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Enhancing Dietary Fiber in Gluten-Free Cakes: The Potential of Date and Olive Seed Powders

Glutensiz Kekte Diyet Lifi Zenginleştirilmesi: Hurma ve Zeytin Çekirdeği Unu Kullanımı

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Abstract

Objective: This study aimed to evaluate the dietary fiber content and sensory properties of gluten-free cakes enriched with date seed powder and olive seed powder for individuals with celiac disease.

Material and Method: Three different cake formulations were prepared; the control group contained only gluten-free flour, and the other two formulations had half of the flour replaced with seed powders. Total dietary fiber content was analyzed using the NMKL 129–AOAC method. Sensory evaluation was conducted with 15 panelists using a 5-point Likert scale, assessing volume, texture, chewiness, softness, pore structure, aroma, odor, taste, color, and overall acceptability.

Results: Cakes containing date seed powder (17.79%) and olive seed powder (16.27%) had significantly higher dietary fiber content compared to the control cake (5.47%). The gluten-free control cake received the highest scores for texture, chewiness, softness, volume, and overall acceptability ($p<0.05$). The cake with date seed powder showed moderate acceptance, whereas the cake with olive seed powder received the lowest scores for these attributes. No significant differences were observed among samples in terms of pore structure, color, odor, and flavor ($p>0.05$).

Conclusion: Date seed powder appears to be a promising ingredient for enhancing the dietary fiber content of gluten-free products. However, increasing substitution levels may negatively affect certain sensory properties. Optimization of formulation parameters, particularly substitution level and particle size, is essential to achieve a balance between nutritional improvement and sensory acceptability.

Keywords: Gluten, date seed, olive seed, dietary fiber.

Özet

Amaç: Bu çalışma, çölyak hastalığı olan bireyler için geliştirilen hurma çekirdeği tozu ve zeytin çekirdeği tozu ile zenginleştirilmiş glutensiz

keklerin diyet lifi içeriğini ve duyusal özelliklerini değerlendirmeyi amaçlamıştır.

Gereç ve Yöntem: Araştırmada üç farklı kek formülasyonu hazırlanmış; kontrol grubunda yalnızca glutensiz un kullanılırken, diğer iki formülasyonda unun yarısı hurma veya zeytin çekirdeği tozu ile ikame edilmiştir. Toplam diyet lifi içeriği NMKL 129–AOAC yöntemi kullanılarak analiz edilmiştir. Duyusal değerlendirme, 15 panelist ile 5'li Likert ölçeği kullanılarak gerçekleştirilmiş; hacim, tekstür, çiğnenebilirlik, yumuşaklık, gözenek yapısı, aroma, koku, tat, renk ve genel kabul edilebilirlik parametreleri değerlendirilmiştir.

Bulgular: Hurma çekirdeği tozu (%17,79) ve zeytin çekirdeği tozu (%16,27) içeren keklerin diyet lifi içeriği, kontrol kekine (%5,47) kıyasla anlamlı düzeyde daha yüksek bulunmuştur. Glutensiz kontrol keki, tekstür, çiğnenebilirlik, yumuşaklık, hacim ve genel kabul edilebilirlik açısından en yüksek puanları almıştır ($p<0,05$). Hurma çekirdeği tozu içeren kek orta düzeyde kabul edilebilirlik gösterirken, zeytin çekirdeği tozu içeren kek bu parametrelerde en düşük puanları almıştır. Gözenek yapısı, renk, koku ve tat açısından örnekler arasında anlamlı fark saptanmamıştır ($p>0,05$).

Sonuç: Hurma çekirdeği tozu, glutensiz ürünlerin diyet lifi içeriğini artırmada umut verici bir bileşen olarak öne çıkmaktadır. Ancak, artan ikame oranları bazı duyusal özellikleri olumsuz etkileyebilmektedir. Besinsel iyileştirme ile duyusal kabul edilebilirlik arasında denge sağlanabilmesi için özellikle ikame oranı ve partikül boyutu gibi formülasyon parametrelerinin optimize edilmesi gerekmektedir.

Anahtar Kelimeler: Gluten, hurma çekirdeği, zeytin çekirdeği, diyet lifi

Introduction

Gluten is a storage protein found primarily in wheat, barley, rye, and oats; it imparts elasticity and viscoelastic properties to dough (1). It consists of prolamin and glutenin fractions, referred to as gliadin–glutenin in wheat, hordein in barley, secalin in rye, and avenin in oats (2). Approximately 80–85% of cereal proteins are gluten-based structures (3).

Celiac disease is a chronic autoimmune disorder that develops in genetically susceptible individuals in response to gluten and related prolamins. It is characterized by villous atrophy and crypt hyperplasia in the small intestine and shows a strong association with HLA-DQ2/DQ8 (4). Epidemiological studies estimate the global prevalence of celiac disease to be between 0.6% and 1% (5). In Türkiye, as of the end of 2022, the number of diagnosed celiac patients corresponds to approximately 0.18% of the total population (6). Clinical manifestations range from typical malabsorptive symptoms during childhood to milder presentations in adulthood (7). Common symptoms include diarrhea, weight loss, and abdominal distension accompanied by malabsorption (4). A strict gluten-free diet is currently the only effective treatment for celiac disease and is essential for achieving clinical improvement and normalization of serological markers (8).

Dietary fiber refers to the edible parts of plants that are resistant to digestion and absorption in the human small intestine and undergo partial or complete fermentation in the colon (9). Evidence from animal models and clinical trials suggests that dietary fiber intake may suppress inflammatory responses and contribute to improved gastrointestinal health, thereby reducing the risk of chronic diseases (10, 11).

The only treatment for celiac disease is strict, lifelong adherence to a gluten-free diet (12). Consequently, various gluten-free products are produced using naturally gluten-free cereals such as rice and corn, as well as ingredients like guar and amaranth (13, 14). However, because gluten-free diets limit the consumption of

traditional cereals, many individuals fail to meet recommended daily fiber intakes. A systematic review consistently demonstrates that both children and adults adhering to gluten-free diets consume insufficient dietary fiber (15).

Rice, corn, and starch-based ingredients commonly used in gluten-free products are naturally low in fiber; therefore, commercial gluten-free foods generally contain less fiber, protein, and certain micronutrients compared to wheat-based products (16, 17). Recent literature and systematic reviews indicate that low fiber intake among individuals on gluten-free diets may adversely affect gastrointestinal function and gut microbiota composition (18-20). For these reasons, increasing the nutritional quality of gluten-free products is considered essential.

Date fruit (*Phoenix dactylifera L.*), particularly its seed, is highlighted as a functional food component due to its high dietary fiber and bioactive compounds (21, 22). Previous studies have demonstrated that date seeds contain substantial amounts of total dietary fiber, making them a promising ingredient for enriching fiber-deficient food products (23-25). These properties make date seeds an economically viable, sustainable, and nutritionally valuable ingredient (26).

The olive (*Olea europaea* L.) seed constitutes approximately 30–35% of the fruit and is rich in lignin, hemicellulose, and cellulose, forming a hard structural matrix (27). Olive seed powders, characterized by low water activity, offer advantages in terms of extended shelf life and structural contribution in food formulations (28). Although olive seeds are not widely used in the food industry, their high fiber content suggests strong potential as a functional ingredient (29).

Date and olive seeds represent two sustainable agro-industrial by-products with high dietary fiber content relevant to functional food development (25, 26). While date seeds are notable for their carbohydrate, protein, and fat composition, olive seeds stand out for their structural fiber components (22, 30).

The aim of this study was to evaluate the effects of date seed powder and olive seed powder incorporation on the dietary fiber content and sensory properties of gluten-free cakes. In addition, the study aims to contribute to sustainability by valorizing date and olive seeds, which are typically regarded as bio-waste.

Material and Method

Preparation of Samples

Commercially available gluten-free flour, eggs, sugar, vegetable oil, milk, baking powder, vanilla, olive seed powder, and date seed powder were used in the study. No preservatives or additives were included in the formulations. The gluten-free flour consisted of corn starch, rice flour, sugar, thickening agents (pectin and xanthan gum), and leavening agents (sodium bicarbonate and sodium acid pyrophosphate), as declared on the product label.

Three cake formulations were prepared according to a standardized recipe: a gluten-free control cake, a date seed–enriched cake, and an olive seed–enriched cake. The control cake contained 200 g gluten-free flour. In the date seed formulation, 100 g of gluten-free flour was replaced with 100 g of date seed powder, while in the olive seed formulation, 100 g of gluten-free flour was replaced with 100 g of olive seed powder. Apart from the flour replacement, all formulations contained identical amounts of the remaining ingredients, including 3 medium-sized eggs, 200 g sugar, 100 mL sunflower oil, 150 mL milk, 10 g baking powder, and 5 g vanilla.

All ingredients were mixed using a standardized procedure. First, eggs and sugar were mixed until a homogeneous and foamy structure was obtained. Then, sunflower oil and milk were added and mixed for approximately 2–3 minutes. Subsequently, the dry ingredients (gluten-free flour or flour–seed powder mixture, baking powder, and vanilla) were added gradually and mixed until a uniform batter was formed. Mixing was carried out at medium speed using a standard kitchen mixer.

The batter was poured into cake molds and baked at 180 °C for 30 minutes. After baking, the cakes were allowed to cool at room temperature.

Each formulation was produced in duplicate; however, sensory evaluation was conducted using samples from a single production batch to ensure uniformity during the panel session.

Sensory Evaluation

Sensory evaluation was conducted at the Department of Nutrition and Dietetics, Faculty of Health Sciences, with 15 voluntary panelists aged 18–65 years using a single-blind protocol (31). Each panelist received the three cake samples developed for the study in a predetermined order: N1 (date seed–enriched cake), N2 (control gluten-free cake), and N3 (olive seed–enriched cake).

Panelists evaluated each sample based on sensory attributes, including volume, pore structure, chewiness, softness, texture, odor, flavor, color, and overall pleasantness. A 5-point Likert scale was used, ranging from 1 (dislike a lot) to 5 (like a lot). Individuals with recent illnesses that could affect their sense of taste or smell, as well as those with known food allergies, were excluded from the study. Panelists were instructed to rinse their mouths with water before each tasting to minimize carry-over effects (32).

Dietary Fiber Analysis

Sample preparation procedures were carried out in a laboratory setting at the Department of Nutrition and Dietetics. Total dietary fiber content was determined in an accredited food analysis laboratory using the enzymatic–gravimetric NMKL 129–AOAC method (33). Homogenized cake samples were analyzed according to the method specifications, and total dietary fiber content was expressed as a percentage (%).

Statistical Analysis

Statistical analyses were conducted using SPSS (Statistical Package for the Social Sciences) version 23.0. Differences among the sensory evaluation parameters were assessed using one-way analysis of variance (ANOVA), and pairwise comparisons were performed with the Tukey post-hoc test. Results were presented as mean ± standard deviation. A p-value of <0.05 was considered indicative of statistical significance.

Ethical Aspects of the Research

Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of the Faculty of Health Sciences (26.12.2024/169). Written informed consent was obtained from all participants prior to the sensory evaluation.

Results

The sensory analysis results of the gluten-free cakes with different formulations are presented in Table 1. The gluten-free cake was statistically the most preferred sample in terms of texture, chewiness, and softness, while the date seed and olive seed cakes consistently formed lower-rated groups ($p = 0.002$, $p < 0.001$, and $p = 0.007$, respectively). A statistically significant difference was also observed for volume ($p < 0.001$), with the gluten-free cake receiving the highest score, followed by the date seed formulation, which also scored significantly higher than the olive seed sample. A statistically significant difference was also observed in overall pleasantness ($p < 0.001$).

The gluten-free sample (4.26 ± 0.70) was statistically the most preferred, while the date seed (3.26 ± 0.88) and olive seed cakes (3.20 ± 0.67) were rated significantly lower. No statistically significant differences were observed in the pore structure, color, odor, and flavor parameters of the gluten-free cakes with different formulations, indicating that all samples were evaluated similarly for these sensory attributes ($p > 0.05$).

Table 1. Sensory evaluation results of gluten-free cakes with different formulations

Parameters	N1 (Date seed)	N2 (Gluten-Free)	N3 (Olive Seed)	p
Pore structure	4.06 ± 0.96	4.46 ± 0.63	3.80 ± 1.01	0.054
Texture	3.66^{a} ± 0.72	4.40^{b} ± 0.73	3.13^{a} ± 1.12	0.002
Chewiness	2.53^{b} ± 0.91	4.53^{a} ± 0.63	2.66^{b} ± 1.11	<0.001
Volume	3.33^{b} ± 1.01	4.13^{c} ± 0.77	2.80^{a} ± 1.08	<0.001

Softness	$3.93^{a} \pm 0.79$	$4.53^{b} \pm 0.63$	$3.73^{a} \pm 0.96$	0.007
Color	4.20 ± 1.01	4.13 ± 0.91	3.80 ± 1.01	0.416
Odor	4.06 ± 0.96	3.86 ± 1.06	3.80 ± 1.14	0.610
Flavor	4.00 ± 0.84	3.93 ± 0.96	3.73 ± 0.70	0.570
Overall pleasantness	$3.26^{a} \pm 0.88$	$4.26^{b} \pm 0.70$	$3.20^{a} \pm 0.67$	<0.001

Values are expressed as mean ± standard deviation. ANOVA was used. Different superscript letters within a row indicate statistically significant differences ($p < 0.05$).

The radar plot indicates that the gluten-free cake (N2) consistently received the highest sensory scores across key attributes, particularly in terms of texture, chewiness, softness, and volume. The date seed formulation (N1) demonstrated intermediate performance, scoring higher than the olive seed cake (N3) in most parameters. All three formulations exhibited similar ratings in pore structure, color, odor, and flavor, indicating no notable differences in these attributes. (Figure 1). The visuals of the samples listed below are given in Figure 2.

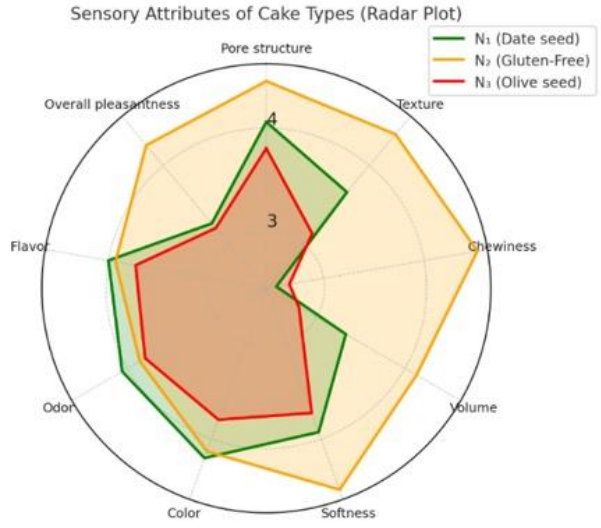

Figure 1. Radar plot illustrating the sensory attribute scores of gluten-free cakes formulated with date seed (N1), gluten-free control (N2), and olive seed (N3).

Figure 2. Cake samples used in the study.

The date seed flour cake (17.79 ± 0.89) and the olive seed flour cake (16.27 ± 0.81) had higher fiber contents than the gluten-free cake (5.47 ± 0.27).

Table 2. Fiber amounts of gluten-free cakes with different formulations

Product	Fiber (%)
Gluten-free cake	5.47 ± 0.27
Cake with date seed flour	17.79 ± 0.89
Cake with olive seed flour	16.27 ± 0.81

Discussion

In this study, the dietary fiber content and sensory properties of gluten-free cakes enriched with date seed powder and olive seed powder were evaluated. The findings demonstrated that the incorporation of both date and olive seed powders substantially increased the fiber content of the cakes compared to the gluten-free control. This result is consistent with previous studies reporting that date seed powder is a promising ingredient for functional food development due to its high dietary fiber content (32, 34).

The sensory evaluation revealed that, despite the higher fiber content, cakes enriched with date seed and olive seed powders exhibited lower scores in texture and chewiness compared to the control sample. These findings are in agreement with previous studies indicating that high substitution levels of seed flours may negatively affect textural properties and overall acceptability (35). The gluten-free control cake was the most preferred sample in terms of

texture, chewiness, softness, and overall acceptability.

No significant differences were observed among the samples in terms of color, odor, and flavor, suggesting that the incorporation of seed powders did not adversely affect these sensory attributes. However, the reduction in texture-related scores may be associated with structural changes in the cake matrix due to the incorporation of high-fiber ingredients. In particular, particle size and grinding characteristics of seed powders have been reported to influence the textural properties and mouthfeel of bakery products (36). Smaller particle sizes may disrupt the crumb structure and lead to increased hardness and reduced chewiness in gluten-free baked products.

Olive seed powder, similar to date seed powder, has been increasingly investigated as a sustainable ingredient for enhancing the nutritional profile of bakery products, particularly due to its high fiber content (37, 38). In the present study, although olive seed powder significantly increased the fiber content of the cakes, it resulted in lower scores for volume, chewiness, and overall acceptability. Comparable findings have been reported in previous studies, where higher substitution levels led to increased hardness and reduced sensory acceptance in baked products (38).

Similarly, studies evaluating the incorporation of date seed powder into bakery products have shown that increasing substitution levels can improve fiber content while adversely affecting textural properties such as hardness and chewiness (35). These findings highlight the importance of optimizing substitution levels to achieve a balance between improved nutritional value and acceptable sensory characteristics.

Given that insufficient fiber intake is commonly reported among individuals adhering to a gluten-free diet (8, 15), the substantial increase in fiber content observed in the present study is particularly relevant. The incorporation of date and olive seed powders into gluten-free products may therefore represent a practical strategy for improving dietary fiber intake in individuals with celiac disease.

However, maintaining sensory acceptability remains a key challenge in gluten-free product development. The results of this study suggest that while nutritional enhancement can be achieved through the use of seed powders, formulation parameters such as particle size, substitution level, and processing conditions should be carefully optimized to minimize negative effects on texture and overall acceptability.

This study has several strengths. The use of standardized formulations ensured that differences among samples were attributable to the incorporation of seed powders. In addition, the use of validated analytical methods for dietary fiber determination enhances the reliability of the findings. The inclusion of a structured sensory evaluation under controlled conditions provides valuable insight into consumer acceptability.

However, several limitations should be acknowledged. The sensory evaluation was conducted using samples obtained from a single production batch, which may limit reproducibility. In addition, the relatively small number of panelists may restrict the generalizability of the results. Only a single substitution level was tested, limiting the ability to identify optimal formulation ratios. Furthermore, texture-related properties were evaluated only through sensory assessment without instrumental analysis. The study also did not include particle size analysis of seed powders or variations in processing conditions such as baking time and temperature.

Despite these limitations, the findings highlight the potential of date and olive seed powders as sustainable ingredients for enhancing the fiber content of gluten-free products. Future studies should focus on optimizing formulation parameters to improve both nutritional quality and sensory acceptability.

In conclusion, the incorporation of date seed powder and olive seed powder significantly increased the dietary fiber content of gluten-free

cakes. However, this improvement was accompanied by a reduction in certain sensory attributes, particularly texture, chewiness, and overall acceptability. These findings highlight the importance of optimizing formulation parameters, including substitution level, particle size, and processing conditions, to achieve a balance between nutritional enhancement and sensory quality. The use of date and olive seed powders, which are typically considered agro-industrial by-products, also represents a sustainable approach to improving the nutritional profile of gluten-free products. Future research should focus on optimizing incorporation levels, evaluating different processing conditions, and investigating strategies to improve textural properties while maintaining consumer acceptability.

Ethical Aspects of the Research

Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of the Faculty of Health Sciences (26.12.2024/169). Written informed consent was obtained from all participants prior to the sensory evaluation.

Author Contributions

Conceptualization: EA, ZMÇ, DA, DSK, PSÇ; Data curation: DA, DSK, PSÇ; Formal analysis: EA, ZMÇ; Funding acquisition: PSÇ; Investigation: DA, DSK, PSÇ; Methodology: EA, ZMÇ, DA, DSK, PSÇ; Project administration: EA; Resources: EA, ZMÇ; Software: EA, ZMÇ; Supervision: EA, ZMÇ; Validation: EA, ZMÇ, DA, DSK, PSÇ; Visualization: EA, ZMÇ; Writing – original draft: EA, ZMÇ; Writing – review & editing: EA, ZMÇ.

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Conflict of Interest

All authors declared that they have no conflict of interest.

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