disparities between the two cookie types, particularly given that participants were blind to the gluten content.

Because hedonic evaluations are closely linked to emotions with positive valence (Samant and Seo 2019), the higher hedonic ratings for the gluten-containing cookies may have contributed to the more frequent positive emotional responses observed. This finding aligns with previous research on gluten-free foods. For example, Aguiar et al. (2022) found that gluten-free bread samples made with rice or bean flour showed correlations between hedonic scores and positive emotional responses, as assessed using 33 facial emojis. In their study, higher overall acceptability ratings were positively associated with the citations of emojis such as the "smiling face with smiling eyes," highlighting the connection between sensory pleasure and emotional expression. In another study, Wardy et al. (2018) examined sensory and emotional responses to gluten-free muffins formulated with varying levels of sucrose or with stevia as a sucrose substitute. The findings showed that muffins made with stevia elicited significantly lower intensities of positive emotions, such as calm, good, pleasant, pleased, happy, and satisfied, compared to those made with sugar. They suggested that these emotional differences were likely driven by the significantly lower liking scores for sweetness, overall taste, and texture-related attributes observed in the stevia-sweetened muffins (Wardy et al. 2018).

The association between sensory appeal and positive emotional responses to food samples was also evident in our study. Although most gluten-free samples received lower ratings for flavor, texture, and overall liking, sample GF_H achieved hedonic scores for flavor and overall impression comparable to those of the gluten-containing cookies. Similarly, although the majority of gluten-free samples were linked to negative emotional responses, sample GF_H did not differ significantly from the gluten-containing cookies across any of the 12 emotional attributes, including those reflecting negative emotions. This finding suggests that certain commercially available gluten-free cookies have the potential to compete with their gluten-containing counterparts not only in sensory appeal but also in eliciting positive emotional responses.

4.3 | Consumers' Purchase Intent Differed Between Gluten-Containing and Gluten-Free Cookie Products

This study demonstrated that, under blind test conditions, consumers were more likely to express purchase intent for gluten-containing cookies over gluten-free options. This observation can be attributed to the higher sensory ratings and more favorable emotional responses associated with the gluten-containing samples. Notably, sample GF_H, which showed no significant differences in sensory and emotional responses compared to the gluten-containing cookies, also received similarly competitive purchase intent scores. These results offer valuable insights for food processors, product developers, and sensory professionals involved in the formulation of gluten-free cookies. In particular, as flavor liking for sample GF_H did not differ significantly from that of the gluten-containing samples, R&D teams may benefit from prioritizing improvements in flavor when developing gluten-free cookie development. Moreover, when considering the results of the JAR ratings, industry professionals may further enhance consumer acceptance by increasing the intensities of chocolate flavor, sweetness, and chewiness, while also optimizing hardness levels. Adjusting these attributes to better align with consumers' ideal intensities could significantly improve the sensory appeal of gluten-free chocolate chip cookies. Additionally, optimizing the hardness of gluten-free chocolate chip cookies may help achieve levels that more closely match consumers' expectations for ideal texture.

The influence of experimental context, such as the availability of product information, on consumer purchase behavior is well documented (Wardy et al. 2018; Samant and Seo 2020; Wang et al. 2021; Gurdian et al. 2022). For example, Wardy et al. (2018) found that providing health-related information (e.g., reduced sugar levels and gluten-free status) significantly increased the overall liking, positive emotional responses, and purchase intent for muffins sweetened with varying levels of stevia. However, their study did not directly compare gluten-free and gluten-containing options. Therefore, future research examining consumer responses to both types of cookies under informed (vs. blind) conditions could yield practical insights, particularly regarding the impact of health and nutrition claims on acceptance.

Additionally, although this study excluded individuals with celiac disease due to the inclusion of gluten-containing cookies, future research should explore how this demographic evaluates the wide range of gluten-free cookie products available commercially, especially in terms of sensory acceptance, emotional response, and purchase behavior. Previous studies have produced mixed results. For example, Laureati et al. (2012) found no significant differences in sensory evaluations of gluten-free bread samples between individuals with and without celiac disease. In contrast, Giménez et al. (2015) reported that participants without celiac disease rated gluten-free pasta made from alternative cereals less favorably in terms of flavor and texture, resulting in lower acceptability and purchase intent compared to evaluations from those with celiac disease.

Although our study included only individuals without celiac disease, the increasing popularity of gluten-free products among the general population (Alencar et al. 2021; Eastlake 2024) emphasizes the relevance of our findings for mainstream product development. Future studies should consider comparing sensory and emotional responses to gluten-free cookies on the basis of participants' frequency of gluten-free product consumption or purchase habits. Furthermore, prior research has shown that demographic factors, such as age, can influence consumer perceptions and acceptance of food products (Luckett et al. 2016; Choi and Seo 2023; Tan et al. 2016), including gluten-free cookies made from wheat alternatives (Ervina 2023). Exploring how age and other demographic variables affect responses to both gluten-free and gluten-containing cookies would provide a more comprehensive understanding of consumer preferences across market segments.

5 | Conclusion

This study identified significant differences between gluten-containing and gluten-free chocolate chip cookies currently available on the market, particularly with respect to consumer acceptance, emotional responses, and purchase intent. Gluten-containing cookies consistently received higher hedonic ratings, elicited more positive and active emotions, and were more likely to be purchased compared to their gluten-free counterparts. These findings support the prevailing view that gluten-free cookies are generally less favored by consumers and are less effective in evoking positive emotional responses, which in turn reduces purchase intent.

Despite substantial efforts by the food industry and academic researchers over the past decades to improve gluten-free products, the results suggest that further enhancements are needed to increase their sensory appeal and emotional impact. Study suggests there remains room to enhance their sensory appeal and emotional impact. However, it is noteworthy that one gluten-free cookie sample performed comparably to the gluten-containing cookies in terms of overall liking, emotional responses, and purchase intent. This indicates that well-formulated gluten-free products can indeed compete successfully in the marketplace. As flavor liking for the comparable sample was not significantly different from that of the gluten-containing cookies, food industry professionals may benefit from focusing on enhancing flavors when developing gluten-free cookie products. Additionally, they may further enhance consumer acceptance of gluten-free cookies by increasing the intensities of chocolate flavor, sweetness, and chewiness, while also optimizing hardness levels.

In conclusion, although most commercially available gluten-free cookies remain less favored than their gluten-containing counterparts in terms of consumer acceptance, emotional responses, and purchase intent, there is clear potential for improvement and market competitiveness through targeted product development. Furthermore, future research should explore non-sensory factors that influence consumer acceptance and behavior toward gluten-free products across a broader range of categories. This includes comparisons between individuals with and without celiac disease, evaluations under both blind and labeled conditions regarding gluten content, and investigations into how varying levels of gluten-free product consumption influence consumer responses.

Author Contributions

Shaelyn Frauenhoffer: conceptualization, methodology, investigation, formal analysis, writing – original draft. **Eniola Ola**: methodology, investigation, formal analysis, writing – review and editing. **Suzanne Jervis**: writing – review and editing. **Susan E. Gauch**: writing – review and editing. **Han-Seok Seo**: conceptualization, methodology, formal analysis, writing – original draft, writing – review and editing, visualization, supervision, resources, funding acquisition.

Acknowledgments

The authors thank Nguyen Ngo and Natalia Calderon for their assistance in sensory evaluation.

Conflicts of Interest

The authors declare no conflicts of interest.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.