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Comparative Analysis of Sensory Attributes, Acceptance, and Evoked-Emotions between Gluten-Free and Gluten-Containing Cookie Products

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Abstract

The demand for gluten-free products has increased over the past few decades as more people have been diagnosed with gluten-related dietary restrictions. Although there has been much research into certain gluten-free food products, there remains a gap in understanding the sensory attribute differences between traditional and gluten-free cookies. The aim of this study was to determine differences in sensory attributes and consumer acceptance of gluten-free versus gluten-containing chocolate chip cookies. Twelve chocolate chips across 11 brands were used in this study with 7 being gluten-free and 5 containing gluten. Eighty-nine participants were involved in the two-day study, with six cookies being evaluated each day. Participants used a 9-point hedonic scale to rate sensory acceptance (appearance, texture, flavor, and overall liking) and a 5-point just-about-right scale (JAR) to rate the level of JAR for specific attribute intensities (chocolate flavor, sweetness, chewiness, and hardness). The circumplex-inspired emotion questionnaire (CEQ) was used to assess emotional responses as well as a 9-point scale used to assess purchase intent. The result of this study found that there were significant differences in attribute liking, purchase intent, JAR attributes, as well as evoked emotions between gluten-containing and gluten-free chocolate chip cookies. In conclusion, gluten-free chocolate chip cookies were found to be less liked in terms of texture and flavor compared to gluten-containing chocolate chip cookies. Our findings offer product developers and sensory professionals enhanced insights into consumer perceptions and acceptance of gluten-free cookies and provide guidance on how to improve the sensory qualities of gluten-free cookie products currently available in the market.

1. Introduction

1.1. Background and need

Over the last decade, the need for gluten-free products has increased as more people have been diagnosed with celiac disease, wheat allergies, and gluten intolerance. Celiac disease, a disorder that causes harm to the small intestine when gluten is ingested, is a genetic disease with as many as one in 133 Americans diagnosed (Demirkesen & Ozkaya, 2020). The treatment for celiac disease, wheat allergies, and gluten intolerance is total avoidance of gluten in diet. However, since 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 (Rajagopal, 2021), 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, 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 & Ozkaya, 2020).

As more people are following a gluten-free diet, the demand for products has increased greatly. In 2019, the global market was valued at $21.61 billion and is projected by 2027 to be around $24 billion (Aguiar et al., 2021). While more products have become available due to growing demands, sensory attributes still tend to be reported as lacking. Gluten-free products are often described as being smaller, more crumbly, lighter in color, blander in flavor, as well as denser than the gluten-containing products they are trying to replace (O'Shea et al., 2014). Since wheat flour cannot be used as an ingredient in gluten-free products, other alternatives have to be used instead. Due to their bland flavors and neutral effects from baking, the most used flours come from potatoes, rice, and maize (O'Shea et al., 2014). The type of flour chosen depends on the product being made, but for gluten-free cookies, rice flour is the most popular (Xu et al., 2020). While these flours have bland flavors, they do have differences when it comes to textures of the final products.

There are several methods used to test sensory properties of gluten-free food products. Discrimination test, descriptive sensory analysis, and affective tests are the three main categories of sensory evaluation. This study was designed to conduct affective tests, especially consumer acceptance tests, to compare consumer acceptability of chocolate chip cookie products as a function of gluten presence. This study also aimed to determine emotional attributes related to chocolate chip cookie products by gluten presence. Since surface colors and textural properties were found to differ between gluten-containing and gluten-free products (O'Shea et al., 2014), instrumental analyses for measuring color characteristics and textural properties of cookie samples were also conducted.

1.2. Problem statement

While many studies over the last decade have focused on gluten-free products, the nutritional differences of gluten-free products compared to gluten-containing products have been a common avenue of research (Jamieson et al., 2018; Taetzsch et al., 2018; Ho et al., 2023). The results of these studies have shown that gluten-free processed products tend to be higher in fat and fall short of key nutrients (Jamieson et al., 2018). Out of gluten-free products, bread is the most researched and is where most of the information on gluten-free products comes from (Aguiar et al., 2021). There is a knowledge gap in the research when it comes to looking at gluten-free products compared to gluten-containing products with a focus on the sensory attributes. Many research projects compared a specific type of gluten-free food product to other gluten-free brands available. These studies focused on the textures, moisture content, analysis of the crumbs, and colors to then determine what specifically makes a certain gluten-free product better than others (Matos & Rosell, 2012). Comparing gluten-free products to those they are meant to be replacing would show what specific sensory attributes are different and how we could adjust gluten-free products to be better.

1.3. Purpose of the study

The purpose of this study was to compare gluten-containing and gluten-free chocolate chip cookie products commercially available in the marketplace in terms of sensory acceptance, evoked emotion, and overall liking. This study also aimed to explore drivers of liking gluten-containing and gluten-free chocolate chip cookie products.

1.4. Research questions

This study aimed to determine the effect of gluten presence on consumer acceptance of chocolate chip cookie samples with respect to four research questions (RQs):

RQ 1: What specific sensory attributes are different between gluten-free chocolate chip cookies and gluten-containing chocolate chip cookies?

RQ 2: What specific emotional attributes are different between gluten-free chocolate chip cookies and gluten-containing chocolate chip cookies?

RQ 3: How do overall likings of gluten-free chocolate chip cookies differ from those of gluten-containing chocolate chip cookies?

RQ 4: What are the drivers behind the liking and disliking of gluten-free cookies?

2. Literature Review

Sensory evaluation is a scientific discipline that has been around for decades and has a number of important applications. Determining what causes people to accept or reject foods, preferences, enjoyment, and thresholds for difference detection are all important results of sensory evaluation and can allow product developers to improve and maintain their products. Factors such as liking, preference, texture, taste, smell, firmness, and more can be determined through different methods of sensory evaluation. Depending on what the purpose of a study is, the methods used differ. However, many studies have utilized both objective assessment tools and subjective assessment. The theories behind food choice and acceptance along with the different testing methods can be applied to the growing number of gluten-free products that are available for consumers.

2.1. Theoretical framework

Sensory evaluation is defined as “The scientific discipline which encompasses all methods that evoke, measure, analyze, and interpret human responses to the properties of foods and materials, as perceived by the five senses: taste, smell, touch, sight, and hearing” (Civille & Oftedal, 2012, p. 598). The order of the sensory process is stimulus, sensation, perception, and then reaction. For example, a bite of food is taken, nerve signals cause a sensation, then the brain processes and interprets the sensation into perception, finally there is recognition of the stimulus, and a reaction is caused. The reaction is either an objective identification of the perception or a subjective affective reaction. An objective identification would be “this is sweet,” whereas a subjective affective reaction would be either rejection or acceptance of the food (Civille & Oftedal, 2012).

A number of factors, psychological and physiological variables, impact food acceptance and rejection (Auvray & Spence, 2008; Luckett et al., 2016; Seo et al., 2021). Social factors, such as friends and family, are also a strong factor in food choice and eating behavior (Eertmans et al., 2001; Pramudya et al., 2022). The environment of the social setting is also known to influence consumer perception and acceptance of food (Seo, 2020). Previous experience and familiarity with food is another important factor for acceptance and choice (Eertmans et al., 2001; Seo et al., 2008; Tan et al., 2016; Jarma Arroyo et al., 2020). Many people create associations between food and memories, which causes acceptance and desire for said foods (Rozin & Tuorila, 1993; Mouritsen et al., 2017). Furthermore, eating is a hedonic experience and is important for the survival of humans (Mouritsen et al., 2017). People tend to make their decisions of what to eat based on the enjoyment of sensory attributes (Eertmans et al., 2001; Samant & Seo, 2020). People tend to seek out foods that are salty, sweet, and/or fatty for taste enjoyment (Mouritsen et al., 2017; Han et al., 2020). Reasoning behind acceptance of food is much easier to determine than why people reject foods (Mouritsen et al., 2017). Bitter foods tend to be rejected, as do foods that are extremely salty or sweet. While previous experience with a food strongly impacts acceptance, it also affects rejection and aversion (Raudenbush & Frank, 1999; Choi & Seo, 2023). If a person had a negative experience with a specific food, they are less likely to want to eat that food again. These factors all influence how a person is likely to accept and even assess a food.

2.2. Conceptual framework

While sensory preferences have long existed, sensory evaluation as it is known today has been around for almost 100 years. Modern sensory evaluation began after WWI when it was realized that soldiers were coming back malnourished because the food they were being provided with had such poor sensory attributes that they refused to eat it (Chambers, 2019). During the 1940s, sensory evaluation methods were being tested and used to determine how to measure responses. The U.S. Army quartermaster crop scientists were studying acceptance testing while descriptive testing was being done by scientists at Arthur D. Little Inc. (Chambers, 2019). The descriptive testing being conducted by Arthur D. Little Inc. was being promoted as a method of quantitatively measuring sensory perception. The armed forces held a symposium in Chicago in 1953 which brought together groups that were studying sensory methods, and the outcome was said to be that civilian and military food had greatly improved in quality due to food testing methods (Chambers, 2019).

Objective assessment tools are instruments that carry out analysis of various characteristics of food (Mihafu et al., 2020). There are a variety of instrumental approaches associated with sensory aspects of food, such as texture analysis (Luckett et al., 2014) and analytical chemical analysis (Mihafu et al., 2020). These assessments provide results very quickly without having to train panelists, while also being able to be used when it might not be safe for a human to test a product. While microbiological tests are used to test the safety of a product (Brnawi et al., 2018), analytical chemical analysis can be useful in predicting sensory qualities of target samples. Conducting instrumental testing on product appearance is also important as visual aspects have an impact on a consumer’s buying (Mihafu et al., 2020).

Sensory evaluation methods look at and measure the response of a subject to a specific stimulus, such as consuming food (Mihafu et al., 2020). There are three basic types of consumer tests that then branch off into subtypes. Discriminative, descriptive, and affective (preference/acceptance) are the three main types of consumer testing (Civille & Oftedal, 2012). Discriminative tests are used to determine if there are sensory differences between products

(Mihafu et al., 2020). Two main types of discriminative tests are triangle tests and duo-trio tests. Triangle tests involve having panelists trying to determine which of the three samples they are given is the one different from the others. A duo-trio test is just an overall discriminative test where the panelists determine if any difference exists between products. Preference/ acceptance testing is considered a subjective method and is done to determine if people like a food and then further to determine if a specific sample is preferred over others. Acceptance testing uses hedonic scales. Hedonic scales are used to indicate how a participant likes a product and attribute rating scales are similar but focus on specific attributes. Preference testing includes paired comparison and ranking of products (Mihafu et al., 2020).

Descriptive sensory analysis is a technique that lets the trained panelist describe sensory attributes of test products and generates quantitative data for individual attributes. Due to the results of descriptive sensory analysis being more detailed, this type of test is considered more comprehensive compared to other types of testing. A lexicon is an important communication tool that should be utilized in descriptive analysis as it allows for more accurate and repeatable information from tests (Suwonsichon, 2019). A lexicon is a standardized set of vocabulary that is used by trained panelists to accurately describe a product. Using a lexicon is beneficial in many aspects of food manufacturing, such as quality, food safety, and product development.

The purpose of a project determines what method will be used. If product understanding is the goal, then either discriminative or descriptive testing methods will be utilized. If consumer understanding is desired, then preference and acceptance methods are needed (Civille & Oftedal, 2012).

2.3. Gluten-free products

Objective assessment tools such as instrumental analysis are often used by researchers when analyzing gluten-free products. In a study done using three commercially available gluten-free breads in the UK, texture analysis was used to test the thickness, softness (verses hardness), staleness after four days, as well as crumbliness (Louis et al., 2019). Visual analysis is often used to determine differences between gluten-free breads (Louis et al., 2019). By using these tools, the data is numerical and can be more reliable than working with human participants.

The use of sensory analysis with human panelists is common with gluten-free studies. Just as with any sensory study using human panelists, before panelists begin a study, they must be assessed and trained in order to ensure that they understand sensory attributes and are comfortable with sensory terms (Laureati et al., 2012). In some studies, already existing, common lexicons are also used (Suwonsichon, 2019). However, sometimes with gluten-free studies a new lexicon is created to be specifically tailored to gluten-free products (Laureati et al., 2012). Difference, preference, acceptance, as well as descriptive analysis testing are often used with gluten-free products, depending on what the purpose of the study is. Studies looking at how different ingredients impact the texture and overall preference/acceptance of gluten-free products are common. These studies utilize these different types of testing and sometimes will actually use multiple methods (Iwamura et al., 2022).

Preferences of gluten-free products are affected by the factors as any other product, but specifically sensory attributes (Eertmans et al., 2001). Often, research conducted on gluten-free products uses bread as the test sample. A study done in Italy using five samples of gluten-free bread found a positive correlation between gluten-free bread preference to sweet taste, porosity, and softness. This same study also found a negative correlation between gluten-free bread preference to salty taste, rubbery, and adhesive (Laureati et al., 2012). As the ingredients used, especially the type of flour, have an impact on the final taste and texture of a product, studies have been conducted to determine what ingredients are preferred. In terms of alternatives to using wheat flour, corn and rice flours tend to be the most commonly used (Gao et al., 2017). Sorghum is another gluten-free cereal that is often used as a wheat flour alternative as it is neutral in taste (Iwamura et al., 2022).

As gluten-free products become more widely available and advancements are made in how they are produced, more sensory evaluation will be conducted for them. With knowledge as to what motivates peoples' food choices, these theories can be applied to panelists on gluten-free studies to further explain their preferences and assessments of products. Furthermore, the many different testing methods have been used to gain insight into how consumers assess gluten-free breads. Acceptance/preference testing has been used as a method to determine what gluten-free products are liked, while descriptive analysis has further specified the characteristics of these products that panelists enjoy.

3. Materials & Methods

3.1. Participants

Eighty-nine participants (60 females and 29 males) of ages ranging from 21 to 70 year [mean age ± standard deviation (SD) = 40 ± 14 years] were recruited from the consumer profile database of the University of Arkansas Sensory Science Center. Participants reported having no dietary restrictions. Table 1 represents demographic profiles of the participants in this study.

This study adhered to the Declaration of Helsinki for human subjects' studies and received approval from the University of Arkansas Institutional Review Board (No. 2311502798). Prior to participation, each participant provided voluntary written informed consent, detailing the study's objectives, procedures, and potential risks or benefits.

3.2. Cookie samples

Twelve samples across eleven brands were used for this study (Figure 1). All samples used in this study were acquired from markets within the United States.

3.3. Color measurement of cookie samples

The color attributes of the twelve cookie samples were assessed using a portable colorimeter (MiniScan XE Plus, HunterLab, Reston, VA, USA). Each cookie was placed in direct contact with the colorimeter to measure the surface color. This analysis was conducted in duplicates, with five cookies from each sample pack. The color was evaluated using the CIE L* a* b* system, which measures parameters including L* (brightness) ranging from 0 (black) to 100 (white), a* for redness (+) or greenness (-), and b* for yellowness (+) or blueness (-). The colorimeter was calibrated using a white standard to ensure accuracy.

3.4. Texture measurement of cookie samples

Textural property of cookie samples were measured using a Texture Analyzer (TA-XT2i, Stable Micro Systems, Godalming, UK). The cookies' hardness was assessed by a compression test using a spherical probe (TA-8B 1/4" dia ball ss), 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.

3.5. Procedure of sensory evaluation

The sensory evaluation procedure involved 89 participants assessing all twelve cookie samples across two days at the University of Arkansas Sensory Science Center (Fayetteville, AR, USA). Each participant received six cookies per day, randomly coded with three digits, and presented individually. Participants were asked to refrain from cigarette smoking, eating, and drinking (except for water) for 2 hours prior to participating in this study (Cho et al., 2017).

Using a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely), participants rated sensory acceptance based on 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) (Jaeger et al., 2020). Based on previous studies (Jaeger et al., 2021; Seo et al., 2023), the layout variant of the CEQ was utilized with a multiple-choice option. 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).

3.6. Statistical analysis

Data analysis was performed using JMP Pro (version 17, SAS Institute Inc., Cary, NC, USA) software and XLSTAT (Addinsoft, New York, NY, USA) software. To determine whether twelve cookie samples could differ in terms of color parameters or texture property, a one-way analysis of variance (ANOVA), treating “cookie sample” or “cookie type” (gluten-containing versus gluten-free) as a fixed effect, was conducted. *Post hoc* tests were conducted using Tukey's honest significant difference (HSD) tests. For sensory and purchase intent data, a two-way mixed model, treating "cookie sample" or "cookie type" (gluten-containing versus gluten-free) as a fixed effect and "participant" as a random effect, was performed. *Post hoc* tests were conducted using Tukey's honest significant difference (HSD) tests. For the JAR data, a penalty-lift analysis was performed to determine the positive and negative drivers of overall liking for cookie samples.

For CATA data of evoked emotions, Cochran's *Q*-test was conducted to test whether cookie samples were different in terms of the proportions of selection of individual terms of the CEQ emotions. A correspondence analysis was also conducted to visualize associations between cookie samples and evoked emotions. Finally, to visualize participants' comments on what they liked or disliked, a word cloud analysis was conducted. A statistical difference was defined when $P < 0.05$.

4. Results

4.1. Color attributes of cookie samples

Three color parameters, L^*, a^*, and b^*, differed significantly among the twelve cookie samples (for all, $P < 0.001$; Table 2). Sample GF_J exhibited significantly greater L^* value than samples GC_A, GC_C, GC_D, GC_E, GC_F, GF_G, GF_H, GF_I, GF_K, and GF_L. Samples GC_D and GC_E exhibited the greatest a^* value, while Sample GC_B showed the highest b^* value.

When examining the effect of gluten presence, the gluten-containing samples had greater L^*, a^*, and b^* values, meaning on average, they are lighter in color, redder, and more yellow than the gluten-free samples (Table 3): L^* (F = 11.98, P = 0.001), a^* (F = 6.12, P = 0.015), and b^* (F = 34.17, P < 0.001).

4.2. Textural property of cookie samples

Table 4 represents a mean comparison among the twelve cookie samples in terms of force. Samples GF_K exhibited the greatest force, indicating the hardest sample. Samples GC_E and GF_I showed significantly smaller force than other samples except for GF_F and GF_G (for all, P < 0.001). Overall, there was no significant difference between the gluten-containing and gluten-free samples in terms of force (Table 5).

4.3. Sensory properties of cookie samples

4.3.1. Hedonic impression

As shown in Figure 2, there were significant differences found when looking at the attribute likings of the different cookies (F = 31.33, P < 0.001). For appearance liking, sample GC_E had the greatest value, meaning that its appearance was the most liked out of all the samples. The lowest appearance liking was for sample GF_L. When looking at appearance liking for all the gluten-containing samples compared to all the gluten-free samples, there was no significant difference (F = 2.95, P = 0.12) (Table 6).

In terms of flavor liking, sample GC_D was liked significantly more than samples GC_B, GF_F, GF_G, GF_I, GF_J, GF_K, and GF_L (F = 22.81, P < 0.001) (Figure 3). There was a significant difference in flavor liking when comparing all the gluten-containing samples to all of the gluten-free samples, with the gluten-containing samples being liked more for flavor (F = 12.91, P = 0.005) (Table 6).

The most liked sample for texture was sample GC_E and it was determined to be significantly different in texture liking to all the gluten-free cookie samples but was not significantly different compared to the other gluten-containing samples, except for sample GC_C ($F = 15.58$, $P < 0.001$) (Figure 4). When comparing the texture liking of all the gluten-containing samples to all the gluten-free samples, a significant difference was found ($F = 27.32$, $P = 0.004$). The gluten-containing samples were found to be liked more than the gluten-free samples in terms of texture (Table 6).

When looking at overall liking, samples GC_D and GC_E were most liked overall and were found to be significantly different compared to samples GF_F, GF_G, GF_I, GF_J, GF_K, and GF_L ($F = 20.59$, $P < 0.001$) (Figure 5). The gluten-containing cookies were found to be more liked overall than the gluten-free cookies as a whole ($F = 18.90$, $P < 0.001$) (Table 6).

4.3.2. Comments on what participants liked or disliked

Based on the comments left by participants about attributes they liked or disliked about the samples, word clouds were made. As shown in Figures 6 and 7, for the liking of both gluten-containing and gluten-free cookies, the words/ phrases that were most frequently used were flavor, appearance, texture, chocolate chip flavor, amount of chocolate chips, and sweetness. The terms most used for disliking were hardness, flavor, appearance, texture, lack of chocolate flavor, and dry (Figures 6 and 7).

4.3.3. JAR attributes

For the gluten-containing samples, the penalty-lift analysis revealed a significance when participants selected too little for chocolate flavor, sweetness, and chewiness JAR as well as when too much for hardness JAR was selected (Figure 8). When selecting too little for chocolate, sweetness, and chewiness JAR, the overall liking of the gluten-containing cookies dropped by 1.93, 1.99, and 1.68, respectively. When too much for hardness JAR was selected, the overall liking dropped by 1.80.

When looking at the JAR scores for the gluten-free samples, it was determined that the results were significant when participants selected too little for chocolate, sweetness, hardness, and chewiness JAR, as well as too much for hardness JAR (Figure 9). The overall liking of the gluten-free cookies dropped by 2.17, 2.74, 2.39, and 1.86 when too little was selected for chocolate flavor, sweetness, hardness, and chewiness JAR. When too much was selected for hardness JAR, the overall liking dropped by 1.93.

4.4. Evoked emotions

Cochran's Q-test revealed that twelve samples differed significantly in terms of emotional attributes, except for "dull/bored" and "blue/uninspired" ($P < 0.05$). When *post hoc* testing was conducted, it was further found that there was no significant difference for "relaxed/calm," "passive/quiet," "dull/bored," or "blue/uninspired" ($P > 0.05$).

A biplot of the correspondence analysis, which explains 89.55% of the total variation, showed that all of the gluten-containing samples had an impact of the participants choosing emotions considered positive (Figure 10). The gluten-free samples, except for sample GF_H, were more likely to evoke negative emotions. The X-axis of the plot explained 82.04% of the samples and most of the cookies were explained here. The Y-axis explained 7.51% of the samples.

4.5. Purchase intent

When looking at the purchase intent of all the samples, samples GC_A, GC_D, and GC_E exhibited greater ratings than samples GF_F, GF_G, GF_I, GF_J, GF_K, and GF_L (F = 17.91, P < 0.001) (Figure 11). Overall, the gluten-containing samples as a group had greater purchase intent ratings compared to the gluten-free samples as a group (F = 17.75, P = 0.002) (Table 7).

5. Discussion

The results of this study found that there are significant differences in sensory attribute liking, which impacted the overall liking of gluten-containing chocolate chip cookies versus gluten-free chocolate chip cookies. The gluten-containing cookies were more liked for texture, flavor, and overall liking than the gluten-free cookies. Previous studies have shown that baked gluten-free products have poorer texture and sensory properties compared to gluten-containing products, which supports these findings (Drabińska et al., 2016). The sample GC_D was liked most overall as well as for flavor. The sample most liked for texture was GC_E, which is a softer cookie and supports the finding that participants did not like samples that were too hard. There was no significant difference in appearance liking between the gluten-containing and gluten-free cookies which disagrees with previous studies that have found that gluten-free products tend to have reduced appearance liking (Schober et al., 2003).

The JAR attribute looked at that had the highest mean drop for both the gluten-containing and gluten-free cookies was “too little” for sweetness. This indicates that consumers like chocolate chip cookies to be sweet, which agrees with the findings of a previously published study that determined that cookies associated with sweetness as a hedonic property were more liked than those not associated with sweetness (Ervina, 2023). Too little chocolate and chewiness as well as too much hardness were other significant drivers of disliking for both the gluten-containing and gluten-free cookies. Too little hardness was also a driver of disliking for the gluten-free samples that were not shared with the gluten-containing cookies.

Ten of the twelve emotions that were looked at with the twelve cookie samples were found to be significant from CATA analysis and then *post hoc* analysis found that only eight of the ten were significant. The gluten-containing samples were all associated with emotions that are considered positive, like “happy/satisfied,” whereas all the gluten-free samples, except for sample GF_H, were associated with negative emotions like “unhappy/dissatisfied.” These results add further context as to the purchase intent, where the gluten-free samples were found to be less likely to be purchased than the gluten-containing samples. Furthermore, the cookie with the lowest purchase intent was also the sample that had the highest frequency of participants selecting “unhappy/dissatisfied,” which was sample GF_F.

6. Conclusion

This study found that differences in sensory attributes, specifically texture and flavor, significantly impact the overall liking between gluten-containing and gluten-free cookies. Attributes such as too much hardness, too little chocolate flavor, too little sweetness, and too little chewiness drove disliking of both gluten-containing and gluten-free cookies. Furthermore, too little hardness also drove the disliking of gluten-free cookies. Emotions caused by the samples were also found to be significantly different, with the gluten-containing cookies evoking more positive emotions whereas the gluten-free samples mostly evoked negative emotions. Purchase intent was also significantly different between the two groups, with participants being more likely to purchase the gluten-containing cookies than the gluten-free. These results indicate that gluten-free chocolate chip cookies could have sensory attributes such as texture and flavor improved to better compared to gluten-containing chocolate chip cookies.

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Table 1. Demographic profiles of the 89 participants of this study

Category	Subcategory	Frequency (%)
Gender	Female	60 (67.4)
	Male	29 (32.6)
Age group	20 to 29 years old	28 (31.5)
	30 to 39 years old	23 (25.8)
	40 to 49 years old	19 (21.4)
	50 to 59 years old	6 (6.7)
Ethnicity	White/Caucasian	61 (68.5)
	Black/African American	12 (13.5)
	Hispanic/Latin American	4 (4.5)
	Asian	10 (11.2)
	Native American	2 (2.3)
Annual household income	< $20,000	9 (10.1)
	$20,000 to $39,999	25 (28.1)
	$40,000 to $59,999	13 (14.6)
	$60,000 to $79,999	13 (14.6)
	$80,000 to $99,999	14 (15.7)
Education level	High school	11 (12.4)
	Some degree	13 (14.6)
	2-4 year college degree	40 (44.9)
	Master’s degree	20 (22.5)
	Doctoral or professional degree	5 (5.6)

Table 2. Mean comparisons (± standard deviation) among the twelve cookie samples with respect to color parameters: *L, *a**, and *b****

Cookie samples	*L**	*a**	*b**
GC_A	54.10cde (± 2.87)	11.14b (± 0.58)	29.22de (± 1.66)
GC_B	60.79ab (± 0.73)	9.85c (± 0.39)	36.24a (± 0.72)
GC_C	59.58b (± 2.38)	8.64de (± 0.32)	27.76e (± 0.49)
GC_D	51.93def (± 3.75)	12.45a (± 0.66)	32.09bc (± 2.12)
GC_E	56.97bc (± 2.29)	9.76a (± 0.59)	33.29b (± 1.71)
GF_F	52.22def (± 2.19)	10.8b (± 0.25)	31.15c (± 1.06)
GF_G	50.66ef (± 2.34)	8.68cd (± 0.50)	25.72fg (± 1.26)
GF_H	55.47cd (± 4.99)	9.00cd (± 1.26)	27.50ef (± 1.34)
GF_I	48.62f (± 1.75)	11.39b (± 0.27)	31.42bc (± 0.76)
GF_J	64.04a (± 1.81)	7.79e (± 0.47)	27.36ef (± 0.65)
GF_K	51.00ef (± 1.85)	11.04b (± 0.55)	31.04cd (± 1.39)
GF_L	52.78de (± 1.39)	8.68d (± 0.39)	25.44g (± 0.84)
F-ratio	32.27	56.79	66.43
P-value	< 0.001	< 0.001	< 0.001

Mean ratings with different letters within a column indicate a significant difference at $P < 0.05$.

Table 3. Mean comparisons (± standard deviation) between the gluten containing and gluten-free cookie samples with respect to color parameters: *L, *a**, and *b****

Cookie types	*L**	*a**	*b**
Gluten-containing	56.67a (± 4.16)	10.37a (± 1.41)	31.72a (± 3.34)
Gluten-free	53.34a (± 5.35)	9.72b (± 1.41)	28.52b (± 2.66)
F-ratio	11.98	6.12	34.17
P-value	0.001	0.02	< 0.001

Mean ratings with different letters within a column indicate a significant difference at $P < 0.05$.

Table 4. Mean comparisons (± standard deviation) among the twelve cookie samples with respect to force

Cookie samples	Force (g)
GC_A	3,420.21c (± 776.43)
GC_B	3,179.95cd (± 278.15)
GC_C	5,078.89b (± 508.51)
GC_D	2,655.84cde (± 351.47)
GC_E	820.28f (± 113.97)
GF_F	1,180.78ef (± 179.40)
GF_G	1,736.50def (± 262.43)
GF_H	3,064.96cd (± 656.20)
GF_I	3,490.56c (± 518.33)
GF_J	632.59f (± 81.32)
GF_K	7,279.66a (± 1675.66)
GF_L	2,442.44cde (± 347.38)
F-ratio	35.21
P-value	< 0.001

Mean ratings with different letters within a column indicate a significant difference at $P < 0.05$.

Table 5. Mean comparisons (± standard deviation) between the gluten containing and gluten-free cookie samples with respect to force

Cookie types	Force (g)
Gluten-containing	3,031.03 (± 1464.70)
Gluten-free	2,832.50 (± 2176.89)
F-ratio	0.13
P-value	0.73

Table 6. Mean comparisons (± standard deviation) between the gluten containing and gluten-free cookie samples with respect to appearance liking, flavor liking, texture liking, and overall liking

Cookie types	Appearance Liking	Flavor Liking	Texture Liking	Overall Liking
Gluten-containing	5.89 (± 1.97)	6.19a (± 1.75)	5.79a (± 1.99)	5.80a (± 2.03)
Gluten-free	4.97 (± 2.19)	4.83b (± 2.33)	4.43b (± 2.22)	4.28b (± 2.34)
F-ratio	2.95	12.91	27.32	18.90
P-value	0.12	0.005	0.004	0.001

Mean ratings with different letters within a column indicate a significant difference at $P < 0.05$.

Table 7. Mean comparisons (± standard deviation) between the gluten containing and gluten-free cookie samples with respect to purchase intent

Cookie types	Purchase intent
Gluten-containing	5.89a (± 2.39)
Gluten-free	3.40b (± 2.33)
F-ratio	17.75
P-value	0.002

Figure 1. Twelve cookie samples used in this study

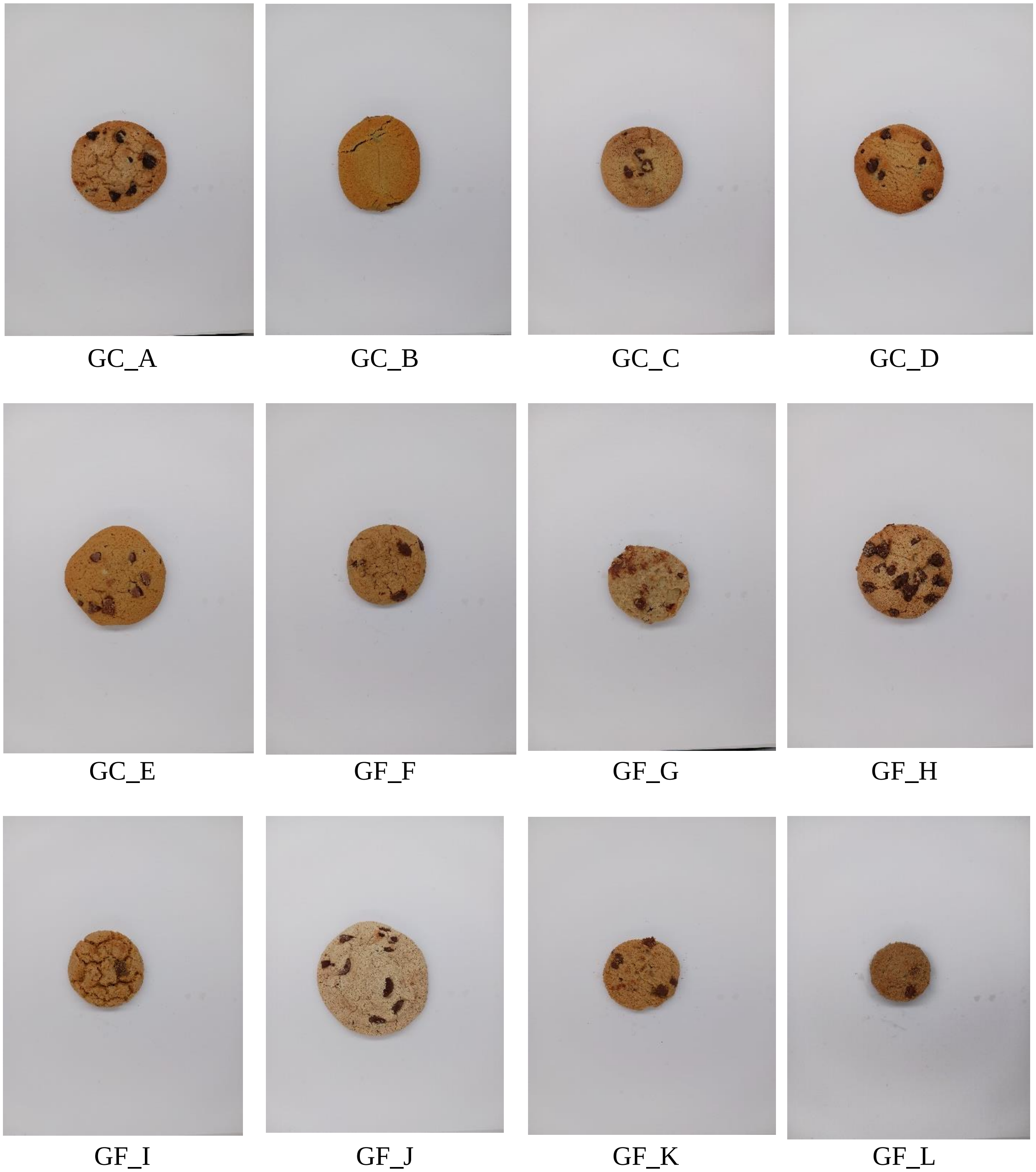
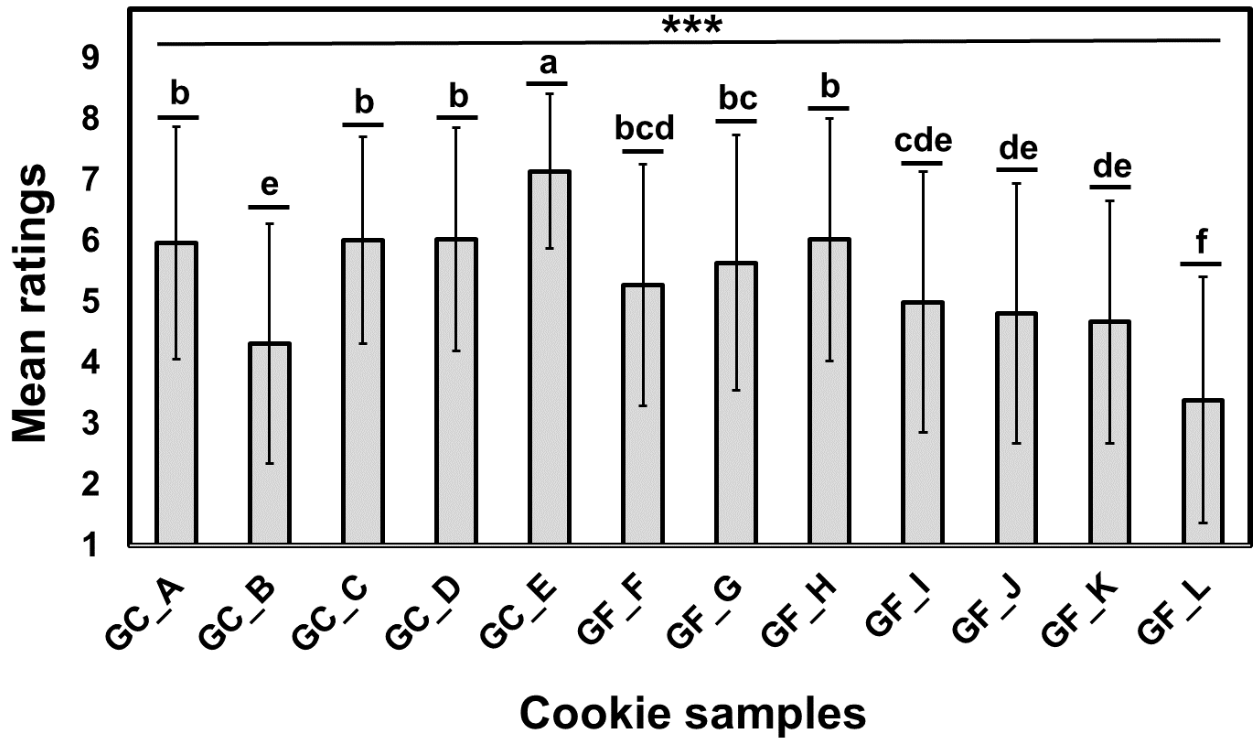
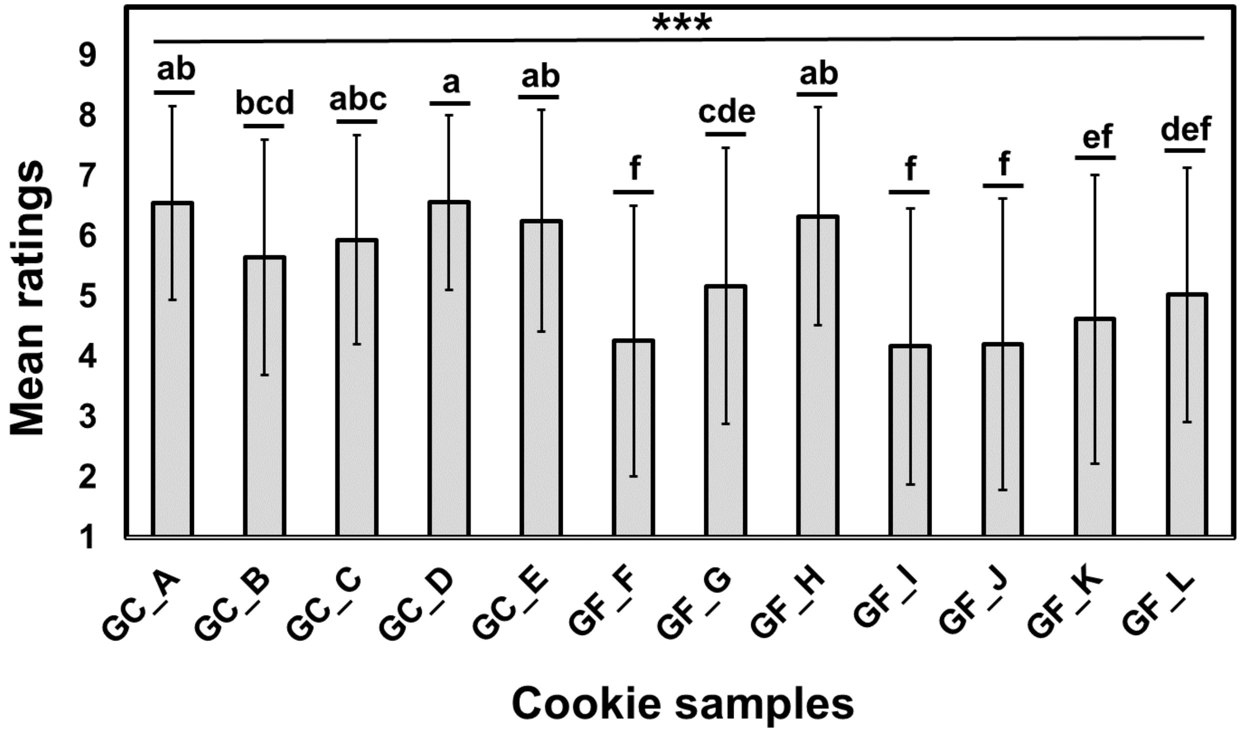


Figure 2. Mean comparisons (error bars: standard deviation) among the twelve cookie samples with respect to appearance liking



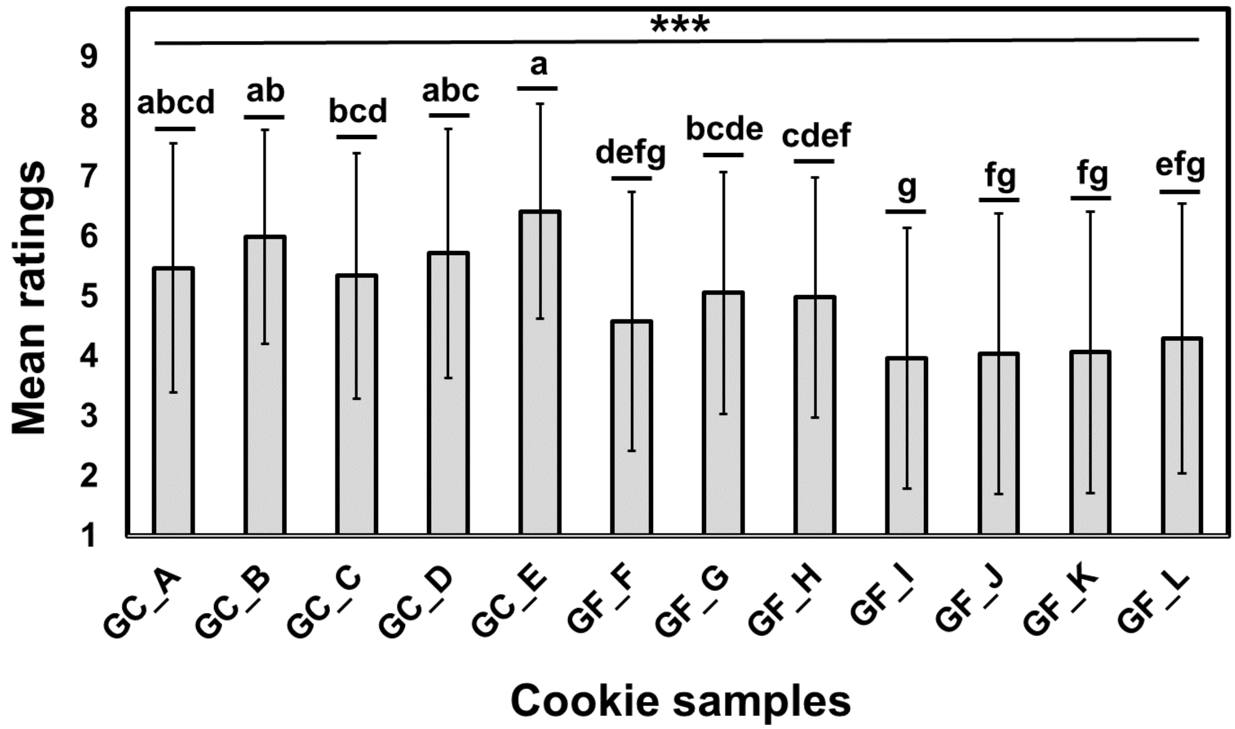
*** represents a significance at $P < 0.001$.
Meant ratings with different letters represent a significant difference at $P < 0.05$.

Figure 3. Mean comparisons (error bars: standard deviation) among the twelve cookie samples with respect to flavor liking



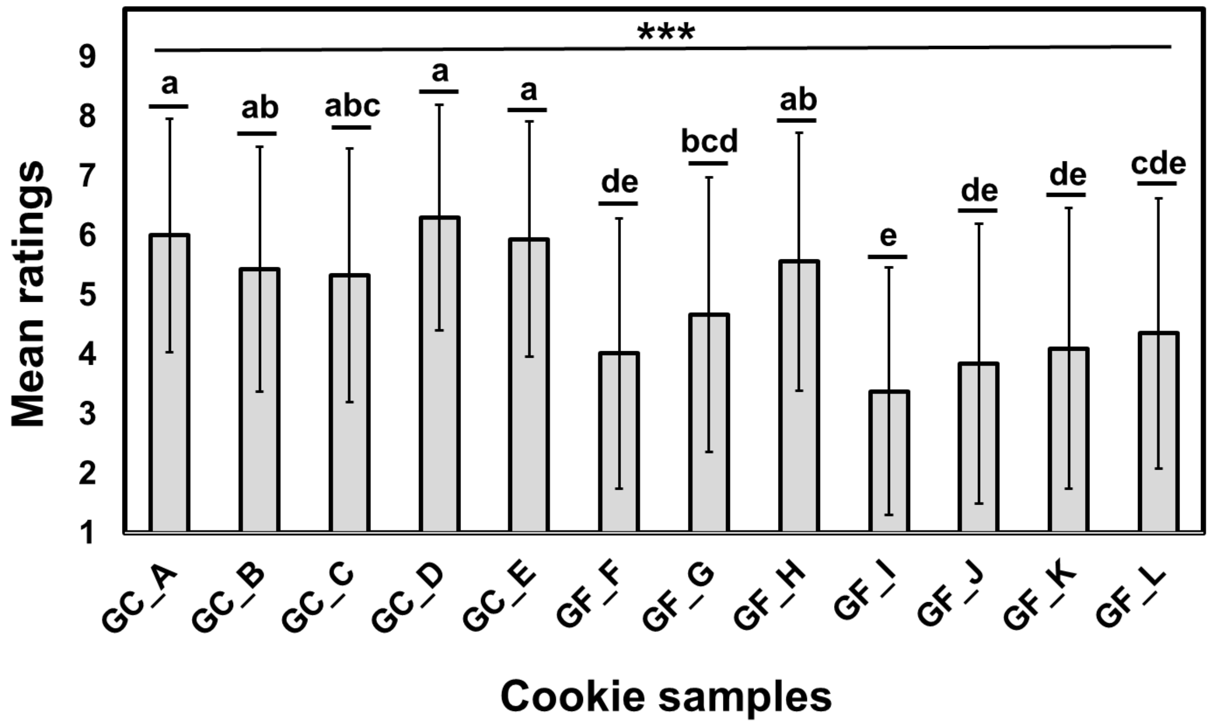
*** represents a significance at $P < 0.001$.
Meant ratings with different letters represent a significant difference at $P < 0.05$.

Figure 4. Mean comparisons (error bars: standard deviation) among the twelve cookie samples with respect to texture liking



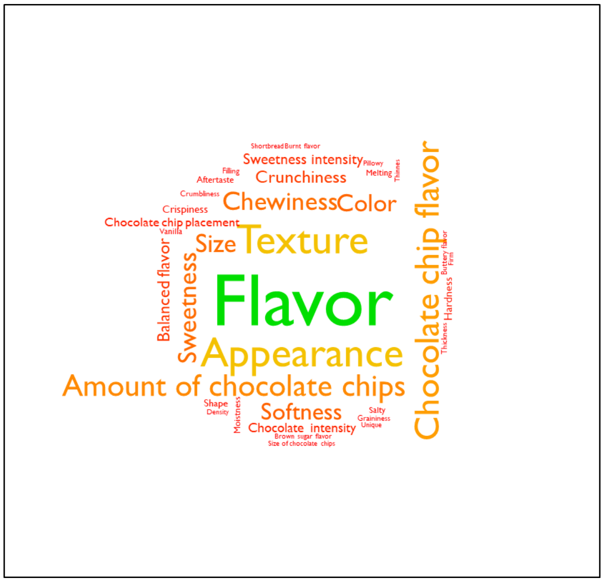
*** represents a significance at $P < 0.001$.
Meant ratings with different letters represent a significant difference at $P < 0.05$.

Figure 5. Mean comparisons (error bars: standard deviation) among the twelve cookie samples with respect to overall liking



*** represents a significance at $P < 0.001$.
Meant ratings with different letters represent a significant difference at $P < 0.05$.

Figure 6. Visualizations (word cloud) of participant comments on what they liked or disliked for the five gluten-containing cookie samples



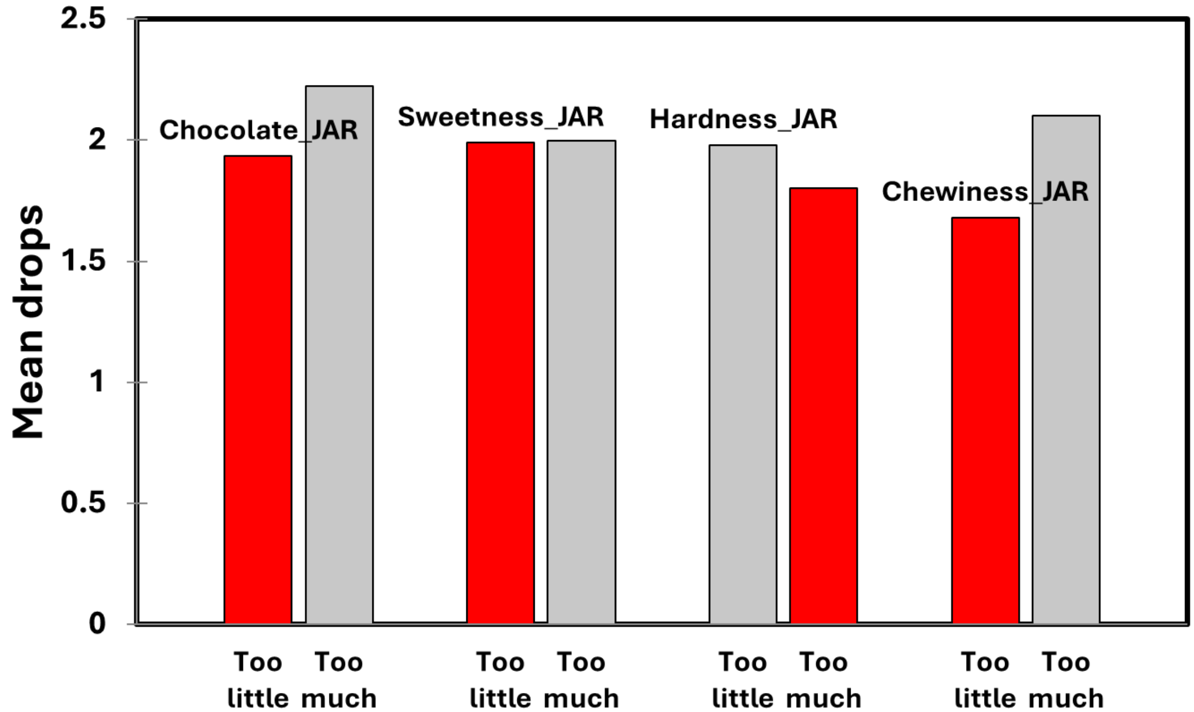
What participants liked

What participants disliked

Figure 7. Visualizations (word cloud) of participant comments on what they liked or disliked for the seven gluten-free cookie samples

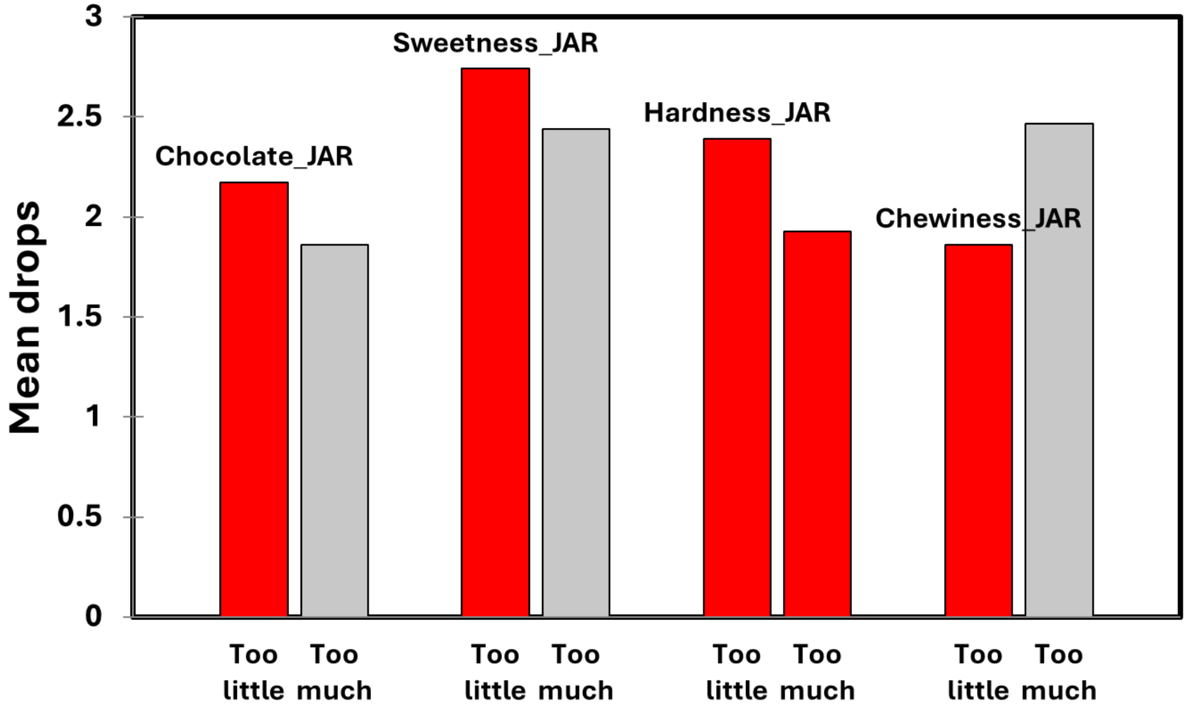
What participants liked **What participants disliked**

Figure 8. Mean drops of overall liking for the just-about-right (JAR) attributes of chocolate flavor, sweetness, hardness, and chewiness in the five gluten-containing cookie samples



Red bars indicate a significance at $P < 0.05$.

Figure 9. Mean drops of overall liking for the just-about-right (JAR) attributes of chocolate flavor, sweetness, hardness, and chewiness in the seven gluten-free cookie samples



Red bars indicate a significance at $P < 0.05$.

Figure 10. A bi-plot of correspondence analysis for visualizing associations between cookie samples and evoked emotions

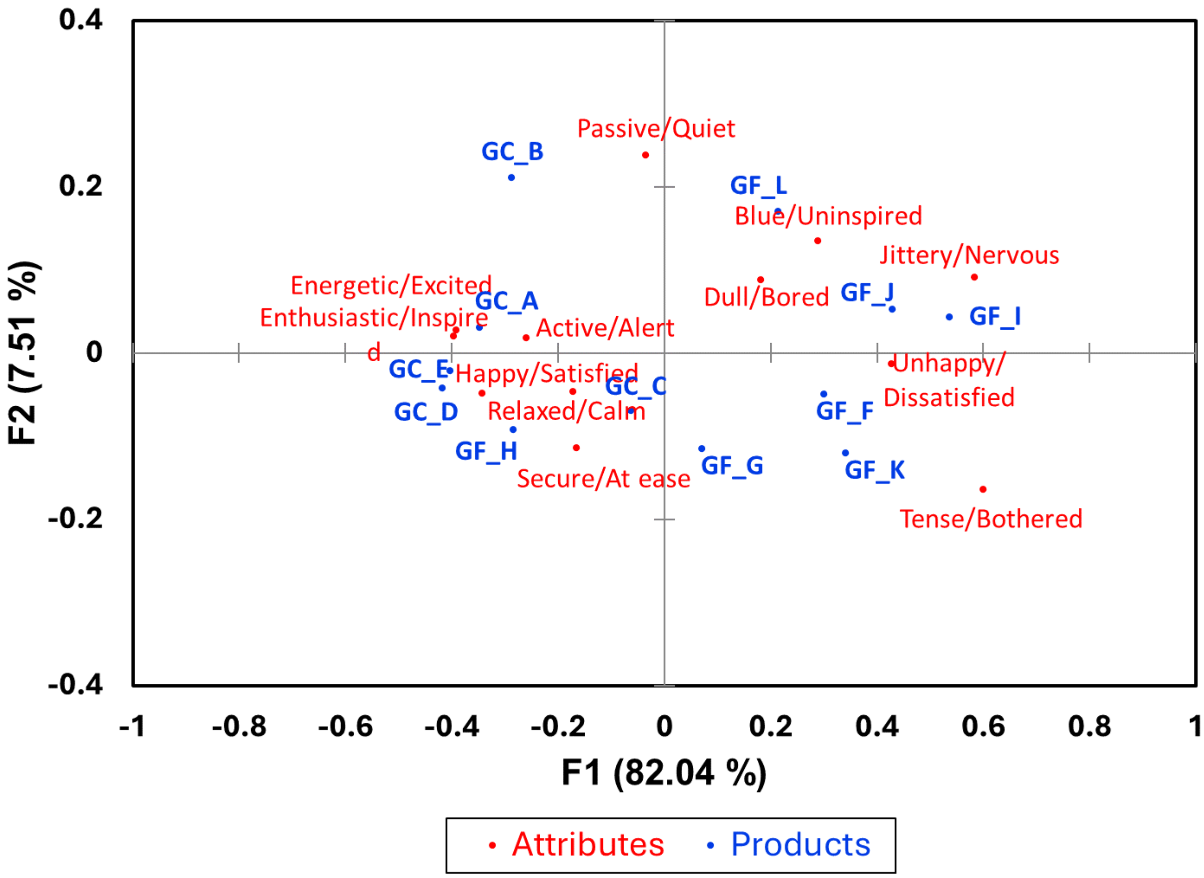
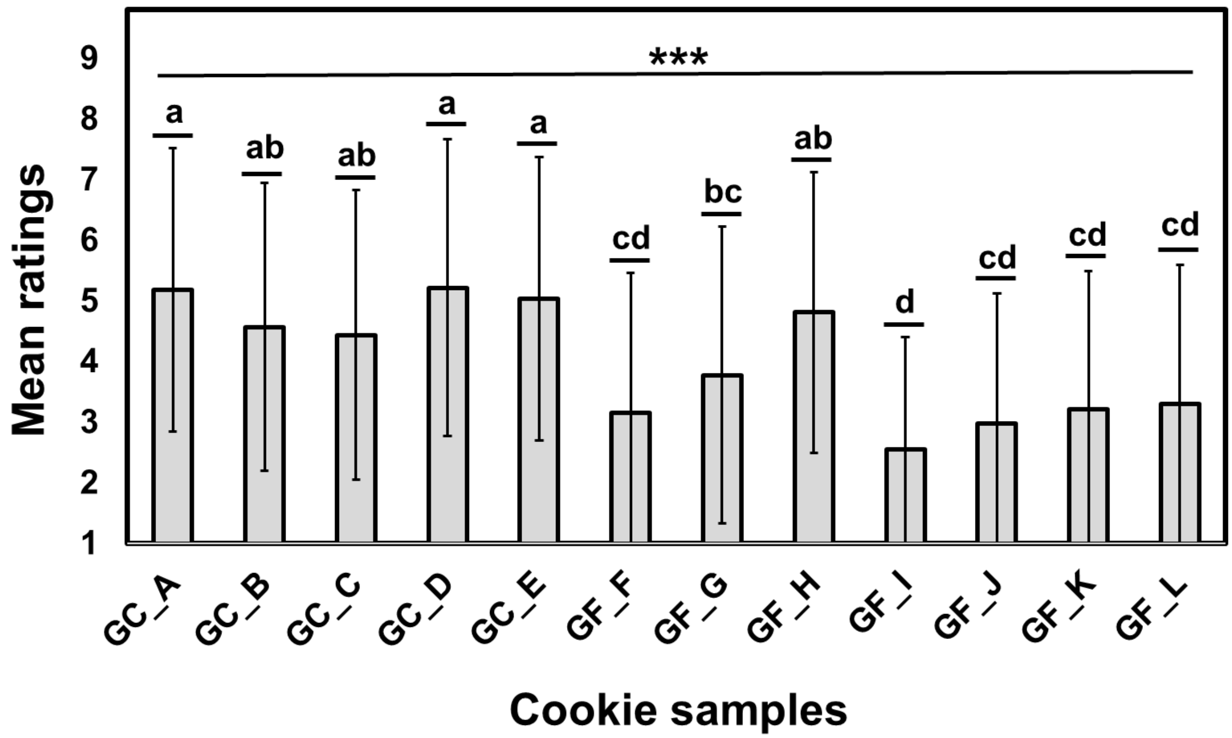


Figure 11. Mean comparisons (error bars: standard deviation) among the twelve cookie samples with respect to purchase intent



*** represents a significance at $P < 0.001$.
Meant ratings with different letters represent a significant difference at $P < 0.05$.