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Research Article

DETERMINING CONSUMER PREFERENCES FOR GRISSINI ENRICHED WITH FUNCTIONAL INGREDIENTS: THE CASE OF HAWTHORN, POMEGRANATE, AND GRAPE SEED FLOUR

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Abstract

The transformation of plant-based by-products generated in food industry processes into value-added functional foods is of great importance both in terms of sustainable production models and enriched food supply. This study aims to determine the place of sea buckthorn, pomegranate, and grape seed flours, which have high functional potential, in whole wheat grissini formulations and the consumer acceptability of these innovative products. In the research, functional grissini produced with the addition of three different fruit seed flours (UG5, NG4, IG3) were analyzed by trained panelists using the Hedonic Scale and Ranking Test methods. The findings revealed that the formulation containing sea buckthorn seed (IG3) was the most successful product sensorially, receiving the highest scores in overall liking, flavor, and desire to eat again parameters. Grape seed (UG5) showed a moderate level of acceptance, while pomegranate seed (NG4) remained at the lowest level of liking due to its dominant bitter character. In conclusion, it was determined that the grissini matrix is a suitable carrier for functional components, but the specific aromatic profile of the kernel flour used plays a decisive role in consumer acceptance.

Keywords: Functional Food, Grissini, Sea Bass, Pomegranate and Grape Seed, Sensory Analysis.

Introduction

The global food processing industry generates substantial quantities of by-products as an inherent output of production processes; indeed, approximately 8.7% of the total industrial waste load in Türkiye originates from the food industry (TUIK, 2024). While these statistical data represent an environmental risk, they simultaneously harbor significant potential for a sustainable bio-economy and resource efficiency (Tuna, 2015). Contrary to traditional approaches, converting these nutritionally rich plant-based by-products into functional foods not only reduces production costs but also enables the development of innovative products that support human health (Şener & Ünal, 2008; Yılmaz, 2013). Functional foods are strategic products that, beyond meeting basic nutritional requirements, optimize physiological functions through their bioactive components (Siró et al., 2008; Demirbağ et al., 2023). In this context, among fruit processing by-products, pomegranate and grape seeds stand out for their high antioxidant capacities, while the oleaster (Elaeagnus angustifolia) fruit emerges as a functional raw material source characterized by its unique mineral and carotenoid profile (Yaman, 2012; Gül et al., 2013). Due to its low water activity and physical matrix suitable for fortification, "grissini" is considered an ideal carrier for delivering these components to broad audiences (Kınay & Duyar, 2021; Suhodol et al., 2022). Based on this scientific framework, the

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primary objective of this study is to design functional grissini formulations enriched with the addition of oleaster, pomegranate, and grape seed flours and to determine the consumer acceptability of these innovative products. In the study, samples were produced by incorporating the respective fruit seed flours into whole wheat flour at specific ratios. The sensory characteristics of the resulting grissini (including color, texture, flavor, and overall acceptability) were analyzed using a hedonic scale to identify the most successful functional formulation (Kınay & Duyar, 2021; Duţă et al., 2025).

Functional Foods: Definition, Characteristics, and Potential Benefits

Functional foods are defined as food products containing components that possess the capacity to improve an individual's health status or reduce the risk of disease, extending beyond their basic nutritional properties (Siró et al., 2008). In addition to providing essential macro- and micronutrients for the body, these foods exert positive effects on various physiological functions through the bioactive components they contain (Roberfroid, 2002). The most fundamental characteristic of functional products is that they are consumable within the daily diet and are presented directly in "food" form, rather than in medicinal forms such as capsules, tablets, or powders (Bigliardi & Galati, 2013).

The potential health benefits of functional foods span a broad spectrum due to the phytochemicals, antioxidants, and dietary fibers they incorporate (Gül et al., 2013). Specifically, antioxidant components are known to develop a protective mechanism against cardiovascular diseases and certain types of cancer by reducing oxidative stress within the body (Kaur & Kapoor, 2001). Furthermore, it has been scientifically proven that functional ingredients exhibiting prebiotic properties support the immune system by optimizing gastrointestinal health (Gibson & Roberfroid, 1995). Consequently, these foods offer a diet-based strategy for the management of chronic degenerative disorders of modern society, such as obesity, diabetes, and hypertension (Mohamed, 2014).

Grissini: Definition and Fundamental Characteristics

Grissini holds a unique position within the baking industry in terms of its historical origins, technical definition, and structural characteristics; in recent years, it has become one of the most preferred matrices in functional food development studies. Traditionally a type of bread native to the Turin region of Italy, grissini is a thin, stick-shaped, and crisp product obtained through the processing of basic ingredients -such as flour, water, salt, and yeast- via specific technological processes (Suhodol et al., 2022). The product's characteristic low moisture content and porous structure render it microbiologically stable and offer the advantage of a long shelf life (Kınay & Duyar, 2021). From a technological perspective, grissini is classified under the category of "low water activity (aw) products," a feature that allows it to maintain its sensory quality for extended periods (Suhodol et al., 2022).

Beyond the traditional formulation, modern food science positions grissini as an ideal "carrier system" for delivering bioactive components (such as plant extracts, seaweed, or whey proteins) to the consumer (Duţă et al., 2025). The product's high surface area-to-volume ratio facilitates the rapid removal of water during baking and the formation of its characteristic crispness, while simultaneously providing a suitable medium for the homogeneous distribution of added functional powders (Fuzinatto et al., 2015). In this context, grissini holds strategic importance in academic research and industrial innovation processes due to both its offering as a low-calorie snack alternative and its high adaptability to nutritional enrichment (Kınay & Duyar, 2021).

Nutritional and Functional Profile of Fruit Seed Flours to Be Used in Grissini

Oleaster Seed (Elaeagnus angustifolia L.) Flour

Known for its medicinal properties, oleaster (Elaeagnus angustifolia) possesses a rich content of carotenoids, flavonoids, and other bioactive compounds, while also exhibiting significant prebiotic potential (Ishaq et al., 2015; Khan et al., 2016). The use of oleaster flour in products such as ice cream to enhance nutritional value and antioxidant capacity has been well-documented in the literature

(Çakmakçi et al., 2015). The fundamental physicochemical properties of oleaster seed flour are presented in Table 1.

Table 1. Fundamental Physicochemical Properties of Oleaster (Elaeagnus angustifolia) Seed Flour

Physicochemical Properties	Value (%)
Total Fat	11,67 ± 0,31
Total Protein	5,98 ± 0,38
Total Starch	10,70 ± 0,10
Total Sugar	47,06 ± 3,38
Total Carbohydrate	57,76 ± 3,38
Dry Matter	71,35 ± 0,63
Moisture	28,65 ± 0,63
Ash	2,59 ± 0,02
Acidity	1,30 ± 0,01

Source: *Karkar (2023)*

Pomegranate Seed (Punica granatum L.) Flour

Pomegranate seed flour is a valuable functional ingredient utilized for the fortification of food products, owing to its high content of phenolic compounds. Studies have reported substantial total phenolic content values in pomegranate seeds, ranging between 43.71 and 54.66 mg GAE/g (Okumuş, 2016; Yıldırım, 2022). Its application in the enrichment of bakery products, such as biscuits, has also been well-documented in the literature (Acun, 2011; Aksoylu, 2012). The fundamental physicochemical properties of pomegranate seed flour are presented in Table 2.

Table 2. Fundamental Physicochemical Properties of Pomegranate (Punica granatum L.) Seed Flour

Physicochemical Properties	Value (%)
Total Fat	21.25±0.93
Total Protein	37.10±0.82
Dry Matter	50.93±0.56
Ash	2.44±0.08
Phenolic Substance	7.20±0.08

Source*: Gölükçü et al., (2005)*

Grape Seed (Vitis vinifera L.) Flour

Grape seed, a valuable by-product of the wine and fruit juice industries, typically contains approximately 40% fiber, 16% fat, 11% protein, and 7% complex phenols (Rockenbach et al., 2011; Lachman et al., 2013). It is well-established that its incorporation into bakery products enhances dietary fiber, total phenolic content, and antioxidant activity. However, it also influences physical characteristics by causing a darkening of the product color (indicated by lower L* values) and an increase in textural hardness and chewiness. While sensory acceptability remains high at low supplementation levels such as 5% in products like cakes it tends to decrease at higher concentrations due to alterations in flavor and texture (Bekar, 2017). The fundamental physicochemical properties of grape seed flour are presented in Table 3.

Table 3. Fundamental Physicochemical Properties of Grape (Vitis vinifera L.) Seed Flour

Physicochemical Properties	Value (%)
Fiber	40
Fat	16
Protein	11
Complex phenols	7
Dry Matter	6
Carbohydrate	26

Source: *Yıldırım (2022) & Bekar (2017)*

Methodology

This study employed a quantitative research design to develop functional grissini formulations enriched with oleaster, pomegranate, and grape seed flours and to determine their consumer acceptability. Since the objective was to obtain measurable data and evaluate these findings through statistical analysis, a positivist approach, grounded in the existence of universal and objective reality, was adopted. The goal was to reach conclusions via objective measurements without interference in the process.

An experimental design focusing on cause-and-effect relationships was utilized to examine the impact of oleaster, grape, and pomegranate seed flours (independent variables) on the sensory properties and consumer liking of the grissini (dependent variables). Within this framework, a control group consisting of plain grissini and experimental groups containing different fruit seed flours were established and compared through sensory analysis tests.

While the population of the study consists of students at Sivas Cumhuriyet University, a purposive sampling method was preferred due to the experimental nature of the study and the technical requirements of the sensory evaluation process. This group, selected via non-probability purposive sampling, comprised 10 trained panelists from the Department of Gastronomy and Culinary Arts who had received formal training in sensory analysis. The number and qualifications of the panelists were determined in accordance with the sensory evaluation criteria recommended by Altuğ Onoğur and Elmacı (2019). Sensory analysis was performed in two replicates. Trained panelists were selected to ensure a more reliable evaluation of the technical attributes of the products.

Data were collected through product development applications conducted in a laboratory environment and sensory evaluation forms. To determine the sensory characteristics and consumer acceptability of the developed grissini samples, a 9-Point Scoring and Ranking Test was employed. The scoring test was preferred to allow panelists to independently evaluate their level of liking or disliking for each sensory attribute (appearance, taste, odor, texture) on a numerical scale; this transforms these attributes into quantitative data suitable for parametric statistical analysis (Carpenter et al., 2000). This method is considered one of the most reliable tools for converting overall acceptability into quantitative data (Carpenter et al., 2000). The Ranking Test was applied to determine the relative differences between the various grissini formulations and to quickly identify the most preferred sample. This method was selected as it allows for the comparison of multiple samples based on a single criterion, such as overall liking (Altuğ Onoğur & Elmacı, 2019). The obtained data were analyzed using the SPSS 25 software package. The significance of the mean differences between sample groups was tested using One-Way Analysis of Variance (ANOVA). In cases where significant differences were identified, the Tukey HSD multiple comparison test which minimizes Type I error in intra-group comparisons and precisely reveals differences between groups was applied (Field, 2013).

Materials

The grape seed, oleaster seed, and pomegranate seed flours used in the study were procured from e-commerce platforms, while the salt, sugar, olive oil, sunflower oil, yeast, and whole wheat flour were obtained from local commercial suppliers.

Production of Grissini Supplemented with Different Fruit Seed Flours

In line with the objective of the study, preliminary trials were conducted to develop an optimal grissini formulation with enhanced dietary fiber and antioxidant capacity. A standard base formulation consisting of whole wheat flour, yeast, olive oil, sunflower oil, sugar, and salt was used. The effects of different fruit seed flours (grape, pomegranate, and oleaster) added to this formulation on dough structure, post-baking crispness, and sensory properties were examined. Preliminary analyses and experimental trials indicated that the addition of fruit seed flours increased the water requirement of the doughs. Therefore, the amount of water was revised to balance the dough rheology and maintain

the shapeability characteristic of traditional grissini. While the water amount used in the control group (C) was kept constant, the water level in the formulations containing fruit seed flours was optimized and increased to 75.56 units in order to improve dough workability.

During the preliminary trials, it was observed that the characteristic aromas of fruit seed flours created a distinctive sensory profile in the final product. In order to benefit from this aromatic and functional richness while also achieving the desired textural quality, grissini formulations were designed using three different seed flours. In these formulations, the amounts of whole wheat flour, yeast, oils, sugar, and salt were kept constant as fixed components, whereas grape seed flour, pomegranate seed flour, and oleaster seed flour were determined as variable parameters. Prior to grissini production, the fruit seed flours were subjected to a two-stage grinding process in order to minimize the undesirable hard shell structure from a textural perspective. In the first stage, pre-grinding was performed in a grinder operating at 28,000 rpm for 5 minutes. Subsequently, a final grinding step was carried out in a coffee grinder for 2 minutes to obtain a more homogeneous particle size and a smoother flour form. A standardized production protocol was applied to all formulations during grissini dough preparation. The dry ingredients and liquid phase were kneaded for 5 minutes until a homogeneous structure was obtained. The dough was then subjected to a fermentation process for 30 minutes to develop the characteristic crispness and porous structure of the product. The doughs were rolled out to a thickness of 1 mm and shaped into rectangles measuring 8 × 5 cm. The shaped samples were baked in a preheated oven at 160 °C using the fan-assisted baking setting for 15 minutes and were then prepared for sensory analysis.The grissini formulations developed in this study and the codes assigned to these formulations (C, ÜG5, NG4, İG3) are presented in Table 4.

Table 4. Grissini Formulations and Sample Codes

	C	**ÜG5**	**NG4**	**İG3**
Whole Wheat Flour (g)	100	100	100	100
Oleaster Seed Flour (g)	-	-	-	50
Grape Seed Flour (g)	-	50	-	-
Pomegranate Seed Flour (g)	-	-	50	-
Yeast (g)	2	2	2	2
Olive Oil (ml)	7,5	7,5	7,5	7,5
Sunflower Oil (ml)	15	15	15	15
Sugar(g)	5	5	5	5
Salt (g)	3	3	3	3
Water (ml)	50	75,56	75,56	75,56

C: Standard grissini; ÜG5: grissini prepared with grape seed flour; NG4: grissini prepared with pomegranate seed flour; İG3: grissini prepared with oleaster seed flour.

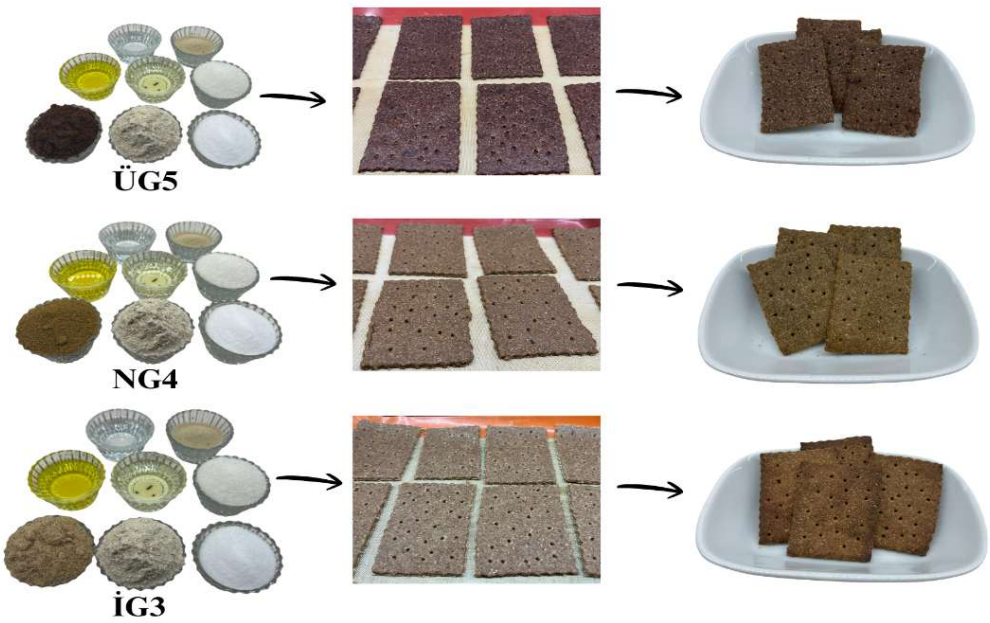

Figure 1. Grissini Enriched with Different Fruit Seed Flours

Findings

This section of the study presents the findings and interpretations derived from the sensory analyses conducted by the panelists on the grissini samples supplemented with different fruit seed flours.

Scoring Test Findings

In the study, the panelists were asked to evaluate the grissini samples prepared with ÜG5 (grape seed flour), NG4 (pomegranate seed flour), and İG3 (oleaster seed flour) using a 1–9 point scale within the scope of the scoring test. The results obtained are presented in Table 5.

Tablo 5. Sensory Scoring Test Findings for Grissini Supplemented with Different Fruit Seed Flours

Parameters	ÜG5	NG4	İG3	F:	p:
Color	8,05±,887^{c}	5,95±,999^{b}	4,75±2,173^{a}	25,723	**,000**
Surface texture	5,95±2,114^{a}	5,75±1,410^{a}	5,85±2,231^{a}	,052	,949
Shape integrity	2,40±1,635^{a}	4,00±2,384^{ab}	4,30±2,755^{b}	3,925	**,025**
Softness/hardness	6,55±1,050^{a}	6,20±1,673^{a}	6,05±2,164^{a}	,460	,634
Crispness level	7,20±1,673^{a}	6,75±1,803^{a}	6,05±2,012^{a}	1,995	,145
Overall chewability	4,40±1,789^{a}	5,40±2,088^{a}	4,60±1,875^{a}	1,517	,228
Melt in the mouth sensation	4,00±1,864 ^{a}	4,95±2,282 ^{a}	4,50±1,573 ^{a}	1,215	,304
Fruity flavor	4,25±1,943 ^{a}	5,35±2,834 ^{a}	5,80±2,285 ^{a}	2,241	,116
Herbal/spicy flavor	5,80±1,908^{ab}	6,70±2,227^{b}	4,55±2,139^{a}	5,309	**,008**
Bitter flavor	5,50±1,878^{ab}	7,00±1,947^{b}	4,55±2,502^{a}	6,743	**,002**
Aftertaste (lingering taste in the mouth)	6,20±1,908^{b}	4,35±1,531^{a}	5,90±2,382^{b}	5,073	**,009**
Overall flavor	6,00±1,947^{ab}	4,55±2,645^{b}	6,40±2,234^{b}	3,604	**,034**
Smell	4,65±1,981 ^{a}	5,40±2,604 ^{a}	5,20±2,587 ^{a}	,520	,597
Overall acceptability	5,80±2,191^{b}	3,55±2,282^{a}	6,70±1,525^{b}	12,806	**,000**
Desire to eat again	5,25±2,447^{b}	2,60±2,415^{a}	6,70±1,455^{b}	18,612	**,000**

a-b: Different exponential letters in the same column indicate a significant difference between samples ($p<0.05$)

Findings for ÜG5 (Grissini Prepared with Grape Seed Flour)

In the ÜG5 sample formulated with grape seed flour, the color score was determined to be 8.05, indicating that the product color was perceived as dark by the panelists (where 1: very light, 9: very dark). A statistically significant difference was detected among the samples regarding the color parameter ($F=25.723$; $p < 0.001$), with ÜG5 being perceived as significantly darker than the other

samples. This is attributed to the natural phenolic compounds and pigments present in grape seed flour being reflected in the final product.When structural characteristics were examined, the surface structure (5.95) and softness/hardness (6.55) scores were found to be at a medium-to-high level; no statistically significant difference was found between samples for these parameters ($p > 0.05$). This finding suggests that the ÜG5 sample was perceived as neither excessively hard nor excessively soft, offering an acceptable textural structure. Although the crispness level was rated high with a score of 7.20, the scores for overall chewiness (4.40) and mouthfeel/disintegration (4.00) remained at a moderate level, indicating that the mastication process was perceived as relatively more demanding by the panelists. However, no statistically significant difference was found among the samples for these specific parameters ($p > 0.05$).Regarding flavor characteristics, the fruity flavor was perceived at a weak-to-moderate level with 4.25 points, whereas the herbal/spicy flavor was felt at a moderate level with 5.80 points. A statistically significant difference was found among the samples in the herbal/spicy flavor parameter ($F = 5.309$; $p = 0.008$), positioning ÜG5 at a moderate level for this attribute. The relatively high scores for bitterness (5.50) and particularly aftertaste (6.20) demonstrate that the characteristic bitter and astringent flavor components of grape seed flour were reflected in the product's flavor profile. A significant difference was identified among the samples in the aftertaste parameter ($F = 5.073$; $p = 0.009$), indicating that ÜG5 created a more pronounced aftertaste perception. The flavor profile resulted in an overall flavor score of 6.00, corresponding to a "liked" level; however, a statistically significant difference was observed among the samples regarding overall flavor ($F = 3.604$; $p = 0.034$), with ÜG5 exhibiting moderate performance in this parameter. Finally, the scores for overall acceptability (5.80) and the desire to re-consume (5.25) remained at a moderate level, and statistically significant differences were detected among the samples for these parameters (overall acceptability: $F = 12.806$, $p < 0.001$; desire to re-consume: $F = 18.612$, $p < 0.001$).

Findings for NG4 (Grissini Prepared with Pomegranate Seed Flour)

In the NG4 sample containing pomegranate seed flour, the color score was determined to be 5.95, indicating that the product color was perceived in medium tones by the panelists (where 1: very light, 9: very dark). A statistically significant difference was identified among the samples regarding the color parameter ($F = 25.723$; $p < 0.001$), with NG4 exhibiting a lighter perception than ÜG5 and a similar perception to İG3 in this regard. When structural characteristics were examined, the scores for surface structure (5.75), softness/hardness (6.20), and crispness (6.75) were found to be closely aligned; no statistically significant difference was detected among the samples for these parameters ($p > 0.05$). This finding suggests that the NG4 sample presents a balanced perception in terms of physical structure. However, the fact that overall chewiness (5.40) and mouthfeel/disintegration (4.95) remained at a moderate level indicates that the textural properties did not significantly enhance consumer liking. Nevertheless, no statistically significant differences were found among the samples for these parameters either ($p > 0.05$).Regarding the flavor profile evaluation, the fruity flavor was perceived at a moderate level with a score of 5.35, whereas the herbal/spicy flavor was distinctly felt with a score of 6.70. A statistically significant difference was identified among the samples in the herbal/spicy flavor parameter ($F = 5.309$; $p = 0.008$), with NG4 possessing the highest mean for this attribute. The bitterness score of 7.00 indicates that the product was evaluated by panelists as being close to bitter, and a significant difference was also found among the groups for this parameter ($F = 6.743$; $p = 0.002$). While the relatively low aftertaste score of 4.35 reveals that the persistence of the flavor in the mouth was limited, it was observed that the dominant bitter and herbal flavors negatively impacted the overall flavor perception. Consequently, the overall flavor score remained at 4.55, corresponding to the "neither liked nor disliked" level, and a statistically significant difference was identified among the samples for this parameter ($F = 3.604$; $p = 0.034$). This negative perception became even more pronounced as the overall acceptability (3.55) and the desire to re-consume (2.60) approached the "disliked" level; significant differences were detected among the samples for both parameters (overall acceptability: $F = 12.806$, $p < 0.001$; desire to re-consume: $F = 18.612$, $p < 0.001$).

Findings for İG3 (Grissini Prepared with Oleaster Seed Flour)

In the İG3 sample prepared using oleaster seed flour, the color score was determined to be 4.75, indicating that the product color was perceived by the panelists as being between light and medium tones. A statistically significant difference was identified among the samples regarding the color parameter ($F = 25.723$; $p < 0.001$), with İG3 being perceived as the sample closest to the lightest tone. It is suggested that this color may have been evaluated as natural and familiar by the panelists. In terms of structural characteristics, the scores for surface structure (5.85), shape integrity (4.30), and softness/hardness (6.05) were found to be balanced; no statistically significant difference was detected among the samples for these parameters ($p > 0.05$). The crispness level was rated at a medium-to-high level with 6.05 points, while overall chewiness (4.60) and mouthfeel/disintegration (4.50) remained within acceptable limits. These findings demonstrate that the İG3 sample offers a texturally balanced structure that does not pose a concern for the consumer. Regarding flavor characteristics, the fruity flavor was perceived at a medium-to-high level with a score of 5.80, whereas herbal/spicy (4.55) and bitter (4.55) flavors were felt at relatively low levels. A statistically significant difference was identified among the samples in the bitterness parameter ($F = 6.743$; $p = 0.002$), with İG3 possessing the lowest values in this regard. The aftertaste score of 5.90 indicates that the lingering flavor in the mouth was not found to be unpleasant and that a balanced flavor profile was presented. This balanced sensory structure allowed the overall flavor score to reach 6.40, corresponding to the "liked" level; a statistically significant difference was identified among the samples for the overall flavor parameter ($F = 3.604$; $p = 0.034$).The most striking results were observed in the scores for overall acceptability (7.70) and the desire to re-consume (6.70); these values reflect consumer acceptance approaching the "liked very much" level. Statistically significant differences were detected among the samples for both parameters (overall acceptability: $F = 12.806$, $p < 0.001$; desire to re-consume: $F = 18.612$, $p < 0.001$), establishing that İG3 possessed the highest means.

Ranking Test Findings

In the study, the panelists were requested to rank the grissini samples prepared with ÜG5 (grape seed flour), NG4 (pomegranate seed flour), and İG3 (oleaster seed flour) based on their appearance, odor, texture, aroma, and flavor characteristics. The results obtained from this evaluation are presented in Table 6.

Table 6. Sensory Ranking Test Findings for Grissini Supplemented with Different Fruit Seed Flours

Parameters	ÜG5	NG4	İG3	F:	p:
Appearance	1,65±,875[a]	1,85±,587[a]	2,60±,681[b]	9,564	**,000**
Smell	1,90±,852[a]	1,50±,688[a]	2,60±,503[b]	12,804	**,000**
Texture	1,85±,813[a]	1,75±,639[a]	2,45±,826[b]	4,914	**,011**
Aroma	1,80±,768[a]	1,50±,513[a]	2,75±,550[b]	22,116	**,000**
Flavor	1,85±,813[a]	1,45±,510[a]	2,75±,550[b]	21,738	**,000**

a-b: Different exponential letters in the same column indicate a significant difference between samples ($p<0.05$)

Findings for ÜG5 (Grissini Prepared with Grape Seed Flour)

In the ranking test, the ÜG5 sample was evaluated as one of the samples with the lowest mean scores across all parameters. The fact that the scores for appearance (1.65), odor (1.90), texture (1.85), aroma (1.80), and flavor (1.85) were close to 1 indicates that consumers generally positioned this product among the least preferred samples. It was determined that ÜG5 belonged to a similar statistical group as NG4 regarding appearance, odor, and aroma parameters; however, it received significantly lower scores than İG3 ($p < 0.001$).This situation suggests that the dark color, distinct phenolic taste, and aftertaste characteristics of grape seed flour created a negative perception in consumer rankings. The ranking test results support the findings of the hedonic scoring test, demonstrating that ÜG5 exhibited limited performance in terms of sensory acceptance.

Findings for NG4 (Grissini Prepared with Pomegranate Seed Flour)

In the ranking test, the NG4 sample received the lowest scores in most parameters or similarly low scores to ÜG5. Mean scores for appearance (1.85), smell (1.50), texture (1.75), aroma (1.50), and flavor (1.45) indicate that consumers frequently ranked NG4 as either the least preferred or the second-to-last sample. Specifically, in the smell, aroma, and flavor parameters, NG4 exhibited the lowest means, and these differences were found to be statistically significant (smell: $F=12.804$, $p<0.001$; aroma: $F=22.116$, $p<0.001$; flavor: $F=21.738$, $p<0.001$). These results reveal that the dominant bitter and herbal flavor characteristics of pomegranate seed flour negatively affected consumer preferences. The poor performance of NG4 in the ranking test is consistent with the low overall acceptability and desire to re-consume findings observed in the hedonic test.

Findings for İG3 (Grissini Prepared with Oleaster Seed Flour)

The İG3 sample stood out as the product with the highest mean scores across all sensory parameters in the ranking test. The fact that scores for appearance (2.60), odor (2.60), texture (2.45), aroma (2.75), and flavor (2.75) were close to 3 indicates that consumers largely ranked this product as the most liked sample. It was determined that İG3 received significantly higher scores than ÜG5 and NG4 across all parameters ($p<0.05$). The high ranking scores obtained particularly in the aroma and flavor parameters suggest that oleaster seed flour offers a balanced and non-irritating taste profile. These results clearly demonstrate that İG3 is the most successful product in terms of consumer acceptance.

Conclusion and Discussion

In this study, the consumer acceptability of functional grissini formulations developed using oleaster, pomegranate, and grape seed flours was evaluated through sensory analysis methods; the fact that the ranking test results supported the hedonic test findings strengthened the consistency of the obtained data. The findings revealed that overall evaluation results exhibited statistically significant sensory differences among the formulations. The İG3 sample, containing oleaster seed flour, was identified as the most successful formulation, receiving the highest scores in the parameters of overall acceptability (6.70), flavor (6.40), and desire to re-consume (6.70). The primary reason for this high acceptance is attributed to the fact that oleaster seed flour does not create a dominant bitterness despite being rich in phenolic compounds. Indeed, these results align with similar studies in the literature. Findings by Demiray Teymuroğlu (2022) and Karkar (2023) similarly indicate that oleaster seed flour creates a balanced taste profile in functional products and does not adversely affect sensory acceptance.

In the ÜG5 sample containing grape seed flour, a moderate level of consumer acceptance was observed. This is thought to stem from the dark color and distinct aftertaste characteristics caused by the concentrated phenolic compounds in the seeds. The literature reports that the addition of grape seed increases the browning index and hardness in foods (Bekar, 2017; Özaltın & Çağındı, 2023), and its use above a certain threshold value reduces sensory scores compared to control samples (Kalyas & Ürkek, 2020; Ürkek et al., 2022; Yıldırım, 2022). The moderate preference for the ÜG5 sample in the current study is parallel to the sensory limitations exhibited by grape seeds in different food matrices.

The NG4 sample, containing pomegranate seed flour, was recorded as the product with the lowest sensory acceptability due to its dominant bitter and herbal flavor profile. This situation is explained by the characteristic bitterness created by ellagitannins in the pomegranate seeds within the grissini matrix. Okumuş (2016) and Yıldırım (2022) have noted that pomegranate-based ingredients limit consumer acceptance by increasing the perception of bitterness in products.

Overall, it was concluded that, contrary to the sensory harmony displayed by oleaster seed in grissini, pomegranate and grape seed flours restricted consumer preference at their current utilization rates, highlighting that formulation optimization is critical for these ingredients. This situation underscores

the necessity of formulation studies aimed at determining the optimum utilization levels, particularly for pomegranate and grape seeds.

In conclusion, this study theoretically supports that bakery products with low water activity can constitute a functional platform for the delivery of bioactive components; from a practical perspective, it demonstrates that within the framework of the "zero waste" principle, seed by-products often perceived as having low economic value can be transformed into high-value-added functional foods.

Suggestions

Based on the findings obtained, it can be concluded that oleaster seed flour is a more advantageous ingredient in the production of functional grissini in terms of sensory balance and consumer acceptance. Although grape and pomegranate seed flours possess high functional value, it is recommended that their utilization rates be optimized or that they be incorporated into formulations alongside flavor-masking or balancing agents to enhance sensory acceptability.

In future studies, it is suggested to determine the threshold values for sensory acceptance by using varying ratios of fruit seed flours and to conduct consumer tests with a broader consumer base in addition to trained panelists. Furthermore, investigating the nutritional, antioxidant, and shelf-life characteristics of the developed functional grissini will contribute to the positioning of these products as functional foods. Finally, it is evaluated that the findings of this study contribute to the literature on the development of functional bakery products and serve as a guide for the transformation of food by-products, such as fruit seeds, into high-value-added products.

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