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Research Article

Effect of Olive Pomace Fiber on the Baking Properties of Wheat Flour and Flat Bread (Barbari Bread) Quality

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The current study is aimed at fortifying Barbari bread with different levels (T_{Co}: 0, $T_{5\%}$: 5%, $T_{10\%}$: 10%, and $T_{15\%}$: 15) of olive pomace dietary fiber (ODF) and investigating the quality properties of enriched bread. The fiber of the defatted olive pomace powder was extracted by an enzymatic process as a green extraction method (α-amylase, protease, amyloglucosidase, and cellulase; incubation time: 4.5 h, 40°C). The effect of ODF addition on the thermal (based on differential scanning calorimetry (DSC)), rheological, physical, textural, and sensory properties of samples was investigated. The DSC curves of samples were a broad endothermic transition peak ($T_{onset} \sim 43$ °C and $T_{peak} = 123.58 - 125.74$ °C). By increasing the ODF level, the water absorption rate of the dough increased while softening degree reduced. There was a negative significant correlation between baking loss and crumb moisture ($R > -0.94$) and aw ($R = -0.769$). By increasing ODF, sample porosity and specific volume decreased. There was a significant difference between hardness and springiness of $T_{15\%}$ and T_{Co}. Replacement of wheat flour with 10% ODF had no significant effect on the sensory parameters of Barbari bread.

1. Introduction

The agrofood industry produces a large amount of waste and by-products which can cause environmental pollution and high economic cost for disposing of such wastes. Regarding reaching a zero waste policy and sustainable agriculture, reutilization of these by-products is one of the most critical issues in the food science and food industry [1]. Furthermore, these by-products are considered potential sources of added-value compounds with high functionality and bioactivity such as dietary fiber, protein, fatty acids, phenols, vitamins, and minerals [2, 3]. Therefore, efficient use of waste is important for both nutritional and environmental reasons.

Considering the growing consumer demands for healthier foodstuffs with acceptable sensorial attributes, developing new food products and reformulation of traditional recipes have received considerable scientific interest. By-products represent an interesting and less expensive source of bioactive and functional ingredients [4–6]. Moreover, bakery products especially bread as the most popular food consumed widely worldwide are a good candidate for fortification by introducing high nutritional value ingredients [5]. In this regard, several studies investigate the possibility of using various by-products such as wheat bran [7, 8], flaxseed [2], coconut residue [9], carrot [10], broad bean hull [11], and grape seed [5, 12, 13] to enhance the nutritional value of bread.

Total olive oil production in Iran was more than 7000 t, and >100,000 ha was devoted to olive cultivation in 2019 [14]. The olive oil process generates a solid residue called olive pomace which formed about 35-40% of processed olives (around 2500-2800 t in Iran) [15]. Olive pomace is a rich source of dietary fiber, polyphenols, carotenoids, fatty acids, and minerals [13, 16]. However, olive pomace is mainly used as plant fertilizer and biogas [17].

Dietary fiber (DF) refers to edible plant polysaccharides that are resistant to digestion and absorption in the human small intestine but undergo complete or partial fermentation in the colon. Based on solubility in hot water, DF can be divided into soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). SDF is a noncellulosic polysaccharide (e.g., oligosaccharides and some indigestible polysaccharides such as inulin, pectin, galactomannan, and beta-glucan), while IDF includes cellulose, lignin, and some hemicelluloses [18]. Depending on fiber source, purity, and SDF to IDF ratio, the properties of the final product fortified with DFs (e.g., bred) may widely vary [19]. The available information about the addition of olive oil pomace dietary fiber (ODF) in the bakery industry is limited. To the best knowledge of the authors, no study has been reported in the literature on the fortification of bakery products with ODF extracted by an enzymatic method (as one of the green extraction methods). Therefore, the present study is aimed at investigating the starch gelatinization, rheological, physical, and sensory properties of Barbari bread as one of the most popular Iranian flat breads supplemented with different levels (5, 10, and 15%) of olive pomace fiber.

2. Materials and Methods

2.1. Materials. Olive pomace was obtained from Khandan Cultivation and Industry Factory (Qazvin, Iran). Wheat flour with an extraction rate of 78% and protein content of 10% was purchased from Golha Co. (Tehran, Iran). Active dry yeast was purchased from the local market. The chemicals utilized in the current study were laboratory grade and purchased from Merck (Merck, India Ltd. and Germany), Dr. Majalli (Tehran, Iran), and Sigma-Aldrich (Sigma-Aldrich Inc., USA). Amyloglucosidase AMG 300 L (EC 3.2.1.3, from *Aspergillus niger*, activity: 300 AGU·g^{-1}), protease Alcalase 2.4 L (EC 3.4.21.62, from Bacillus licheniformis, activity: 2.4 AU·g^{-1}), Celluclast 1.5 L (EC 3.2.1.4, Cellulase from *Trichoderma reesei* ATCC 26921, activity: 700 U.g^{-1}), and Termamyl 300 L type DX (EC 3.2.1.1, a heat-stable α-amylase from *Bacillus licheniformis*, activity: 300 KNU.g^{-1}) were obtained from Novozymes Biotechnology Co., Ltd. (Tianjin, China). The chemicals utilized in the present work were analytically pure.

2.2. Preparation of Defatted Olive Pomace Flour. Olive pomace was defatted using a Soxhlet apparatus (FALC, Italy) [20]. The samples were dried in a 50°C oven (BINDER GmbH Ltd. Co., Germany). The dried pomace was ground (Pars Khazar, Tehran, Iran) and sieved (50-micron mesh) to obtain olive meal powder. The samples were kept in a dark glass and at refrigerator temperature until fiber extraction.

2.3. Enzymatic-Assisted Extraction of Olive Pomace Fiber. First, around 10.00 g of olive pomace powder was sufficiently mixed with 0.2 mL $CaCl_2$ (1 M) and 400 mL phosphate-buffered saline (PBS, pH 6). Then, 500 μL Termamyl was added to the mixture and incubated in the 40°C water bath for 1.5 h. The enzymatic digestion was followed by protease (500 μL, pH 7.5, 40°C for 1 h) and amyloglucosidase (200 μL, pH 4.5, 40°C for 1 h). Then, 50 mL of the prepared mixture was added into 500 mL phosphate buffer (0.1 M, pH = 5.0) and mixed with 0.3 g cellulase (1 h, 40°C). This mixture was incubated at 100°C for 10 min to inactive enzymes. After centrifugation at 5,000 × g for 15 min, the residues were rinsed with distilled water twice and freeze-dried to obtain the IDF. The supernatants were mixed with 95% ethanol (fourfold volumes) for 2 h at room temperature. The residues were washed with 100% ethanol and dried to obtain SDF [21–23]. Based on our experiments, the yield of olive pomace fiber was 92.12% in which 21.68% of this fiber was SDF (moisture content: 5.55 ± 0.06%, protein content: 2.13 ± 0.05, and ash content: 0.46 ± 0.06), and 70.44 of ODF was IDF (moisture content: 3.34 ± 0.12%, protein content: 3.19 ± 0.04, and ash content: 5.38 ± 0.23).

2.4. Preparation of Dough and Baking Barbari Bread. Bread dough was prepared using 100 g of flour ODF (100 : 0, 95 : 5, 90 : 10, and 85 : 15), 1 g of dry yeast, 1 g of salt, and water. All ingredients were mixed with the appropriate amount of water (based on the farinograph chart) in a laboratory mixer (EK-230 M-Electra) at 140 rpm for 15 min. The dough was placed in a dark place for 1 hour (resting time of dough to activate the yeast) and divided into 300 g pieces. Each piece was rolled and left to rest for 45 min. Each ball was rolled on a flat surface into ~2 cm thickness and baked in an electric oven (UM model, Memmert, Germany) for 30 min at 210°C. All Barbari breads were packed in polyethylene bags and kept at room temperature to be evaluated for various parameters [19].

2.5. Differential Scanning Calorimetry (DSC). Thermal properties regarding starch gelatinization of hydrated wheat flour-olive pomace fiber blends were assessed with Perkin Elmer Thermal Analysis equipment (STA 600). For DSC analysis, ~3 mg of each hydrated sample was loaded and hermetically sealed into a DSC stainless steel pan. The temperature profile in the center of the bread crumb during baking was simulated under the following scanning conditions: samples were kept at 40°C for 1 min, then heated from 40 to 150°C at a rate of 10°C/min. Thermal transitions of starch samples were defined as T_o (onset) and T_p (peak of gelatinization) [24].

2.6. Dough Farinograph Properties. The effect of wheat flour replacement with different levels of ODF (zero, 5, 10, and 15%) on the farinograph characteristics of dough (i.e., water absorption rate (%), dough development time (min), stability time (min), softening degree after 12 min (BU), and farinograph quality number (FQN)) was investigated. For this purpose, wheat flour or fiber-enriched flour was mixed with distilled water in a 50 g farinograph container. Farinograph features were performed based on the AACC 21-54 method using farinograph-E (Brabender, model 827504, Germany) in three repetitions [25].

2.7. Specific Volume. Bread volume was evaluated by the standard rapeseed displacement method AACC 10–05. The loaf-specific volume was calculated by dividing loaf volume by loaf weight at 1.5 h after baking [26].

2.8. Baking Loss. The baking loss was calculated based on equation (1) [27]:

$$\text{Baking loss (\%)} = \frac{\text{initial weight before baking} - \text{loaf weight at 1.5 after baking}}{\text{initial weight before baking}} \times 100. \quad (1)$$

2.9. Porosity Percentage. An image processing method was used to evaluate the porosity of bread crumb. A piece of 4 × 4 cm was cut from the crumbs of the bread. Sample images were obtained by scanner with 300 dpi resolution (Hp Scanjet G3010 model). The porosity analysis was done by ImageJ, a free Java-based image processing package (http://rsb.info.nih.gov/ij/), converting the image to binary, and the porosity percentage of the sample was calculated by applying the JPOR plugin of ImageJ [28].

2.10. Water Activity. Approximately 2.00 g of each bread sample was minced into fine pieces and placed into a water activity meter chamber (HygroLab 2, Rotronic, Bassersdorf, Switzerland). This test was done at 25°C.

2.11. Textural Profile Analysis (TPA). Texture profile analysis (TPA) including hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience was measured by a Texture Pro CT V 1.5 Build 20 (Brookfield Engineering Laboratories Inc. Middleboro, MA. USA) fitted with an aluminum 36 mm diameter cylindrical P/36 R probe. The breads were cut into a cube (2 cm width), and the following parameters were adopted: compression to 50% of the initial height, pretest speed (1 mm/s), test speed (1 mm/s), and posttest speed (5 mm/s) [29].

2.12. Sensory Analysis. The panel group included ten semi-trained members (six females and four males) from personnel and students of the Food Science and Technology Department (Islamic Azad University, Qazvin, Iran). The sensory panel evaluation form is presented in Figure 1. Samples were provided in white plates at ambient temperature. The panelists were asked to evaluate each sample for taste, odor, texture, and color. The samples were scored on a five-point hedonic scale (1 = dislike very much, 3 = neither like nor dislike, and 5 = like very much) at 24 h and 72 h after baking. Overall acceptance was calculated based on a weighted average of sensory parameters (considered coefficients for taste, texture, odor, and color were 4, 3, 2, and 1, respectively) [30].

2.13. Statistical Analysis. The obtained data were subjected to a one-way/two-way analysis of variance (ANOVA) using Minitab 17 software (State College, PA, USA). All experiments were done in triplicate. Tukey's multiple range test was used to determine significant differences between the means (at the 95% level).

Sensory panel evaluation form

ID: Date:

Please evaluate each sensory attributes of the sample by using the rating scale (1-5)

1 = Dislike very much 3 = Neither like nor dislike (medium) 4 = Like

2 = Dislike 5 = Like very much

Sample #	Taste	Odor	Texture	Color

Figure 1: Sensory panel evaluation form.

3. Results and Discussions

3.1. Gelatinization Properties. Differential scanning calorimetry was applied to investigate starch gelatinization of hydrated wheat flour-ODF blend (Figure 2). It was obviously recognized that a similar tendency was displayed throughout the thermogram curves of samples. The DSC curves showed a broad endothermic transition peak with an onset temperature of ~43°C. The onset temperature is related to the melting temperature of recrystallized amylopectin. During the bread-baking process, starch gelatinization includes a loss of crystalline and molecular order of starch and generates swollen, collapsed disaggregated, and deformed granules [31]. However, these deformed granules are not disrupted because of limited dough water. Simulation of the baking process of the hydrated wheat flour-ODF blends caused swelling of the amorphous regions and destabilization of the crystalline region of the starch granules which occurs at melting temperature (<60°C) [24]. The ungelatinized granules will melt at higher temperatures. The replacement of up to 15% wheat flour with ODF did not have any noticeable effect on the gelatinization properties and starch thermal properties of the flour mixture. In the current study, peak temperature (Tp) occurred at 123.58-125.74°C. The changes in the dough gelatinization temperature during baking are affected by the dough formulation. By increasing fiber content, Tp slightly increased. The intermolecular interference between amylopectin and ODF can be considered a factor affecting the pasting and gelatinization characteristics of dough [24]. Quality and concentration of dietary fiber may affect the thermal transitions of hydrated flour-fiber blends. In this regard, Kotsiou et al. also reported that the addition of 20% roasted yellow split pea flour in a wheat dough had no significant effect on the thermal properties of flour dough [32]. However, Santos et al. reported that by increasing fiber concentration in the wheat blend, T_o and T_p increased. They found that the presence of dietary fibers in the wheat blends resulted in restricting or delaying the swelling of starch granules [24].

As seen in Figure 2, the curves of various samples were distinguished from each other in terms of the magnitude of the heat flow. By increasing the fiber content, the heat flow increased. The difference between the heat flow of T_{Co} and $T_{5\%}$ and $T_{10\%}$ was not noticeable, while the magnitude of heat flow of the sample containing 15% ODF was greater

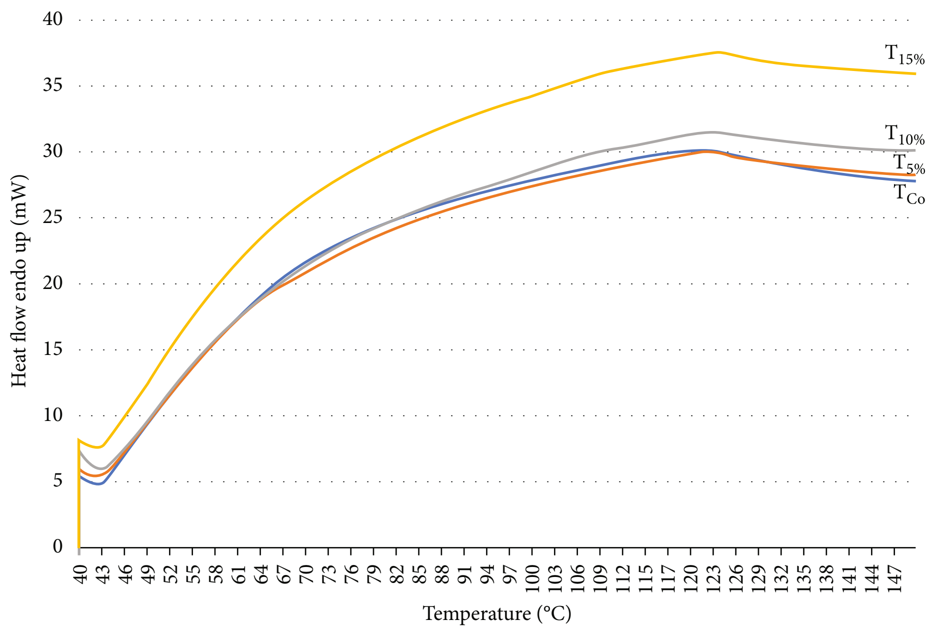

Figure 2: The effect of olive pomace fiber (ODF) on differential scanning calorimetry curves of various Barbari samples for investigating starch gelatinization of hydrated wheat flour-ODF fiber blend. T_{Co}: control sample; $T_{5\%}$: wheat flour replacement with 5% ODF; $T_{10\%}$: wheat flour replacement with 10% ODF; $T_{15\%}$: wheat flour replacement with 15% ODF.

than others. The higher moisture content and lower porosity of $T_{15\%}$ can be the main reasons for this phenomenon [33].

3.2. Farinograph Properties. Table 1 presents the effect of ODF addition on water absorption rate and dough mixing characteristics. Water absorption is the amount of water that is needed to prepare a dough with the desired consistency [34]. By increasing the ODF level, the water absorption rate increased from 63.73 to 68.63 ($P < 0.05$). These results are in agreement with those reported by several previous authors [3, 5, 35, 36]. It may be related to a large number of hydroxyl groups in the fiber structure. The hydroxyl groups form hydrogen bonds with water molecules and increase the water absorption capacity of the dough. In general, a high water absorption rate may lead to more appropriate bakery products [37]. However, Gunathilake et al. reported that when fiber-rich coconut flour is added to wheat flour, the water absorption rate of the dough is reduced [38]. Coconut flour contains other compositions besides fiber; these compounds can also affect the water absorption rate of the dough.

Dough development time and stability time are indicators of flour strength [23].

The dough development time is the time required to develop a gluten network and reflects the increase in dough consistency. Gluten network formation can be affected by mechanical mixing, water availability, and protein content [7]. As shown in Table 1, by increasing ODF level, a fluctuating trend was observed in the dough development time. Generally, by increasing the fiber level to 10%, the dough development time increased, but by adding more than 10% ODF, a decreasing trend was found in the dough development time. The competition of fiber and gluten for water absorption can cause dehydration of the gluten matrix during the mixing process and resistance to mixing and consequently decrease the gluten network elasticity [37]. The reduction in development time at high fiber levels can also be attributed to gluten dilution [3].

Dough stability indicates the resistance of the dough to the process. The addition of 10% ODF increased the stability time from 4.37 to 12.43 minutes. But increasing the fiber to 15% had no significant effect on the dough stability time. These results are in line with the findings of some previous studies [12, 39]. It was reported that gluten dilution can occur at high concentrations of fiber. Fiber competes with gluten and prevents the complete hydration of the protein and disturbs the gluten matrix [40, 41]. However, the replacement of wheat flour with Moldavian dragonhead seed residue (up to 12%) [3] and beet leaf powder [35] decreased the stability time. Disturbance in the intermolecular interactions of dough gluten proteins can be a probable reason for this reduction trend [35]. Moreover, Nawrocka et al. also reported that the enrichment of wheat dough with oat fiber increased dough stability from 3 to 8 minutes, while other fiber sources (apple cranberry, cocoa, and carob) decreased the dough stability time [42]. Therefore, the type and concentration of fiber, its chemical structure, and the compounds associated with fiber (such as protein, minerals, and fat) can affect the dough's stability. For example, some fiber sources are rich in phenolic compounds. Phenolic compounds not only affect the oxidative reactions of food [43], but the hydroxyl group of these compounds can directly bond with flour proteins and affect the quality and functional properties of food [5, 44–46]. Therefore, the possible presence of phenolic compounds in ODF can also be the reason for the higher stability of the dough contacting ODF.

Table 1: The farinograph properties of the doughs supplemented with different levels of olive pomace dietary fiber (ODF).

Farinograph factor	ODF level (%)			
	0	5	10	15
Water absorption rate (%)	63.73 ± 0.32^{C}	65.40 ± 0.57^{B}	66.31 ± 0.43^{B}	68.63 ± 0.64^{A}
Dough development time (min)	3.63 ± 0.15^{BC}	3.31 ± 0.10^{C}	4.56 ± 0.42^{A}	4.03 ± 0.15^{AB}
Stability (min)	4.37 ± 0.16^{B}	3.73 ± 0.31^{C}	12.43 ± 0.21^{A}	12.27 ± 0.15^{A}
Softening degree (BU)	60.67 ± 4.34^{A}	55.83 ± 1.62^{A}	31.47 ± 1.94^{B}	22.43 ± 1.12^{C}
Farinograph quality number (FQN)	48.10 ± 1.95^{B}	55.57 ± 2.40^{B}	82.67 ± 4.73^{A}	77.67 ± 2.52^{A}

All data are presented in the manner of means ± SD ($n = 3$). The different letters for each parameter indicate significant difference ($P < 0.05$).

Table 2: The effect of the replacement wheat flour with different levels of olive pomace fiber (ODF: 0, 5, 10, and 15%) on the basic physical properties of Barbari bread.

Parameter	ODF level (%)			
	0	5	10	15
Volume ($cm^3 \cdot g^{-1}$)	2.20 ± 0.07^{A}	2.08 ± 0.05^{AB}	2.00 ± 0.03^{BC}	1.85 ± 0.08^{C}
Baking loss (%)	14.33 ± 0.06^{A}	12.93 ± 0.31^{B}	11.83 ± 0.38^{C}	11.10 ± 0.10^{D}
Porosity (%)	24.00 ± 1.00^{A}	23.33 ± 0.58^{AB}	21.00 ± 1.00^{B}	18.00 ± 1.00^{C}
Moisture (24 h) (%)	27.45 ± 0.08^{C}	28.08 ± 0.69^{C}	31.08 ± 0.50^{B}	32.57 ± 0.15^{A}
Moisture (72 h) (%)	25.68 ± 0.25^{D}	26.72 ± 0.45^{C}	29.99 ± 0.34^{B}	31.89 ± 0.19^{A}
Water activity (aw)	0.70 ± 0.011^{B}	0.71 ± 0.008^{AB}	0.71 ± 0.004^{AB}	0.72 ± 0.006^{A}

All data are presented in the manner of means ± SD ($n = 3$). The diverse letters for each parameter indicate significant difference ($P < 0.05$).

A high water absorption rate and a low softening degree indicate a dough with good tolerance against mixing [47]. The softening degree decreased from 60.67 to 22.43 with increasing fiber. Anil also reported that by increasing the level of hazelnut fiber, the softening degree decreased from 78 to 28 BU. It can be related to phenolic compounds [39]. The hydroxyl group of polyphenols can directly bond with the wheat flour proteins and decrease the softening degree of the dough [5, 44–46].

FQN (farinograph quality number) shows a dough's ability to retain its structure during the mixing process [48]. By increasing the fiber level, the FQN also increased significantly. Aghamirzaei et al. showed that the replacement of 5% wheat flour with grape pomace increased FQN (significantly). But the addition of ≥10% grape pomace reduced the FQN [12]. Therefore, fiber concentration and compounds extracted together with fiber (e.g., polyphenols, protein, and minerals) may affect the activity of alpha-amylase and consequently rheological properties [5].

3.3. Basic Physical Properties. Table 2 shows the basic physical properties of the Barbari bread containing different levels of olive pomace dietary fiber. The replacement of wheat flour with ODF resulted in a slight decrease in the baking loss of samples (14.33-11.1%). There was a negative and significant correlation between baking loss and crumb moisture after 24 h ($R = -0.942$), after 72 h ($R = -0.950$), and aw ($R = -0.769$). In other words, the hydroxyl groups of dietary fiber structure formed hydrogen bonds with water; consequently, doughs containing a higher fiber content showed a higher moisture content. A part of water molecules binds to the hydrophilic groups of fibers as bound water which is more difficult to evaporate during the baking process [33]. For this reason, water activity in samples containing 10% fiber is not significantly different from the control one (Table 2).

Increasing the fiber level caused a decrease in specific volume (2.2 to 1.85 $cm^3 \cdot g^{-1}$) and crumb porosity (24.00-18.00%). Overall, the replacement of wheat flour with dietary fiber leads to a reduction in gluten content, disruption of the gluten network, weakening of the dough structure (Section 3.1), and consequently a decrease in porosity and specific volume [3]. However, there were no statistical differences in crumb porosity and specific volume of $T_{5\%}$, T_{Co}, and $T_{10\%}$ ($P > 0.05$). The results supported the findings of farinograph analysis (Section 3.2).

3.4. Texture Profile Analysis. The texture profile analysis (TPA) of the Barbari bread fortified with ODF is presented in Table 3. Hardness decreased by the partial replacement of wheat flour with olive dietary fiber. The hardness of $T_{15\%}$ was significantly higher than that recorded for the control one. However, the difference between T_{Co}, $T_{5\%}$, and $T_{10\%}$ was not significant ($P > 0.05$). Furthermore, there was no significant difference between samples enriched with ODF ($P > 0.05$). Arı Akın et al. reported that the tea fiber addition to bread formulation significantly increased the hardness of samples. But the difference between samples containing 2.5, 5, and 7.5% tea fiber was not significant [44]. It can be associated with the cross-linking between gluten proteins and starch, the thickening of the walls surrounding the gas cells, and decreasing crumb porosity and volume after fiber enrichment of the Barbari bread samples [2, 3, 7, 11, 33, 49]. In this regard, it was found that hardness has a negative correlation with specific loaf volume [49].

Table 3: The effect of the replacement wheat flour with different levels of olive pomace fiber (ODF: 0, 5, 10, and 15%) on the textural profile analysis (TPA) of Barbari bread samples.

Parameters	Storage time (hours)	ODF level (%)			
		0	5	10	15
Hardness (N)	24	8.29 ± 0.84^{B}	8.43 ± 0.65^{AB}	8.56 ± 0.57^{AB}	9.68 ± 0.42^{A}
	72	12.39 ± 0.92^{A}	12.37 ± 0.99^{A}	12.74 ± 0.91^{A}	14.05 ± 0.67^{A}
Adhesiveness (N)	24	0.15 ± 0.06^{A}	0.20 ± 0.08^{A}	0.18 ± 0.05^{A}	0.25 ± 0.06^{A}
	72	0.18 ± 0.09^{A}	0.175 ± 0.05^{A}	0.27 ± 0.1^{A}	0.3 ± 0.08^{A}
Resilience	24	0.15 ± 0.03^{A}	0.13 ± 0.01^{A}	0.13 ± 0.01^{A}	0.13 ± 0.01^{A}
	72	0.12 ± 0.01^{A}	0.13 ± 0.05^{A}	0.11 ± 0.01^{A}	0.12 ± 0.01^{A}
Cohesiveness	24	0.29 ± 0.02^{A}	0.30 ± 0.03^{A}	0.29 ± 0.01^{A}	0.27 ± 0.04^{A}
	72	0.24 ± 0.02^{A}	0.24 ± 0.03^{A}	0.26 ± 0.01^{A}	0.23 ± 0.03^{A}
Springiness (mm)	24	8.07 ± 0.65^{A}	7.43 ± 0.20^{AB}	7.76 ± 0.54^{AB}	6.91 ± 0.68^{B}
	72	7.34 ± 0.17^{A}	7.10 ± 0.11^{A}	7.01 ± 0.19^{A}	6.39 ± 0.20^{B}
Gumminess (N)	24	2.36 ± 0.20^{A}	2.58 ± 0.35^{A}	2.32 ± 0.09^{A}	2.58 ± 0.34^{A}
	72	2.70 ± 0.02^{B}	2.78 ± 0.08^{AB}	2.87 ± 0.06^{AB}	2.92 ± 0.14^{A}
Chewiness (mJ)	24	18.67 ± 0.29^{A}	18.68 ± 1.65^{A}	18.68 ± 0.70^{A}	18.65 ± 0.53^{A}
	72	21.15 ± 1.45^{B}	21.38 ± 2.03^{B}	24.70 ± 0.58^{A}	26.17 ± 0.39^{A}

All data are presented in the manner of means ± SD ($n = 3$). The diverse letters for each parameter indicate significant difference ($P < 0.05$).

Table 4: The effect of the replacement wheat flour with different levels of olive pomace fiber (ODF: 0, 5, 10, and 15%) on the sensory properties of Barbari bread.

Parameter	Time (hours)	ODF level (%)			
		0	5	10	15
Odor	24	4.70 ± 0.48^{A}	4.80 ± 0.42^{A}	4.80 ± 0.42^{A}	4.70 ± 0.48^{A}
	72	4.10 ± 0.57^{AB}	4.10 ± 0.57^{AB}	3.70 ± 0.68^{B}	3.80 ± 0.63^{B}
Taste	24	4.50 ± 0.53^{A}	4.50 ± 0.71^{A}	4.40 ± 0.84^{A}	3.50 ± 0.52^{B}
	72	3.90 ± 0.57^{AB}	3.80 ± 0.63^{AB}	3.70 ± 0.48^{AB}	3.30 ± 0.48^{B}
Color	24	4.30 ± 0.48^{A}	4.00 ± 0.47^{A}	4.30 ± 0.48^{A}	4.00 ± 0.47^{A}
	72	4.00 ± 0.47^{A}	3.80 ± 0.79^{A}	4.00 ± 0.47^{A}	3.60 ± 0.52^{A}
Texture	24	4.20 ± 0.42^{A}	3.90 ± 0.32^{AB}	3.90 ± 0.48^{AB}	3.20 ± 0.42^{CD}
	72	3.20 ± 0.42^{CD}	3.40 ± 0.52^{BC}	3.10 ± 0.47^{CD}	2.70 ± 0.68^{D}
Overall	24	4.43 ± 0.33^{A}	4.33 ± 0.41^{A}	4.32 ± 0.39^{A}	3.70 ± 0.28^{BC}
	72	3.74 ± 0.34^{B}	3.74 ± 0.26^{B}	3.55 ± 0.30^{BC}	3.25 ± 0.33^{C}

All data are presented in the manner of means ± SD ($n = 3$). The diverse letters for each parameter indicate significant difference ($P < 0.05$).

Adhesiveness and springiness can indicate the elasticity of bread [11]. As seen in Table 3, there was a significant difference between the springiness of the $T_{15\%}$ and T_{Co} at both storage times ($P < 0.05$). This result was in agreement with that reported in a previous study [7]. The lower springiness of samples containing fiber can be related to the partial dehydration and dilution of gluten as well as insufficient starch swelling and gelatinization during baking. The elasticity of bread is associated with the interaction between water, gluten, and starch [11].

During storage, an increase in hardness and crumbliness (decrease of cohesiveness) of Barbari samples besides a decrease in elasticity was observed which is also a typical indicator of bread staling. However, the decreasing trend in cohesiveness was not significant ($P > 0.05$). Starch retrogradation, gluten dehydration, amylopectin recrystallization, and the transition from rubbery to the glassy state of the protein network are some reasons for increasing hardness and decreasing springiness after 72 hours of bread storage [33]. Springiness decreasing of T_{Co} and $T_{15\%}$ during storage was ~9.04% and 7.52%, respectively, while hardness increasing of these samples was 49.46% and 45.10%, respectively. Pan et al. reported higher hardness and lower springiness for the control bread sample as compared to fiber-rich ones [8].

The addition of ODF had a small and no significant effect on adhesiveness, resilience, cohesiveness, gumminess (at 24 h), and chewiness (at 24 h). Zarzycki et al. also showed

Figure 3: The color of Barbari breads fortified with various levels of olive pomace fiber. T_{Co}: control sample; $T_{5\%}$: wheat flour replacement with 5% ODF; $T_{10\%}$: wheat flour replacement with 10% ODF; $T_{15\%}$: wheat flour replacement with 15% ODF.

that the addition of Moldavian dragonhead seed residue had a significant effect on the hardness and chewiness of bread. However, this fiber source had no significant effect on cohesiveness and springiness [3]. However, Ni et al. reported that the addition of broad bean hull powder significantly reduced the cohesiveness and resilience as well as increased the adhesiveness of bread [11]. This difference in results can be related to the different levels of total dietary fiber, soluble/insoluble fiber ratio, and the formulation of bread.

3.5. Sensory Analysis. Table 4 presents the sensory analysis of Barbari samples. The control sample received the highest sensory score (except for odor), while the lowest scores were obtained for bread enriched with 15% ODF. There was no significant difference between the control sample and bread enriched with 5 and 10% ODF ($T_{5\%}$ and $T_{10\%}$). On the contrary, the texture, taste, and overall score of $T_{15\%}$ were significantly lower than those of the control ones. Although the color of samples containing olive pomace fiber was clearly darker than that of the control one (Figure 3), this color was acceptable for panelists, and the difference between the color scores of samples was not significant ($P > 0.05$). At high ODF concentrations (15%), some panelists felt a slightly bitter and gassy taste. These tastes may be related to the phenolic compounds of ODF [5]. After 72 hours of baking, the odor score of $T_{10\%}$ and $T_{15\%}$, the texture score of T_{Co} and $T_{10\%}$, and an overall score of T_{Co}, $T_{5\%}$, and $T_{10\%}$ decreased significantly ($P < 0.05$). Barbari bread containing 10% ODF was scored less than the control one, but these scores were within the threshold limit (score > 3). However, for the texture parameter, the bread enrichment with 15% ODF did not receive an acceptable score from the panelists (score < 3). These results are in accordance with those reported in the previous study [5]. Generally, the replacement of wheat flour with 10% ODF had no significant effect on the sensory parameters of Barbari bread. These results are in agreement with those reported in previous sections.

4. Conclusions

The results of the current research show the potential of olive pomace fiber as an interesting food ingredient for bread formulation that can be particularly important from nutritional, environmental, and economical perspectives. The addition of ODF did not have a notable effect on the thermogram curves of the samples. Regarding dough rheology, by increasing the ODF level, the water absorption rate increased while softening degree reduced. The stability time, dough development, and farinograph quality number increased by increasing the ODF level up to 10%, and after that, these values decreased. By increasing the ODF level, the bread volume, weight loss, and porosity decreased, while moisture content increased. ODF level had no significant effect on the water activity of bread samples. By growing the share of ODF, the hardness of samples increased, and their springiness reduced. The sensory evaluation of all samples was within the acceptable limit (except the texture score of a sample containing 15% ODF after 72 h storage). Overall, among the Barbari bread supplemented with ODF (5, 10, and 15%), 10% fortification had no adverse effect on the physical, textural, and sensorial properties. However, fortification with higher ODF levels can provide more nutritional benefits for consumers. Further research is required to optimize bread formulation with higher fiber content and low or free gluten and to improve quality properties.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Additional Points

Practical Applications. Current study results show the potential of olive pomace fiber as a suitable ingredient for bread formulation that can be particularly important from nutritional, environmental, and economical perspectives. The addition of ODF did not have any notable effect on the gelatinization properties of hydrated wheat flour-olive pomace fiber blends. The addition of up to 10% ODF did not show adverse effects on the rheology, textural, and sensory properties of Barbari bread. However, adding more ODF levels produced bread with higher nutritional value. Further research is required to optimize bread formulation with higher fiber content and low or free gluten.

Ethical Approval

This article does not contain any studies with animals performed by any of the authors. Prior to the sensory evaluation test, ethical clearance was obtained and informed consent of the sensory panelists was obtained in accordance with national ethical standards.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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