Hindawi
Journal of Food Quality
Volume 2023, Article ID 8111233, 13 pages
https://doi.org/10.1155/2023/8111233

WILEY | Hindawi

Research Article

Effect of Apple Pomace Powder Addition on the Physicochemical Properties of Oily Cakes and Ranking Samples by Delphi Fuzzy Approach

Maryam Sabet Ghadam,[1] Mohammad Reza Saeedi Asl,[1] Akram Sharifi,[2] Ahmad Pedram Nia,[1] and Mohammad Armin[3]

[1]*Department of Food Science and Technology, Sabzevar Branch, Islamic Azad University, Sabzevar, Iran*
[2]*Department of Food Science and Technology, Qazvin Branch, Islamic Azad University, Qazvin, Iran*
[3]*Department of Agronomy and Plant Breeding, Sabzevar Branch, Islamic Azad University, Sabzevar, Iran*

Correspondence should be addressed to Akram Sharifi; asharifi81@gmail.com

Received 14 September 2022; Revised 22 February 2023; Accepted 3 May 2023; Published 16 May 2023

Academic Editor: Daniel Cozzolino

The current study is aimed to compare the effect of fat and/or wheat-flour substitution with apple pomace on the physicochemical and shelf-life of oily cakes. The sensory quality of samples was evaluated using the Delphi-Fuzzy logic method. The oily-cakes include the following: T_{CO}: control; $T_{W10\%}$ and $T_{W20\%}$: flour substitution with apple pomace (10 and 20% w/w); $T_{O10\%}$ and $T_{O20\%}$: fat substitution with apple pomace (10 and 20% w/w); $T_{W\&O(5:5)}$ and $T_{W\&O(10:10)}$: fat and wheat-flour substitution with apple pomace (5 : 5 and 10 : 10% w/w). The lowest and highest protein content were recorded for $T_{w20\%}$ ($10.0 \pm 0.12\%$) and $T_{O20\%}$ ($11.0 \pm 0.45\%$) ($p < 0.05$). There was no significant difference between the fat content of control samples with $T_{W10\%}$, $T_{W20\%}$, and $T_{O\&W(5:5)}$ ($p > 0.05$). $T_{W20\%}$ exhibited the highest fiber content (2.12%) and the lowest caloric (385.0 kcal/100 g) values. There was a significant difference between baking loss of $T_{O10\%}$ (9.87%) and $T_{O20\%}$ (9.36%) samples with control one (11.6%) ($p < 0.05$). By reducing the fat content, smaller and lower porous was observed. The antioxidant and antimicrobial potential of apple pomace was not significant. Therefore, apple pomace had no significant effect on the shelf-life of cakes. Based on defuzzification values, the sensory ranking of samples was as follows: T_{CO} (64.4) > $T_{W20\%}$ (63.9) > $T_{W\&O(5:5)}$ (63.7) > $T_{W10\%}$ (63.6) > $T_{O10\%}$ (60.2) > $T_{W\&O(10:10)}$ (60.1) > $T_{O20\%}$ (58.8). Overall, apple pomace could be considered a cost-effective, sustainable, and healthy alternative to partial wheat-flour. Further research is required to produce reduced-fat cakes. Adding fruit powder along with fat replacers can be suggested for future studies.

1. Introduction

Plants are considered as valuable natural sources that have got a great attention in food industry due to their antioxidant potentials [1]. In food industry, different fruits and vegetables are processed to produce various value-added products. These processes generate a large number of by-products [2]. However, these by-products are a rich source of valuable bioactive compounds and dietary fiber [3].

Apple pomace is one of the valuable by-products. The most frequent disposal method for apple pomace is to discard it directly into the landfill soil, resulting in serious environmental pollution and public health issues [4–6]. Therefore, it is necessary to explore safe, cost-effective, and efficient ways to utilize apple pomace in the food and nutraceutical industries. Apple pomace not only is a rich source of various nutrients, it is particularly high in nondigestible carbohydrates and dietary fibers (around 40%).

Baked products are the most widely consumed food item in the world. Thus, they can be utilized as a suitable carrier for dietary fiber [3]. Cakes, especially oily ones, are high in carbohydrates and fat, and consequently, they are high-calorie products [7, 8]. In addition, cakes are low in fiber content [9]. These features make cakes unsuitable choices for a healthy diet. The addition of apple pomace to the cake can improve the dietary fiber content and offer various health benefits [4, 6, 10].

During the product development process, dietary fiber sources can be completely or partially substituted with one or more cake ingredients such as flour, sugar, and fat [9, 11]. Currently, there are several studies focused on flour or fat-substitution with apple pomace or another dietary fiber sources to produce bakery products and enhance the flavor, their nutritional value, and baking properties [4, 6, 10, 12–14]. Based on the best knowledge of the authors, this is the first study comparing the effect of fat and or wheat flour substitution in various concentrations with apple pomace on the physical, chemical, caloric, structure, color, and shelf-life of the oily cake.

Moreover, consumer acceptance is very important in the development of a food formulation. However, sensory analysis is associated with linguistic variables which make the selection procedure a challenging task. To overcome this challenge, a multicriteria decision making technique such as the Delphi-Fuzzy logic method can be a good solution [15, 16]. Fuzzy logic deals with uncertainty by human knowledge and linguistic variables (such as "low," "bad," "often," "good," and so on.) instead of traditional binary set and crisp value. This method uses relative graded membership theory to evaluate an event. Delphi-Fuzzy logic is a suitable way to solve complicated, ambiguous, and uncertain problems based on linguistic variables instead of crisp ones [16–21]. Therefore, in the current study, the sensory properties of oily cake were considered based on a Delphi-Fuzzy logic method.

Thus, the proposed study is aimed to compare the effect of fat and/or wheat flour substitution with apple pomace in various conditions on the structure, color, chemical composition, caloric value, and shelf-life of oily cake samples and to evaluate the sensory quality of samples based on the Delphi-Fuzzy logic method.

2. Material and Methods

2.1. Material. Apple samples (around 10 kg; *Malus domestica* cv. Golden Delicious at fully ripe maturity stage) were obtained from the region of Damavand city (Tehran, Iran). The ingredients used for cake preparation were purchased from local supermarkets (Shiraz, Iran). All chemical materials in the analytical grade were purchased from Merck Chemicals Co. (Darmstadt, Germany) and Dr. Mojalali (Tehran, Iran).

2.2. Preparation of Apple Pomace Powder. After washing and cutting the apples, their juice was extracted by using a home juicer machine (Model 700 P, Pars Khazar, Tehran, Iran) and their pomace was dried at room temperature (25 ± 2°C) and shade (for 55 h). Then, the pomace was grounded (grounder machine Model 320 P; Pars Khazar, Tehran, Iran).

2.3. Proximate Composition. Moisture, crude protein, crude fat, crude fiber, and ash content of wheat flour, apple pomace, and cake samples were measured based on the AOAC method [22]. Chemical composition analysis of samples was performed in triplicate.

2.4. Determination of Total Phenolic Content of Apple Pomace. The total phenolic content (TPC) was measured with the Folin–Ciocalteu method. The absorbance of each sample was read at a wavelength of 725 nm. The TPC of apple pomace was expressed as mg gallic acid equivalent (GAE) per g of dry weight by using the calibration curve of gallic acid [23].

2.5. Preparation of Oily Cakes. Cake samples were prepared based on batters containing 0%, 10%, or 20% apple pomace powder as substituting levels of wheat flour and/or fat. The formulation of each sample is presented in Table 1. Liquid and dry ingredients of oily cakes were creamed in a mixer bowl by an electric blender (Model: MFQ36460, BOSCH, Germany) for about 10 min and poured onto muffin paper and baked at 150°C for 30 min. The apple pomace powder was mixed with milk and added to each formulation. After baking and cooling, cakes (three replicates for each sample) were packed in plastic bags and stored at room temperature for 14-day storage (at 23 ± 3°C; RH: 35%) and analyzed at 7-day intervals over the whole period. Chemical composition analysis of samples was performed in triplicate.

2.6. Calorific Value. Calorific values of the cake samples were determined by using Oxygen Bomb Calorimeter (BXT-ZDHW-9B, BAXIT Co, China) and expressed as kcal per 100 g.

2.7. Baking Loss and Structure Properties of the Cakes. A digital caliper was used to calculate the height of the cakes. The structure of oily cake samples was evaluated by using image analysis. The baking loss was measured using the following equation:

$$\text{Baking loss rate }(\%) = \frac{\text{batter weight} - \text{cake weight }(g)}{\text{batter weight }(g)} \times 100. \quad (1)$$

2.8. Colorimetric Analysis. Images of cake samples (crumb and crust) were acquired against a white background using a Canon digital camera (Model SX430 IS, 20.5 megapixels resolution, Sensor: CCD, diaphragm: f/3.5–f/6.8 Canon, Tokyo, Japan). A sealed MDF box ($1 \times 1 \times 1\,m^3$) equipped with four fluorescent lamps and plastic light diffusers was applied to measure the various color parameters (L^*: lightness, a^*: redness-greenness and b^*: yellowness-blueness). The image processing containing noise reduction, adjusting contrast, and white balance was done by Adobe Photoshop® CC2019 (Adobe System Inc., San Joes, California, USA). Total color difference (ΔE^*) was evaluated by the following equation:

Table 1: Formulations of prepared oily cakes.

Ingredients	T_{CO}	T_{W10}	T_{W20}	T_{O10}	T_{O20}	$T_{W\&O(5:5)}$	$T_{W\&O(10:10)}$
Wheat flour (g)	125	113	100	125	125	119	113
Oil (g)	40	40	40	36	32	38	36
Apple pomace powder (g)	0	12	25	4	8	8	16
Sugar (g)	75	75	75	75	75	75	75
Milk (mL)	75	75	75	75	75	75	75
Whole egg (g)*	100	100	100	100	100	100	100
Baking powder (g)	3	3	3	3	3	3	3
Vanilla (g)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Salt (g)	0.7	0.7	0.7	0.7	0.7	0.7	0.7

*Equivalents to two small eggs. T_{Co}: control sample; $T_{W10\%}$: wheat substitution with pomace (10% w/w); $T_{W20\%}$: wheat substitution with pomace (20% w/w); $T_{O10\%}$: fat substitution with pomace (10% w/w); $T_{O20\%}$: fat substitution with pomace (20% w/w); $T_{W\&O(5:5)}$: fat and wheat substitution with pomace (5 : 5% w/w); $T_{W\&O\,(10:10)}$: fat and wheat substitution with pomace (10 : 10% w/w).

$$\Delta E = \sqrt{\left(L_t^* - L_{t0}^*\right)^2 + \left(a_t^* - a_{t0}^*\right)^2 + \left(b_t^* - b_{t0}^*\right)^2}, \quad (2)$$

where the subscripts t and t_0 represent the color parameters during the same storage time and the color parameter of the control sample (T_{CO}) at the initial time, respectively [24, 25]. $\Delta E^* < 1$, $1 < \Delta E^* < 3$, and $\Delta E^* > 3$ indicated that the color differences are not obvious for the human eye, not appreciative by the human eye, and obvious for the human eye, respectively [26]. The results of colorimetric analysis are the average of at least three replicates.

2.9. Oxidation Properties

2.9.1. Lipid Extraction of Cake. For lipid extraction from oily cakes, 100 g of samples were grounded, added to a flask with 200 mL *n*-hexane (98% purity), and shaken for 1 h. This mixture was filtered through Whatman paper (No. 1). For removing *n*-hexane from the extracted oil, a Rotary vacuum evaporator (Strike 300, Parsfaraso, Tehran, Iran) at 50°C was used [27].

2.9.2. Peroxide Value. The peroxide value (PV) of oily cake samples was measured with the sodium thiosulfate 0.01 N method according to INSO 37. PV was expressed as milliequivalent peroxide per kg of extracted oil (meq.O_2.kg^{-1}) at different times of storage [27].

2.9.3. FFA Value. Free fatty acids (FFA), as oleic acid percentages of extracted oil, were evaluated based on the titration method [27].

2.10. Microbial Stability

2.10.1. Total Microbial Count (TMC). TMC of oily cake samples was evaluated according to standard plate count agar (PCA Merck) described in ISO 8443:2003. Plates were incubated at 30°C for 48 h [28].

2.10.2. Enterobacteriaceae Count. The *Enterobacteriaceae* population was determined based on ISO 21528-1:2017 and 21528-2:2017 methods on Violet Red Bile Glucose (VRBG) Agar media. The plates were incubated at 37°C for 24 h [29, 30].

2.10.3. Yeasts and Molds Count (YMC). A load of yeasts and molds was evaluated using the methods explained by ISO 21527-2: 2008. The samples were spread onto the plate surface of the Sabouraud dextrose agar medium. The plates were incubated at 25 ± 1°C for 5 d [31]. The number of *Enterobacteriaceae* population, TMC, and YMC colonies was expressed into logarithms of the number of colony-forming units (CFUs) per gram ($\log_{10}$ CFU·g^{-1}). The maximum acceptable limits for *Enterobacteriaceae* population, TMC, and YMC are considered 2.00, 5.00, and 3.00 log CFU·g^{-1}, respectively [32, 33]. All microbial tests were done in triplicates.

2.11. Sensory Evaluation by Fuzzy Analysis. The panel group included ten trained members (five females and males) from personnel and students of the Food Science and Technology Department (Shiraz University, Shiraz, Iran). The sensory parameters including taste, aroma, appearance (symmetry and puffiness of the cake), texture, crust color, and crumb color as well as the scoring method were introduced to the panel group. Each member used check marks (✓) to score the cake sample during the storage period. Therefore, 30 data were collected for each oily cake sample. Samples were judged based on "Very Poor," "Poor," "Fair" "Good," and "Very Good" words.

The major steps involved in the Delphi-Fuzzy logic include fuzzification of sensory scores in triangular membership functions in equation (3), calculating the importance of each sensory parameter and defuzzification of them, evaluating overall sensory scores in the triangular membership function in equation (4) , defuzzification of them, and ranking various oily cake samples. The fuzzy program was run under MATLAB software (version 2020a, Mathworks Inc., Natick, MA, USA).

$$s_r\text{Aroma} = \frac{n_1(0\,0\,25) + n_2(0\,25\,50) + n_3(25\,50\,75) + n_4(50\,75\,100) + n_5(75\,100\,100)}{n_1 + n_2 + n_3 + n_4 + n_5}, \tag{3}$$

where $(n_1 + n_2 + n_3 + n_4 + n_5)$: the total number of panelists; the subscript "r": sample number, n_1, n_2, n_3, n_4 and n_5: the number of panelists giving "Very Poor," "poor," "Fair," "Good" and "Very Good" scores to each sample, respectively. This equation was designed for the calculation of the fuzzified aroma score of samples which can be generalized to other sensory features.

$$S_rO = Q\text{Taste}_{\text{rel}} + Q\text{Aroma}_{\text{rel}} + Q\text{Texture}_{\text{rel}} + Q\text{Appearance}_{\text{rel}} + Q\text{Color.crust}_{\text{rel}} + Q\text{Color. crumb}_{\text{rel}}, \tag{4}$$

where S_rO: overall sensory score of each sample in triangular membership function; the subscript "r": sample number or name; $Q\text{Taste}_{\text{rel}}$, $Q\text{Aroma}_{\text{rel}}$, $Q\text{Texture}_{\text{rel}}$, $Q\text{Apperance}_{\text{rel}}$, $Q\text{Color.crust}_{\text{rel}}$ and $Q\text{Color.crumb}_{\text{rel}}$ weighted sensory scores in triangular membership (for example defuzzified value of the importance score for Aroma $\times$ s_rAroma) for each oily cake sample.

Triangular membership function distribution pattern consisted "very poor/very unimportant (0, 0, 25)," "poor/unimportant (0, 25, 50)," "fair/somewhat important (25, 50, 75)," "Good/important (50, 75, 100)," and "Very Good/highly important (75, 100, 100)" [34].

2.12. Statistical Analysis. Fuzzy analysis was applied to evaluate the sensory score of samples, conducted by MATLAB software (version 2020a, Mathworks Inc., Natick, MA, USA). The other obtained data were subjected to a one-way analysis of variance (ANOVA) using Minitab 17 software (State College, PA, USA). All experiments were done in triplicate, and the results are expressed as mean ± standard deviation. Three replications were used for each analysis. Tukey's multiple range test was used to determine significant differences between the means ($\alpha = 0.05$).

3. Results and Discussions

3.1. Chemical Compositions of Apple Pomace. The chemical composition of apple pomace and wheat flour: Pomace apple had lower contents of moisture (7.16 ± 0.24 vs. 10.0 ± 0.44 g $100\,\text{g}^{-1}$) and protein (4.88 ± 0.34 vs. 10.4 ± 0.17 g $100\,\text{g}^{-1}$) than wheat flour, whereas the ash (1.81 ± 0.14 vs. 1.25 ± 0.10 g $100\,\text{g}^{-1}$), fat (2.07 ± 0.32 vs. 1.03 ± 0.11 g $100\,\text{g}^{-1}$), and crude fiber (2.50 ± 0.17 vs. 12.11 ± 0.26 g $100\,\text{g}^{-1}$) contents were higher than wheat flour ($p < 0.05$). The fiber, protein, fat, and moisture contents of apple pomaces were reported in a range of 4.4–47.3%, 2.7–5.30%, 1.10–3.60%, and 6.55–9.75%, respectively [5, 11, 14].

The differences between various findings reported previously may be related to differences in apple cultivars and varieties, growing and harvesting conditions, processing methods, and storage conditions [5]. The low moisture content (<10%) helps to maintain the quality and storage stability of the apple pomace [35]. The high fiber content of apple pomace also showed a high potential of this ingredient to produce high fiber, healthy, and value-added food products.

Total phenolic contents of apple pomace were $6.11 \pm 0.43\,\text{mg}\cdot\text{g}^{-1}$. This result was in agreement with those reported in previous findings (in the range of $4.93–10.2\,\text{mg}\cdot\text{g}^{-1}$) [9, 14, 36].

3.2. Chemical Analysis of Muffins. Table 2 presents the proximate analysis of various oily cakes enriched with apple pomace.

3.2.1. Protein Content. The lowest and highest protein content were recorded for $T_{w20\%}$ ($10.0 \pm 0.12\%$) and $T_{O20\%}$ ($11.0 \pm 0.45\%$) ($p < 0.05$). The protein content of wheat flour was higher than apple pomace (Section 3.1). Therefore, wheat flour substitution with apple pomace resulted in a decrease in the protein content of samples, while fat substitution increased the protein content of samples. However, there was no significant difference between other samples ($p > 0.05$). These results were in agreement with previous findings [6, 10, 37].

3.2.2. Fat Content. Fat content of various samples was in a range of 17.13 ($T_{O20\%}$) to 19.88 ($T_{W20\%}$) and the difference between the two samples was significant at a level of 5%. There was no significant difference between control samples with $T_{W10\%}$, $T_{W20\%}$, and $T_{O\&W\,(5:5)}$ ($p > 0.05$).

3.2.3. Ash. The maximum and minimum ash content was obtained for $T_{W20\%}$ ($1.03 \pm 0.01\%$) and T_{Co} ($0.97 \pm 0.02\%$), respectively ($p < 0.05$). The ash content of oily cake was increased, by increasing the apple pomace content of the formulation. The results are allied with the research of Younes et al. [14]. The reported ash content of muffins enriched by apple pomace was 1.12–1.69 depending on apple variety and formulation [14].

3.2.4. Fiber. The fiber content of apple pomace was higher than that of wheat flour. Therefore, wheat flour and or fat substitution with the apple pomace increased the fiber content of cake samples. Thus, $T_{w20\%}$ exhibited the highest fiber (2.12%). These results are supported by the findings of

Table 2: The effect of wheat flour and or fat substitution with apple pomace on the physicochemical properties of the oily cake.

Parameters	T_{CO}	$T_{W10\%}$	$T_{W20\%}$	$T_{O10\%}$	$T_{O20\%}$	$T_{O\&W\,(5:5)}$	$T_{O\&W\,(10:10)}$
Protein (%)	10.5 ± 0.25^{AB}	10.3 ± 0.20^{AB}	10.0 ± 0.12^{B}	10.7 ± 0.31^{AB}	11.0 ± 0.45^{A}	10.4 ± 0.21^{AB}	10.3 ± 0.14^{AB}
Fat (%)	19.6 ± 0.35^{AB}	19.8 ± 0.32^{A}	19.9 ± 0.17^{A}	18.4 ± 0.10^{C}	17.1 ± 0.15^{D}	19.0 ± 0.19^{BC}	18.6 ± 0.25^{C}
Ash (%)	0.97 ± 0.02^{C}	0.99 ± 0.01^{BC}	1.02 ± 0.01^{AB}	1.00 ± 0.02^{ABC}	1.03 ± 0.01^{A}	1.00 ± 0.01^{ABC}	1.02 ± 0.01^{AB}
Fiber (%)	1.25 ± 0.13^{E}	1.72 ± 0.08^{B}	2.12 ± 0.08^{A}	1.43 ± 0.07^{D}	1.62 ± 0.09^{C}	1.60 ± 0.11^{C}	1.82 ± 0.05^{B}
Energy (kcal/100 g)	411 ± 2.14^{A}	399 ± 4.5^{B}	385 ± 3.4^{C}	401 ± 4.0^{B}	391 ± 2.28^{BC}	400 ± 3.9^{B}	388 ± 3.4^{C}
Baking loss (%)	11.6 ± 0.43^{ABC}	11.7 ± 0.29^{AB}	12.0 ± 0.42^{A}	9.87 ± 0.20^{D}	9.36 ± 0.27^{D}	10.8 ± 0.20^{C}	11.0 ± 0.19^{BC}
Height_{min} (cm)	3.13 ± 0.12^{D}	3.61 ± 0.07^{BC}	4.07 ± 0.06^{A}	3.37 ± 0.12^{BCD}	3.67 ± 0.13^{B}	3.27 ± 0.23^{CD}	4.07 ± 0.06^{A}
Height_{max} (cm)	4.56 ± 0.10^{A}	4.40 ± 0.17^{AB}	4.31 ± 0.10^{ABC}	3.97 ± 0.25^{CD}	3.82 ± 0.08^{D}	4.07 ± 0.12^{BCD}	4.14 ± 0.08^{BCD}
ΔHeight (cm)	1.43 ± 0.03^{A}	0.79 ± 0.18^{B}	0.24 ± 0.05^{BC}	0.60 ± 0.36^{BC}	0.15 ± 0.17^{C}	0.80 ± 0.35^{B}	0.07 ± 0.04^{C}

All data are presented in the manner of means ± SD ($n = 3$). The diverse letters for each parameter indicate significant difference ($p < 0.05$). T_{CO}: control sample; $T_{W10\%}$: wheat substitution with pomace (10% w/w); $T_{W20\%}$: wheat substitution with pomace (20% w/w); $T_{O10\%}$: fat substitution with pomace (10% w/w); $T_{O20\%}$: fat substitution with pomace (20% w/w); $T_{W\&O\,(5:5)}$: fat and wheat substitution with pomace (5 : 5% w/w); $T_{W\&O\,(10:10)}$: fat and wheat substitution with pomace (10 : 10% w/w).

Younes et al. [14], who found that the apple powder-enriched muffins had crude dietary fiber content in a range of 1.16–3.13%. An increase in dietary fiber can decrease the glycemic index and improve the health-promoting properties of oily cakes [10, 37].

3.3. Caloric Values of Oily Cakes. As seen in Table 2, there was a significant difference between various samples. All treated samples had a lower caloric value than the control ones ($p < 0.05$). $T_{W20\%}$, $T_{W\&O\,(10:10)}$, and $T_{O20\%}$ showed lower energy values than the control one. Therefore, the caloric values of the samples were decreased by increasing the level of apple pomace powder in the oily cake formulation. The addition of apple pomace powder into the oily cake formulation obtains a healthier food. These results were supported by previous findings [2, 5, 14].

3.4. Baking Loss. The cake weight loss during baking can be directly related to water loss. Table 2 exhibits the effect of apple pomace on the baking loss of samples. There was a significant difference between baking loss of $T_{O10\%}$ (9.87%) and $T_{O20\%}$ (9.36%) samples with control one (11.6%) ($p < 0.05$). The difference between other samples ($T_{W10\%}$, $T_{W20\%}$, $T_{O\&W\,(5:5)}$, and $T_{O\&W\,(10:10)}$) and T_{CO} was not significant ($p > 0.05$). Jahanbakhshi and Ansari [38] did not find any significant difference between the weight loss of cakes fortified with olive stone powder and the control ones [38]. However, Collar et al. [39] reported that weight loss could be reduced by adding soluble cocoa fiber to the bread formulation [39]. The baking loss of various samples can be described by batter consistency and the water-holding capacity of the cake ingredients.

3.5. Height. As seen in Table 2, fat substitution with apple pomace decreased the cake volume, and the maximum height decreased from 4.56 to 3.82 cm by increasing the apple pomace. Moreover, the difference between the minimum and maximum height (height of the corners and the middle of the cakes) of these samples was significantly lower than the control one ($p < 0.05$). Although the difference between the minimum and maximum height of $T_{W20\%}$ and $T_{W\&O\,(10:10)}$ was lower than $T_{O20\%}$, the $\text{height}_{(\max)}$ of these two samples was 4.31 and 4.14 cm, respectively, and the $\text{height}_{(\min)}$ that was more than the control one indicated a voluminous matrix. This shape can be there due to the distribution patterns of bubbles within the cake matrix (Section 3.6 and Figure 1(a)).

3.6. Structure Properties. Figure 1(a) shows the cross-sections of vertically cut oily cakes containing different levels of apple pomace. As seen, the control sample had a bell shape and there is a relatively high difference between the height of the corners and the middle of the cake (Table 3), while the $T_{W10\%}$ and $T_{W20\%}$ exhibited a convex shape, and the difference between the middle and two sides of the cake decreased with increasing apple pomace powder. Differences in the shape of cakes could be related to the distribution patterns of bubbles within the cake matrix. In the control sample, larger bubbles were concentrated in the middle of the product and appeared to form a tunnel shape, while as the amount of apple pomace increased, these bubbles were observed throughout the cake crumb. In other words, the distribution of bubbles in $T_{W10\%}$ and $T_{W20\%}$ was more uniform. In agreement with the current study, Jahanbakhshi and Ansari [38] reported that the size of the porous is smaller in the control sample as compared to the cake fortified with 35% olive stone powder [38]. This finding is in line with other research that reported a falling tendency in firmness, by increasing apple pomace replacement level [2]. In this regard, Al-Sayed and Ahmed [40] reported that the porosity of cake increased parallel to increasing levels of watermelon rind and Sharlyn melon peel powder [40]. However, several authors have reported a reduction trend in a specific volume after adding dietary fibers to cake formulation due to a disruption in the gluten network and reduced gas retention capacity [6, 13, 35]. In the current study, when fat was replaced with apple pomace, the volume of the cake was also decreased. The nature and amount of fiber source and type of cake and replacement can affect the texture properties of cakes [41].

It has been reported that a suitable and sufficient degree of batter consistency has a positive effect on cake volumes [38]. Probably, in the current formulation, the flour

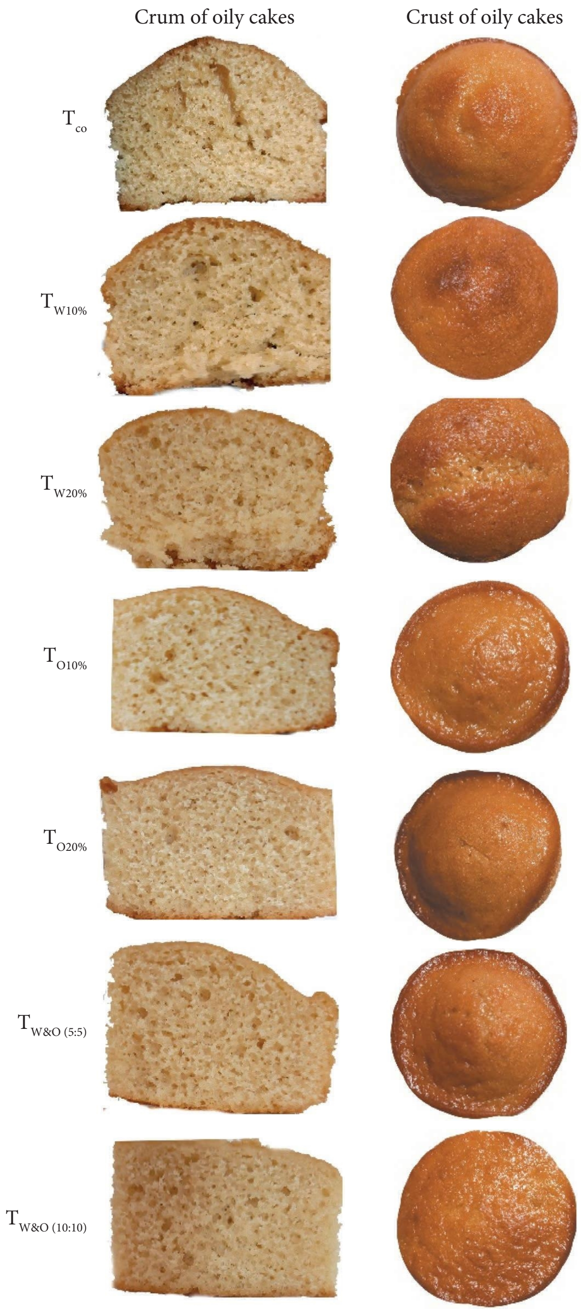

Figure 1: The effect of fat and or wheat flour substitution with apple pomace on crumb and crust of oily cakes. T_{Co}: control sample; $T_{W10\%}$: wheat substitution with pomace (10% w/w); $T_{W20\%}$: wheat substitution with pomace (20% w/w); $T_{O10\%}$: fat substitution with pomace (10% w/w); $T_{O20\%}$: fat substitution with pomace (20% w/w); $T_{W\&O(5:5)}$: fat and wheat substitution with pomace (5 : 5% w/w); $T_{W\&O(10:10)}$: fat and wheat substitution with pomace (10 : 10% w/w).

substitution with pomace apple caused improving the batter consistency. This could help to facilitate the evaporation of water and consequently a good distribution of bubbles in the cake matrix.

Overall, fat substitution with apple pomace resulted in major changes in the physical properties of oily cakes. The functionality of fat in cake is very versatile. As seen in Figure 1(a), by reducing the fat content of cake formulation, the stability of air bubbles was decreased and smaller and lower porous were observed. Therefore, the crumb hardness of the $T_{O10\%}$ and $T_{O20\%}$ samples was higher than the other ones. The lowest volume was also observed in these two samples. Fat can trap air bubbles in the cake batter during mixing, stabilize the gas bubbles, prevent the release of gas, and consequently give a softer and smoother texture to the cake. Fat interrupts the protein particles and breaks gluten continuity and tenderizes the crumb [8, 42–44]. Therefore, replacing fat in the cake formulation led to a decrease in the stability of air bubbles and reduced volume and made a firmer, gummier, and less cohesive texture. The texture of the $T_{W\&O(5:5)}$ and $T_{W\&O(10:10)}$ samples can be considered between the texture of other treated samples. By reduction of the fat content, the cake volume decreased, and wheat flour substitution by apple pomace resulted in a decrease in the uniformity and homogeneity of the porosity structure of cakes.

3.7. Color Properties. Color has an important role in consumer acceptance of a product. The crust and crumb color (L^*, a^*, b^*, and ΔE^*) values of the oily cakes were individually presented in Table 3.

3.7.1. Crust Color. The L^* value of samples varied in a small range of 52.33 ($T_{W10\%}$) to 57.33 ($T_{O10\%}$), where the difference between these two samples was significant ($p < 0.05$). However, there was no significant difference between the lightness of the treated samples and the control ones. Moreover, the addition of apple pomace did not have any significant effect on the a^* and b^* values ($p > 0.05$). Overall, as shown in Figure 1(b), there is not much color difference between the samples. The color difference, ΔE^*, was used to show the influence of apple pomace additions. Although the ΔE^* showed an obvious difference for the human eye ($\Delta E^* > 3$), this difference is not noticeable enough to have a significant diverse effect on consumer acceptance (Section 3.9). The biggest difference in color (ΔE^*) was observed between the control and $T_{O10\%}$ samples ($p < 0.05$). In this regard, Gómez et al. [45] showed that the addition of various fibers (orange, pea, wheat, and cellulose) did not have any significant effect on the cake crust color [45]. Aydogdu et al. [41] did not show any significant color difference between the crust color of cakes containing various lemon or apple pomace powder concentrations [41]. However, some authors observed significant differences between the crust of the control cake and the fiber-rich samples [38, 40]. The crust color of bakery products is mainly associated with Maillard and caramelization reactions. The addition of fruit powder can change the physicochemical properties of the cake batter (amino acids, sugar, water content, and pH) and consequently change the final color of the products. On the other hand, the interaction between ingredients during various processes can also affect Maillard or caramelization reactions [13, 46]. The color of fruit pomace also can influence the crust and crumb color of bakery products.

Table 3: The effect of fat and or wheat flour substitution with apple pomace on color parameters of oily cake crust and crumb.

Treatment	L^*	a^*	b^*	ΔE^*
Crust				
T_{CO}	55.7 ± 2.08^{ABC}	26.7 ± 1.15^{A}	45.7 ± 0.57^{A}	0.00 ± 0.00^{B}
$T_{W10\%}$	52.3 ± 1.53^{C}	30.0 ± 2.00^{A}	49.3 ± 1.16^{A}	5.66 ± 1.38^{A}
$T_{W20\%}$	53.0 ± 1.00^{BC}	28.3 ± 3.06^{A}	49.3 ± 1.53^{A}	5.36 ± 1.40^{A}
$T_{O10\%}$	57.3 ± 0.58^{A}	25.7 ± 2.08^{A}	47.0 ± 1.00^{A}	3.48 ± 1.14^{AB}
$T_{O20\%}$	56.0 ± 1.73^{AB}	25.0 ± 2.00^{A}	49.0 ± 1.73^{A}	4.61 ± 1.75^{A}
$T_{W\&O(5:5)}$	54.3 ± 1.53^{ABC}	25.7 ± 1.52^{A}	49.3 ± 2.08^{A}	4.32 ± 2.01^{A}
$T_{W\&O(10:10)}$	56.3 ± 1.16^{ABC}	28.0 ± 1.73^{A}	45.7 ± 1.53^{A}	4.86 ± 1.76^{A}
Crumb				
T_{CO}	70.3 ± 1.53^{A}	6.33 ± 0.58^{B}	27.7 ± 0.58^{AB}	0.00 ± 0.00^{B}
$T_{W10\%}$	67.3 ± 0.16^{AB}	7.66 ± 1.15^{AB}	29.7 ± 1.15^{A}	4.63 ± 2.42^{AB}
$T_{W20\%}$	65.3 ± 1.53^{B}	10.0 ± 1.73^{A}	30.3 ± 1.53^{A}	7.41 ± 2.49^{A}
$T_{O10\%}$	69.0 ± 1.00^{AB}	6.67 ± 1.52^{AB}	27.0 ± 2.67^{AB}	3.45 ± 0.40^{AB}
$T_{O20\%}$	67.7 ± 0.57^{AB}	7.66 ± 1.52^{AB}	24.0 ± 1.73^{B}	4.85 ± 0.86^{AB}
$T_{W\&O(5:5)}$	68.0 ± 1.00^{AB}	9.00 ± 1.00^{AB}	28.3 ± 2.08^{AB}	4.22 ± 0.47^{AB}
$T_{W\&O(10:10)}$	65.0 ± 2.65^{B}	9.67 ± 1.53^{AB}	27.7 ± 2.31^{AB}	6.78 ± 3.67^{A}

All data are presented in the manner of means ± SD ($n = 3$). The diverse letters for each parameter indicate significant difference ($p < 0.05$). TCO: control sample; $T_{W10\%}$: wheat substitution with pomace (10% w/w); $T_{W20\%}$: wheat substitution with pomace (20% w/w); $T_{O10\%}$: fat substitution with pomace (10% w/w); $T_{O20\%}$: fat substitution with pomace (20% w/w); $T_{W\&O(5:5)}$: fat and wheat substitution with pomace (5 : 5% w/w); $T_{W\&O(10:10)}$: fat and wheat substitution with pomace (10 : 10% w/w).

3.7.2. Crumb Color. Crumb color of cakes varied with the quantity and the replacement type (e.g. fat or/and wheat flour). According to Table 3, with increasing the level of apple pomace, the crumb color became darker (lower L^* values), more reddish, and yellowish (higher a^* and b^* values). The highest and lowest lightness (L^*) were observed in the control sample (70.33) and $T_{W\&O(10:10)}$ (65.00), respectively ($p < 0.05$). Moreover, the maximum a^* value was obtained for $T_{W20\%}$ (10.0), and the difference between this sample and the control one (6.33) was significant ($p < 0.05$). The results showed that when the fat was replaced with pomace apple, the b^* value decreased while wheat flour substitution with apple pomace resulted in a significant increase in b^* value ($p < 0.05$). However, the difference between the control sample and the treated ones was not significant ($p > 0.05$). Regarding the color difference index (ΔE^*), the largest difference was recorded for $T_{W20\%}$ and $T_{O\&W(10:10)}$. The difference between these two cakes and the control sample was significant at the level of 5%, while other samples did not show significant color differences from the control one. This color difference can be related to the natural color pigments of apple pomace. The results were in agreement with previous studies [13, 14, 38, 47]. Kırbaş et al. [13] also reported that the lightness of the cake crumb decreased with the addition of apple pomace sources, while the crumb of cakes containing carrot or orange pomace powder was lighter than the control one [13]. During cake baking, the temperature of the cake crumb is not high enough for the Millard and caramelization reactions (above 100°C). Thus, the crumb color of cake samples is largely due to the color of raw materials and the interaction between various ingredients [40]. Moreover, the darkness of cake by increasing the apple pomace of samples can be related to nonenzymatic browning [48].

3.8. Shelf-Life Investigation

3.8.1. Moisture Content. Based on Table 4, on the first day of storage, only the difference between samples $T_{O20\%}$ (19.7%) and $T_{W20\%}$ (18.4%) was significant ($p < 0.05$). This phenomenon may be related to the difference in the batter consistency of various cake samples. On the other hand, when apple pomace was replaced with oil, the moisture content of the product was higher. In the $T_{W20\%}$ sample, the consistency of the cake batter resulted in producing a hollower and more voluminous cake structure, while the $T_{O20\%}$ sample is a tough rubbery cake. After 7 days of storage, a gradual decrease in the moisture content was recorded in all samples. However, this decreasing trend was significant only in the control sample. At the end of two weeks of storage, the moisture content of the control sample was significantly lower than the other ones. The moisture difference between the 7^{th} and 14^{th} days was not significant in any of the samples. However, the moisture content of the control sample followed a decreasing trend, while in treated ones, an increasing trend can be observed ($p > 0.05$). The increasing moisture content of treated samples may be due to the hygroscopic nature and a higher water capacity for moisture retention of apple pomace, owing to the water-holding capacity of the dietary fiber [10, 37, 49]. Moreover, the higher growth of microorganisms in the treated samples can cause the release of bound water [50].

3.8.2. Peroxide Value and FFA Content. Table 4 presents the effects of apple pomace addition on the peroxide values and free fatty acid (FFA) content of oily cakes during storage. An increase in peroxide value and FFA content was observed in all samples during storage ($p < 0.05$). Although there were no significant differences between the PV of various cake samples on the first day of storage, this parameter was lower in the samples with lower fat content (e.g., $T_{O20\%}$, $T_{O10\%}$, and

Table 4: The effect of wheat flour and/or fat substitution with apple pomace on shelf-life parameters of the oily cake during two-weeks storage period.

Storage time (days)	Treatment T_{CO}	$T_{W10\%}$	$T_{W20\%}$	$T_{O10\%}$	$T_{O20\%}$	$T_{W\&O(5:5)}$	$T_{W\&O(10:10)}$
Moisture content (%)							
0	19.0 ± 0.46^{ABa}	18.7 ± 0.31^{ABa}	18.4 ± 0.44^{Ba}	19.3 ± 0.51^{ABa}	19.7 ± 0.44^{Aa}	18.8 ± 0.38^{ABa}	18.6 ± 0.45^{ABa}
7	18.0 ± 0.35^{Bb}	18.4 ± 0.21^{ABa}	18.2 ± 0.25^{Ba}	19.1 ± 0.17^{Aa}	19.4 ± 0.20^{Aa}	18.5 ± 0.15^{ABa}	18.5 ± 0.37^{ABa}
14	17.7 ± 0.15^{Bb}	18.8 ± 0.32^{Aa}	18.5 ± 0.36^{Aa}	18.7 ± 0.31^{Aa}	19.0 ± 0.42^{Aa}	19.1 ± 0.50^{Aa}	19.4 ± 0.65^{Aa}
Peroxide value (meq kg $^{-1}$ oil)							
0	0.27 ± 0.05^{Ac}	0.29 ± 0.04^{Ac}	0.28 ± 0.02^{Ac}	0.13 ± 0.11^{Ac}	0.08 ± 0.13^{Ac}	0.27 ± 0.02^{Ac}	0.24 ± 0.03^{Ac}
7	0.81 ± 0.03^{Ab}	0.76 ± 0.04^{Ab}	0.83 ± 0.05^{Ab}	0.64 ± 0.04^{Ab}	0.57 ± 0.02^{Bb}	0.73 ± 0.04^{Ab}	0.70 ± 0.11^{Ab}
14	2.34 ± 0.32^{Aa}	2.42 ± 0.23^{Aa}	2.15 ± 0.12^{Aa}	1.94 ± 0.10^{Aa}	1.97 ± 0.31^{Aa}	2.19 ± 0.18^{Aa}	2.35 ± 0.34^{Aa}
Free fatty acid content (%)							
0	0.13 ± 0.02^{Ac}	0.14 ± 0.01^{Ac}	0.15 ± 0.01^{Ac}	0.11 ± 0.01^{Ac}	0.12 ± 0.01^{Ac}	0.15 ± 0.02^{Ac}	0.13 ± 0.02^{Ac}
7	0.28 ± 0.04^{Ab}	0.26 ± 0.03^{Ab}	0.28 ± 0.04^{Ab}	0.22 ± 0.04^{Ab}	0.19 ± 0.03^{Ab}	0.26 ± 0.03^{Ab}	0.23 ± 0.02^{Ab}
14	0.46 ± 0.06^{Aa}	0.47 ± 0.07^{Aa}	0.47 ± 0.04^{Aa}	0.39 ± 0.02^{Ba}	0.31 ± 0.14^{Ba}	0.49 ± 0.05^{Aa}	0.52 ± 0.10^{Aa}
Total microbial count (Log CFU·g $^{-1}$)							
0	1.63 ± 0.44^{Ac}	1.48 ± 0.40^{Ac}	1.45 ± 0.24^{Ac}	1.62 ± 0.27^{Ac}	1.55 ± 0.38^{Ac}	1.78 ± 0.47^{Ac}	1.61 ± 0.36^{Ac}
7	3.04 ± 0.16^{Ab}	3.83 ± 0.71^{Ab}	3.63 ± 0.30^{Ab}	3.35 ± 0.49^{Ab}	3.53 ± 0.54^{Ab}	3.71 ± 0.39^{Ab}	3.69 ± 0.41^{Ab}
14	$>5^{a}$	$>5^{a}$	$>5^{a}$	$>5^{a}$	$>5^{a}$	$>5^{a}$	$>5^{a}$
Yeast and mold count (Log CFU·g $^{-1}$)							
0	<1	<1	<1	<1	<1	<1	<1
7	1.85 ± 0.33^{A}	1.80 ± 0.31^{A}	1.88 ± 0.40^{A}	1.93 ± 0.37^{A}	1.86 ± 0.22^{A}	1.77 ± 0.11^{A}	1.89 ± 0.26^{A}
14	>3	>>3	>>3	>>3	>>3	>>3	>>3

All data are presented in the manner of means ± SD ($n = 3$). The diverse small letters for each parameter indicate significant difference between times ($p < 0.05$). The diverse capital letters for each parameter indicate significant difference between samples ($p < 0.05$). T_{CO}: control sample; $T_{W10\%}$: wheat substitution with pomace (10% w/w); $T_{W20\%}$: wheat substitution with pomace (20% w/w); $T_{O10\%}$: fat substitution with pomace (10% w/w); $T_{O20\%}$: fat substitution with pomace (20% w/w); $T_{W\&O(5:5)}$: fat and wheat substitution with pomace (5 : 5% w/w); $T_{W\&O\,(10:10)}$: fat and wheat substitution with pomace (10 : 10% w/w).

$T_{W\&O(10:10)}$). In general, adding apple pomace had not a significant influence on retarding oxidation of the sample. However, on the 7th day of storage, a PV of $T_{O20\%}$ was significantly lower than others. Moreover, at the end of storage, the PV of $T_{O20\%}$ and $T_{O10\%}$ was under the acceptable threshold limit of PV (2.00 meq kg^{-1}) [51, 52]. On the 14th day of storage, the FFA content of samples $T_{O10\%}$ and $T_{O20\%}$ was significantly lower than other ones. However, the FFA content of all samples was higher than the acceptable limit (0.3%) [51]. In this regard, Saeidi et al. [53] reported that cakes enriched with pomegranate seed powder had a lower PV than the control samples [53]. Al-Sayed and Ahmed [40] indicated that the addition of watermelon rinds and Sharlyn melon peel powders into cake formulation can decrease the rate of peroxide and free fatty acids formation. They attributed this phenomenon to the antioxidant potential of watermelon rinds and Sharlyn melon peels [40]. However, in the current study, the potency of the antioxidant apple pomace was not significant ($p > 0.05$). Bioactive compounds, especially phenolics, are sensitive to high temperatures which have led to their degradation [54]. Furthermore, differences in the type of by-products and the cake formulation can also be the reason for differences between the results obtained in various investigations.

3.8.3. Microbiological Stability. On the first day of storage, no mold and yeast colonies were seen in the samples (Table 4). Lack of YMC could be related to the susceptibility of yeast and mold to high baking temperatures as compared to bacteria (Saranraj and Geetha, 2012). Moreover, fecal bacteria belonging to the *Enterobacteriaceae* family were not detected in the oily cake samples, and the total microbial count had no significant difference between the microbial load of the control and treated samples ($p > 0.05$), and the TMC and YMC of oily cakes containing apple pomace were higher than T_{CO}. At the end of the storage period in all samples (except the control sample and two replicates of $T_{O10\%}$), mold growths were clearly observed on the surfaces of oily cakes. Although fresh cakes are free of molds, it is during then when the storage period become contaminated as a result of secondary contamination by mold spores from the air and bakery equipment [34, 55]. At the end of storage, the TMC of T_{CO} and $T_{O10\%}$ was also much higher than the acceptable limit (TMC: 5 logCFU · g^{-1}; YMC: 3 logCFU · g^{-1}). In this regard, Khalifa et al. [56] reported that TMC and YMC of wheat flour cupcakes were higher in samples containing potato peel residues during the storage period [56]. In the study by Samsudin et al. [57], different purée and powders of banana were used to prepare cake samples. The results showed that different moisture contents of various cakes affected the microbial quality of the cakes [57]. However, it was shown that the bioactive component of tomato pomace enhanced the microbial quality of muffin samples [33].

3.9. Sensory Analysis by Delphi-Fuzzy Logic. Table 5 presents the sensory responses obtained from ten panelists during 14 days of storage. The best sample for taste, aroma, texture,

Table 5: Panelists preference for specific quality parameters of oily cake samples and triplets related with sensory scores.

Treatment	V.P (0 0 25)	P (0 25 50)	F (25 50 75)	G (50 75 100)	V.G (75 100 100)	Sensory scores triplet	Defuzzification
Taste							
T_{CO}	6	4	4	8	8	(36.67 56.67 75.00)	56.2
$T_{W10\%}$	8	2	5	7	8	(35.83 54.17 72.50)	54.2
$T_{W20\%}$	8	2	3	8	9	(38.33 56.67 74.17)	**56.5**
$T_{O10\%}$	2	7	13	8	0	(24.17 47.50 72.50)	47.9
$T_{O20\%}$	1	9	12	8	0	(23.33 47.50 72.50)	47.7
$T_{W\&O(5:5)}$	8	2	4	8	8	(36.67 55.00 73.33)	55.0
$T_{W\&O(10:10)}$	9	1	6	8	6	(33.33 50.83 70.83)	51.5
Aroma/smell							
T_{CO}	7	3	4	11	5	(34.17 53.33 74.17)	53.7
$T_{W10\%}$	8	2	4	10	6	(35.00 53.33 73.33)	53.7
$T_{W20\%}$	7	3	3	8	9	(38.33 57.50 75.00)	57.1
$T_{O10\%}$	1	3	12	9	5	(37.50 61.67 82.50)	60.8
$T_{O20\%}$	0	5	8	11	6	(40.00 65.00 85.00)	**63.7**
$T_{W\&O(5:5)}$	7	3	5	8	7	(35.00 54.17 73.33)	54.2
$T_{W\&O(10:10)}$	8	2	6	7	7	(34.17 52.50 71.67)	52.7
Texture							
T_{CO}	3	5	8	10	4	(33.33 55.83 77.5)	55.6
$T_{W10\%}$	3	2	12	8	4	(34.48 56.90 78.45)	56.7
$T_{W20\%}$	2	4	11	6	7	(36.67 60.00 79.17)	**59.0**
$T_{O10\%}$	1	13	11	5	0	(17.50 41.67 66.67)	41.9
$T_{O20\%}$	3	16	9	2	0	(10.83 33.33 58.33)	34.0
$T_{W\&O(5:5)}$	2	4	10	11	3	(34.17 57.50 80.00)	57.3
$T_{W\&O(10:10)}$	3	4	9	11	3	(33.33 55.83 78.33)	55.8
Appearance							
T_{CO}	0	0	4	12	14	(58.33 83.33 96.67)	**80.4**
$T_{W10\%}$	0	0	5	12	13	(56.67 81.67 95.83)	79.0
$T_{W20\%}$	0	0	8	16	6	(48.33 73.33 93.33)	72.1
$T_{O10\%}$	0	0	10	12	8	(48.33 73.33 91.67)	71.7
$T_{O20\%}$	0	0	14	8	8	(45.00 70.00 88.33)	68.3
$T_{W\&O(5:5)}$	0	0	9	10	11	(51.67 76.67 92.50)	74.4
$T_{W\&O(10:10)}$	0	2	16	10	2	(35.00 60.00 83.33)	59.6
Color (crust)							
T_{CO}	0	0	8	12	10	(51.67 76.67 93.33)	74.6
$T_{W10\%}$	0	0	8	13	9	(50.83 75.83 93.33)	74.0
$T_{W20\%}$	0	0	7	13	10	(52.50 77.50 94.17)	75.4
$T_{O10\%}$	0	0	7	14	9	(51.67 76.67 94.17)	74.8
$T_{O20\%}$	0	0	8	11	11	(52.50 77.50 93.33)	75.2
$T_{W\&O(5:5)}$	0	0	6	14	10	(53.33 78.33 95.00)	**76.2**
$T_{W\&O(10:10)}$	0	0	9	11	10	(50.83 75.83 92.50)	73.7
Color (crumb)							
T_{CO}	0	0	8	10	12	(53.33 78.33 93.33)	**75.8**
$T_{W10\%}$	0	0	8	13	9	(50.83 75.83 93.33)	74.0
$T_{W20\%}$	0	0	11	12	7	(46.67 71.67 90.83)	70.2
$T_{O10\%}$	0	0	7	14	9	(51.67 76.67 94.17)	74.8
$T_{O20\%}$	0	0	6	16	8	(51.67 76.67 95.00)	75.0
$T_{W\&O(5:5)}$	0	0	9	11	10	(50.83 75.83 92.50)	73.7
$T_{W\&O(10:10)}$	0	0	9	12	9	(50.00 75.00 92.50)	73.1

V.P: very poor; *P*: poor; *F*: fair; *G*: good; V.G: very good. T_{CO}: control sample; $T_{W10\%}$: wheat substitution with pomace (10% w/w); $T_{W20\%}$: wheat substitution with pomace (20% w/w); $T_{O10\%}$: fat substitution with pomace (10% w/w); $T_{O20\%}$: fat substitution with pomace (20% w/w); $T_{W\&O(5:5)}$: fat and wheat substitution with pomace (5 : 5% w/w); $T_{W\&O(10:10)}$: fat and wheat substitution with pomace (10 : 10% w/w). The bold numbers represent the best samples.

appearance, crust color, and crumb color was introduced as follows: $T_{W20\%}$, $T_{O20\%}$, $T_{W20\%}$, T_{CO}, $T_{W\&O(5:5)}$, and T_{CO}, respectively. Following the addition of apple pomace to the formulation, the fruity flavor of the cake increased while the grain taste was reduced. Also, replacing fat in foods adversely influences the taste of the cake. When fat substitution with apple pomace happened, the samples received the lowest score for texture and taste. Sensory evaluators noted that the pleasant taste and aroma of apple pomace besides lower rancidity taste of the $T_{O20\%}$ sample during storage time resulted in a "very bad" score, which is not being recorded for the aroma of this sample. This result was in agreement

Table 6: Sum of individual preference to the importance of quality attributes of samples in general.

Sensory attribute	V.UI	UI	SI	*I*	HI	Scores triplet	Defuzzification
Taste	0	0	0	2	18	(72.50 97.50 100.0)	0.92
Aroma/Smell	0	0	0	4	16	(70.00 95.00 100.0)	0.90
Texture	0	0	0	1	19	(73.75 98.75 100.0)	0.93
Appearance	0	1	9	10	0	(36.25 61.25 86.25)	0.61
Color (crust)	0	0	4	12	4	(50.00 75.00 95.00)	0.74
Color (crumb)	0	0	7	11	2	(43.75 68.75 91.25)	0.68

V.UI: very unimportant; UI: unimportant; SI: somewhat important; *I*: important; HI: highly important.

with a previous study [58]. When fat substitution with apple pomace happened, the deffuzified value for the texture of the samples was lower than 50 (fair score). Although $T_{W\&O(10:10)}$ samples received "good" to "very good" scores for aroma, taste, and texture on the first day of storage, at the end of storage, the score of this sample was "bad"-"very bad" due to rancidity and odor of mold spoilage (Table 5).

The texture is the sensory attribute most influenced by the presence of apple pomace in the cake. As seen in Table 5, wheat flour substitution with apple pomace improved the texture score of samples as compared to the control, while fat substitution with apple pomace decreased the texture score. Generally, when fat was replaced by apple pomace, a harder texture can be observed. These results were supported by previous authors, which claimed that wheat flour substitution with apple pomace decreased the firmness of cake [59]. However, Hosseini Ghaboos et al. [60] reported that increasing the level of substitution from 0 to 20% pumpkin powder resulted in an increase in the density and firmness of the cake [60]. Negi et al. [10] reported that the texture score was reduced by increasing the apple pomace powder concentration. However, this change was acceptable for the panelist group up to 30% replacement [10]. Masoodi et al. [4] reported acceptable physical properties for cakes prepared by adding 5, 10, or 15% of apple pomace to wheat flour [4]. Food is a complex composition, and many factors such as type and level of fiber source, consistency of the cake batter, and formulation can highly affect the texture [41, 59]. In this regard, Lebesi and Tzia [59] claimed that the texture of cakes fortified with dietary fiber was softer than cereal bran cakes [59]. A darker color of cake crumb decreased the color score of samples in which wheat flour was substituted with apple pomace. However, the defuzzified values of various samples were close to each other.

Table 6 shows the importance of various sensory properties. None of the sensory parameters were considered "very unimportant" by panelists. The most important sensory attributes were texture (0.93), taste (0.92), and aroma (0.90) properties, while appearance (asymmetry and puffiness) showed lower importance as compared to other properties. However, the defuzzification score of these parameters was higher than 0.6. Thus results were in agreement with the findings of previous studies [21, 34].

The overall sensory scores of oily cakes are presented in Figure 2. Based on defuzzified values, the ranking of samples was as followed: T_{CO} (64.4) > $T_{W20\%}$ (63.9) > $T_{W\&O(5:5)}$ (63.7) > $T_{W10\%}$ (63.6) > $T_{O10\%}$ (60.2) > $T_{W\&O(10:10)}$ (60.1 > $T_{O20\%}$ (58.8).

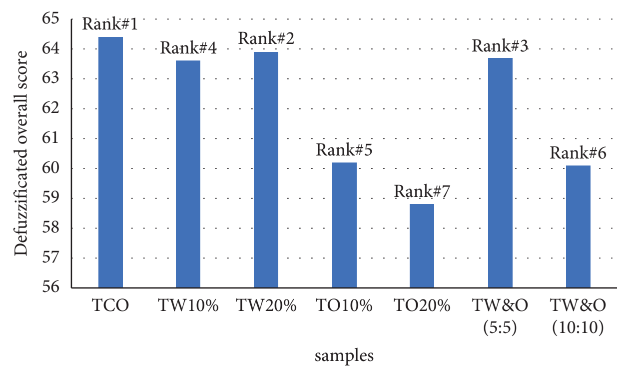

Figure 2: Overall score of various oily cakes and ranking T_{CO}: control sample and scores triplet (43.02, 65.47, 83.55); $T_{W10\%}$: wheat substitution with pomace (10% w/w) and scores triplet (42.54, 64.50, 82.98); $T_{W20\%}$: wheat substitution with pomace (20% w/w) and scores triplet (42.67, 64.96, 83.22); $T_{O10\%}$: fat substitution with pomace (10% w/w) and scores triplet (36.65, 61.01, 82.14); $T_{O20\%}$: fat substitution with pomace (20% w/w) and scores triplet (35.36, 59.72, 80.56); $T_{W\&O(5:5)}$: fat and wheat substitution with pomace (5 : 5% w/w) and scores triplet (42.38, 64.68, 83.16); $T_{W\&O(10:10)}$: fat and wheat substitution with pomace (10 : 10% w/w) and scores triplet (38.78, 60.60, 80.48).

Wheat flour substitution with apple pomace (20%) had no adverse effect on the sensory score of oily cakes. Moreover, this replacement can improve the texture and taste of the product. However, the cake contains apple pomace prone to microbial spoilage (especially mold) and rancidity, which reduces the sensory score during storage. Therefore, this formulation can be recommended for fresh consumption (short shelf-life).

4. Conclusion

The result of the current study revealed that by increasing the level of apple pomace powder in oily cake formulation, the caloric values of the samples were decreased and the fiber content was enhanced. Using apple pomace (20%) to replace wheat flour can enhance the nutritional value without showing significant changes in the sensory profile of samples. However, apple pomace cannot sufficiently imitate the techno-functional properties of fat. By reducing the fat content of oily cakes, the volume of cakes decreased while wheat flour substitution by apple pomace resulted in an enchantment of the distribution of the bubbles in the cake matrix. The antioxidant and antimicrobial potential of apple pomace was not significant. Therefore, apple pomace powder has no significant effect on the shelf-life of oily cakes.

Following the addition of apple pomace to the formulation, the fruity flavor of the cake increased while the grain taste was reduced. Thus, apple pomace has a good potential to enhance the nutritional as well as the sensory profile of oily cakes. Apple pomace could be considered a cost-effective, sustainable, and healthy alternative for part of wheat flour, recommended in an industrial setting. Further research is needed to produce reduced-fat cakes. The investigation of the effect of the addition of fruit pomace powder(s) along with fat replacers and a natural preservative (such as plant essential oils and extracts) besides optimizing cake formulations can be suggested for future research.

Data Availability

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

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

M.S is responsible for validation, formal analysis, resources, editing, writing-original draft, and funding acquisition. MR.S is responsible for supervision. A.SH is responsible for conceptualization, methodology, extracting the data, and writing the original draft. A.P and M.A are responsible for supervision.

References

[1] K. Sharifi and A. Sharifi, "Comparison of antibacterial and antioxidant potentials of pure and nanoemulsified Nepeta pogonosperma essential oil," *Food Science and Nutrition*, vol. 11, no. 4, pp. 1797–1807, 2022.

[2] F. Lyu, S. F. Luiz, D. R. P. Azeredo, A. G. Cruz, S. Ajlouni, and C. S. Ranadheera, "Apple pomace as a functional and healthy ingredient in food products: a Review," *Processes*, vol. 8, no. 3, p. 319, 2020.

[3] A. Quiles, G. M. Campbell, S. Struck, H. Rohm, and I. Hernando, "Fiber from fruit pomace: a review of applications in cereal-based products," *Food Reviews International*, vol. 34, no. 2, pp. 162–181, 2018.

[4] F. A. Masoodi, B. Sharma, and G. Chauhan, "Use of apple pomace as a source of dietary fiber in cakes," *Plant Foods for Human Nutrition*, vol. 57, no. 2, pp. 121–128, 2002.

[5] R. C. Skinner, J. C. Gigliotti, K.-M. Ku, and J. C. Tou, "A comprehensive analysis of the composition, health benefits, and safety of apple pomace," *Nutrition Reviews*, vol. 76, no. 12, pp. 893–909, 2018.

[6] M. Usman, S. Ahmed, A. Mehmood et al., "Effect of apple pomace on nutrition, rheology of dough and cookies quality," *Journal of Food Science and Technology*, vol. 57, no. 9, pp. 3244–3251, 2020.

[7] N. Mishra and R. Chandra, "Development of functional biscuit from soy flour & rice bran," *International Journal of Agricultural and Food Science*, vol. 2, no. 1, pp. 14–20, 2012.

[8] Z. Nazari and A. Ehtiati, "Evaluation of the effect of fat replacer gel on physicochemical and rheological properties of low-calorie cake dough and texture," *Journal of Food Science and Technology*, vol. 19, no. 122, pp. 209–220, 2022.

[9] M. Sudha, V. Baskaran, and K. Leelavathi, "Apple pomace as a source of dietary fiber and polyphenols and its effect on the rheological characteristics and cake making," *Food Chemistry*, vol. 104, no. 2, pp. 686–692, 2007.

[10] T. Negi, D. Vaidya, A. Tarafdar et al., "Physico-functional evaluation, process optimization and economic analysis for preparation of muffin premix using apple pomace as novel supplement," *Systems Microbiology and Biomanufacturing*, vol. 1, no. 3, pp. 302–310, 2021.

[11] H. Gazalli, A. H. Malik, A. H. Sofi et al., "Nutritional value and physiological effect of apple pomace," *International Journal of Food and Nutrition Science*, vol. 5, no. 1, pp. 11–15, 2014.

[12] E. Azadfar, A. H. Elhami Rad, A. Sharifi, and M. Armin, "Effect of olive pomace fiber on the baking properties of wheat flour and flat bread (barbari bread) quality," *Journal of Food Processing and Preservation*, vol. 2023, Article ID 1405758, 9 pages, 2023.

[13] Z. Kırbaş, S. Kumcuoglu, and S. Tavman, "Effects of apple, orange and carrot pomace powders on gluten-free batter rheology and cake properties," *Journal of Food Science and Technology*, vol. 56, no. 2, pp. 914–926, 2019.

[14] M. B. Younas, A. Rakha, M. Sohail, S. Rashid, and H. Ishtiaq, "Physicochemical and sensory assessment of apple pomace enriched muffins," *Pakistan Journal of Food Sciences*, vol. 25, no. 4, pp. 224–234, 2015.

[15] L. Balezentiene, D. Streimikiene, and T. Balezentis, "Fuzzy decision support methodology for sustainable energy crop selection," *Renewable and Sustainable Energy Reviews*, vol. 17, pp. 83–93, 2013.

[16] B. Shahidi, A. Sharifi, L. Roozbeh Nasiraie, M. Niakousari, and M. Ahmadi, "Phenolic content and antioxidant activity of flixweed (Descurainia sophia) seeds extracts: ranking extraction systems based on fuzzy logic method," *Sustainable Chemistry and Pharmacy*, vol. 16, Article ID 100245, 2020.

[17] M. Bouzon, K. Govindan, C. M. T. Rodriguez, and L. M. Campos, "Identification and analysis of reverse logistics barriers using fuzzy Delphi method and AHP," *Resources, Conservation and Recycling*, vol. 108, pp. 182–197, 2016.

[18] M. Moosavi-Nasab and S. Khoshnoudi-Nia, "Combining knowledge-and data-driven fuzzy approach to evaluate shelf-life of various seafood products," *Food Quality and Safety*, vol. 5, 2021.

[19] R. Sasikumar, K. Vivek, and S. Deka, "Sensory evaluation of ultrasound assisted microwave treated fruit (Haematocarpus validus) juice through fuzzy logic approach," *International Food Research Journal*, vol. 26, no. 4, 2019.

[20] A. Sharifi and S. Khoshnoudi-Nia, "Ranking novel extraction systems of seedless barberry (Berberis Vulgaris) bioactive compounds with fuzzy logic-based term weighting scheme," *Sustainable Chemistry and Pharmacy*, vol. 25, Article ID 100561, 2022.

[21] Z. Tahsiri, M. Niakousari, S. Khoshnoudi-Nia, and S. M. H. Hosseini, "Sensory evaluation of selected formulated milk barberry drinks using the fuzzy approach," *Food Science and Nutrition*, vol. 5, no. 3, pp. 739–749, 2017.

[22] AOAC International, "Official methods of analysis of aoac international," *Agricultural Chemicals, Contaminants*, vol. 1, AOAC International, Rockville, MD, USA, 2010.

[23] V. L. Singleton, R. Orthofer, and R. M. Lamuela-Raventós, "Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent," in *Methods in Enzymology*, vol. 299, pp. 152–178, Elsevier, Amsterdam, Netherland, 1999.

[24] M. Fathi, M. Mohebbi, and S. M. A. Razavi, "Application of image analysis and artificial neural network to predict mass transfer kinetics and color changes of osmotically dehydrated kiwifruit," *Food and Bioprocess Technology*, vol. 4, no. 8, pp. 1357–1366, 2011.

[25] S. Khoshnoudi-Nia, M. Moosavi-Nasab, S. M. Nassiri, and Z. Azimifar, "Determination of Total viable count in rainbow-trout fish fillets based on hyperspectral imaging system and different variable selection and extraction of reference data methods," *Food Analytical Methods*, vol. 11, no. 12, pp. 3481–3494, 2018.

[26] R. Baixauli, A. Salvador, and S. Fiszman, "Textural and colour changes during storage and sensory shelf life of muffins containing resistant starch," *European Food Research and Technology*, vol. 226, no. 3, pp. 523–530, 2008.

[27] Iranian National Standardization Organization, *Biscuit-Specifications and Test Methods*, Iranian National Standardization Organization, Karaj, Iran, 2019.

[28] International Organization for Standardization, *Microbiology of Food and Animal Feeding Stuffs: Horizontal Method for the Enumeration of Microorganisms: Colony-count Technique at 30° C*, International Organization for Standardization, Geneva, Switzerland, 2003.

[29] International Organization for Standardization, *Microbiology of the Food Chain- Horizontal Method for the Detection and Enumeration of Enterobacteriaceae- Part 1: Detection of Enterobacteriaceae*, International Organization for Standardization, Geneva, Switzerland, 2017.

[30] International Organization for Standardization, *Microbiology of the Food Chain - Horizontal Method for the Detection and Enumeration of Enterobacteriaceae - Part 2: Colony-count Technique*, International Organization for Standardization, Geneva, Switzerland, 2017.

[31] International Organization for Standardization, *Microbiology of Food and Animal Feeding Stuffs—Horizontal Method for the Enumeration of Yeasts and Moulds—Part 2: Colony Count Technique in Products with Water Activity Less than or Equal to 0,95*, International Organization for Standardization, Geneva, Switzerland, 2008.

[32] Iranian National Standardization Organization, *Microbiology of Pastry and Confectionery Products- Specifications and Test Methods*, Iranian National Standardization Organization, Karaj, Iran, 2019.

[33] D. Mehta, P. Prasad, R. S. Sangwan, and S. K. Yadav, "Tomato processing byproduct valorization in bread and muffin: improvement in physicochemical properties and shelf life stability," *Journal of Food Science and Technology*, vol. 55, no. 7, pp. 2560–2568, 2018.

[34] N. Youseftabar-Miri, N. Sedaghat, and S. Khoshnoudi-Nia, "Effect of active edible coating on quality properties of green-raisin and ranking the samples using fuzzy approach," *Journal of Food Measurement and Characterization*, vol. 15, no. 1, pp. 46–58, 2021.

[35] V. Lavelli and S. Corti, "Phloridzin and other phytochemicals in apple pomace: stability evaluation upon dehydration and storage of dried product," *Food Chemistry*, vol. 129, no. 4, pp. 1578–1583, 2011.

[36] G. Ćetković, J. Čanadanović-Brunet, S. Djilas, S. Savatović, A. Mandić, and V. Tumbas, "Assessment of polyphenolic content and in vitro antiradical characteristics of apple pomace," *Food Chemistry*, vol. 109, no. 2, pp. 340–347, 2008.

[37] P. Naknaen, T. Itthisoponkul, A. Sondee, and N. Angsombat, "Utilization of watermelon rind waste as a potential source of dietary fiber to improve health promoting properties and reduce glycemic index for cookie making," *Food Science and Biotechnology*, vol. 25, no. 2, pp. 415–424, 2016.

[38] R. Jahanbakhshi and S. Ansari, "Physicochemical properties of sponge cake fortified by olive stone powder," *Journal of Food Quality*, vol. 2020, Article ID 1493638, 2020.

[39] C. Collar, C. M. Rosell, B. Muguerza, and L. Moulay, "Breadmaking performance and keeping behavior of cocoa-soluble fiber-enriched wheat breads," *Food Science and Technology International*, vol. 15, no. 1, pp. 79–87, 2009.

[40] H. M. Al-Sayed and A. R. Ahmed, "Utilization of watermelon rinds and sharlyn melon peels as a natural source of dietary fiber and antioxidants in cake," *Annals of Agricultural Science*, vol. 58, no. 1, pp. 83–95, 2013.

[41] A. Aydogdu, G. Sumnu, and S. Sahin, "Effects of addition of different fibers on rheological characteristics of cake batter and quality of cakes," *Journal of Food Science and Technology*, vol. 55, no. 2, pp. 667–677, 2018.

[42] A. Quiles, E. Llorca, C. Schmidt et al., "Use of berry pomace to replace flour, fat or sugar in cakes," *International Journal of Food Science and Technology*, vol. 53, no. 6, pp. 1579–1587, 2018.

[43] S. A. Rather, R. Akhter, F. Masoodi, A. Gani, and S. Wani, "Utilization of apple pomace powder as a fat replacer in goshtaba: a traditional meat product of Jammu and Kashmir, India," *Journal of Food Measurement and Characterization*, vol. 9, no. 3, pp. 389–399, 2015.

[44] J. Rodríguez-García, A. Puig, A. Salvador, and I. Hernando, "Optimization of a sponge cake formulation with inulin as fat replacer: structure, physicochemical, and sensory properties," *Journal of Food Science*, vol. 77, no. 2, pp. 189–197, 2012.

[45] M. Gómez, F. Ronda, C. A. Blanco, P. A. Caballero, and A. Apesteguía, "Effect of dietary fibre on dough rheology and bread quality," *European Food Research and Technology*, vol. 216, no. 1, pp. 51–56, 2003.

[46] M. A. Gularte, E. de la Hera, M. Gómez, and C. M. Rosell, "Effect of different fibers on batter and gluten-free layer cake properties," *LWT--Food Science and Technology*, vol. 48, no. 2, pp. 209–214, 2012.

[47] K. Ben Jeddou, F. Bouaziz, S. Zouari-Ellouzi et al., "Improvement of texture and sensory properties of cakes by addition of potato peel powder with high level of dietary fiber and protein," *Food Chemistry*, vol. 217, pp. 668–677, 2017.

[48] A. Raymundo, P. Fradinho, and M. C. Nunes, "Effect of Psyllium fibre content on the textural and rheological characteristics of biscuit and biscuit dough," *Bioactive carbohydrates and dietary fibre*, vol. 3, no. 2, pp. 96–105, 2014.

[49] A. Aparicio-Saguilán, S. G. Sáyago-Ayerdi, A. Vargas-Torres, J. Tovar, T. E. Ascencio-Otero, and L. A. Bello-Pérez, "Slowly digestible cookies prepared from resistant starch-rich lintnerized banana starch," *Journal of Food Composition and Analysis*, vol. 20, no. 3-4, pp. 175–181, 2007.

[50] B. Wu, M. Zhou, X. Dai, and X. Chai, "Mechanism insights into bio-floc bound water transformation based on synchrotron X-ray computed microtomography and viscoelastic

acoustic response analysis," *Water Research*, vol. 142, pp. 480–489, 2018.
[51] Isiri, *Cake –Specification and Test Methods*, Institute of Standards and Industrial Research of Iran, Karaj: Iran, 2016.
[52] L. D. Latip, W. Zzaman, and T. Ayang, "Application of response surface methodology to optimize the extraction of Asian catfish (Clarias Batrachus) oil using superheated steam treatment," *Food Science and Technology*, vol. 2, no. 6, pp. 69–76, 2014.
[53] Z. Saeidi, B. Nasehi, and H. Jooyandeh, "Optimization of gluten-free cake formulation enriched with pomegranate seed powder and transglutaminase enzyme," *Journal of Food Science and Technology*, vol. 55, no. 8, pp. 3110–3118, 2018.
[54] S. Khoshnoudi-Nia, N. Sharif, and S. M. Jafari, "Loading of phenolic compounds into electrospun nanofibers and electrosprayed nanoparticles," *Trends in Food Science & Technology*, vol. 95, pp. 59–74, 2020.
[55] F. Boscaino, G. Cammarota, A. Ottombrino et al., "Chemical, volatile profile and shelf life of muffin enriched with supplementation chestnut cream," *Journal of Food Processing and Preservation*, vol. 41, no. 4, Article ID 13013, 2017.
[56] I. Khalifa, H. Barakat, H. A. El-Mansy, and S. A. Soliman, "Physico-chemical, organolyptical and microbiological characteristics of substituted cupcake by potato processing residues," *Food and Nutrition Sciences*, vol. 6, no. 1, pp. 83–100, 2015.
[57] N. Samsudin, N. Roslan, M. Nor-Khaizura, and H. Hasan, "Shelf life extension of ambient-stored banana cake using banana powder," *International Food Research Journal*, vol. 26, no. 1, 2019.
[58] R. V. Rios, M. D. F. Pessanha, P. F. D. Almeida, C. L. Viana, and S. C. D. S. Lannes, "Application of fats in some food products," *Food Science and Technology*, vol. 34, no. 1, pp. 3–15, 2014.
[59] D. M. Lebesi and C. Tzia, "Effect of the addition of different dietary fiber and edible cereal bran sources on the baking and sensory characteristics of cupcakes," *Food and Bioprocess Technology*, vol. 4, no. 5, pp. 710–722, 2011.
[60] S. Hosseini Ghaboos, S. Seyedain Ardabili, and M. Kashaninejad, "Physico-chemical, textural and sensory evaluation of sponge cake supplemented with pumpkin flour," *International Food Research Journal*, vol. 25, no. 2, 2018.