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Production of enriched cakes by apple pulp and peel powder and evaluation of chemical, functional and textural properties

Producción de pasteles enriquecidos por pulpa de manzana y cáscara en polvo y evaluación de propiedades químicas, funcionales y texturales

Ahmadreza Hosseini [1]
Fahimeh Pazhouhandeh [2]

[1] Department of Food Science and Technology, Ferdowsi University of Mashhad, PO Box: 91785-1163, Mashhad, Iran. ORCID: 0000-0003-0051-9067.
[2] Department of Food Science and Technology, Ferdowsi University of Mashhad, PO Box: 91785-1163, Mashhad, Iran. ORCID: 0000-0003-0380-1359.

Corresponding author: ahmadrezahosseini@um.ac.ir

Abstract
Background: Apple pomace is a by-product of the fruit juice industry and comprises peel, seed, stem, and pulp tissues. This by-product contains dietary fibers, polyphenols, vitamins, and organic acids that can benefit human health and have a high potential as a dietary source. Baked products are well-known food types to humans and have a key role in feeding people worldwide. Nowadays, enriched products such as bread, cakes, and biscuits are available in stores. Different studies worldwide have been done about applying the by-products of the fruit juice industry in the bakery.
Objective: This research aimed to evaluate apple peel (APE) and pulp (APU) powders separately as a partial substitute for wheat flour in cake production.
Methods: Apple peel and pulp separately produced as the residual wastes of juicing were dried for 3 hours in oven (60°C). The dried pulp and peel were ground and sieved using a 60 µm mesh. In this research, chemical and physicochemical analyses were performed according to AACC (Approved Methods of the American Association of Cereal Chemists) and standard food analysis methods. Textural characteristic was analyzed by a texture analyzer (Brookfield CT3-10 Kg, US) equipped with an aluminum probe.
Results: Different levels of APE and APU powders (10%, 20%, and 30 %) were used to enrich the cakes. The ash content, fat content, water adsorption capacity, and oil absorption capacity of the wheat flour were lower than APU and APE, whereas the moisture content, protein content, bulk density, and pH showed a reverse trend. Adding APU and APP to the cake formula increased total dietary fiber (TDF) from 4.14 % in the control sample to 27.71 % in the sample with 30 % apple peel powder (APE-30). The highest *a** colorimetric parameter (redness) in the cake core was 3.82 in the APE-30 sample. The addition of APE and APU significantly increased the hardness, gumminess, and chewiness of the samples ($p<0.05$). APE-10 samples could improve the nutritional properties of the cakes without significant reduction ($p>0.05$) in overall acceptance compared to the control sample.
Conclusion: The results of this research demonstrated that a partial replacement of the wheat flour with apple pulp and peel significantly increased the dietary fibers, especially insoluble dietary

fiber, compared to the control sample. Apple pulp and apple peel powders had the potential for use in cake making as a good source of dietary fibers.
Keywords: Apple pomace powders, Enriched cake, Textural properties, Dietary fiber, Apple peel.

Resumen

Antecedentes: la pulpa de manzana es un subproducto de la industria del jugo de frutas y se compone de tejidos de cáscara, semillas, tallo y pulpa. Este subproducto contiene fibra dietética, polifenoles, vitaminas y ácidos orgánicos que pueden ser beneficiosos para la salud humana y tienen un alto potencial como fuente dietética. Los productos horneados son de tipos de alimentos bien conocidos para los seres humanos y son clave en la alimentación de las personas de todo el mundo. Hoy en día, los productos enriquecidos como pan, pasteles y galletas están disponibles en las tiendas. Se han hecho diferentes estudios en todo el mundo sobre la aplicación del subproducto de la industria del jugo de frutas en la panadería.

Objetivo: El propósito de esta investigación fue evaluar los polvos de cáscara de manzana (APE) y pulpa (APU) como sustituto parcial de la harina de trigo en la producción de pasteles.

Métodos: Cáscaras de manzana y pulpa producidas por separado como desechos residuales de jugos, se secaron durante 3 horas en el horno (60 °C). La pulpa seca y la cáscara fueron molidas y tamizadas usando una malla de 60 micras. En esta investigación el análisis químico y físico-químico realizado de acuerdo con el AACC (Aprobado Métodos de la Asociación Americana de Químicos del Cereales) y los métodos estándar de análisis de alimentos. La característica textural fue analizada por el analizador de textura (Brookfield CT3-10 Kg, US) equipado con una sonda de aluminio.

Resultados: Se utilizaron diferentes niveles de polvos APE y APU (10, 20 and 30 %) para enriquecer los pasteles. La capacidad de absorción de ceniza, grasa, agua y aceite de la harina de trigo fue menor que la APU y APE, mientras que la humedad, la proteína, la densidad a granel y el pH mostraron una tendencia inversa. Además, APU y APE en fórmula de pastel, aumentaron la fibra dietética total (TDF) de 4.14 % en la muestra de control a 27.71 % en la muestra con un 30 % de polvo de pelar de manzana (APE-30). El parámetro más alto a* colorimétrico en núcleo de pastel fue de 3.82 (enrojecimiento) en la muestra APE-30. La adición de APE y APU aumentó significativamente la dureza, gomosidad y masticabilidad de las muestras ($p<0.05$). Las muestras de APE-10 podrían mejorar las propiedades nutricionales de los pasteles sin reducción significativa ($P<0.05$) en aceptación general, en comparación con la muestra de control.

Conclusión: Los resultados de este estudio demostraron que un reemplazo parcial de la harina de trigo por pulpa de manzana y cáscara aumentó significativamente la fibra dietética especialmente la insoluble, cuando se compara con la muestra de control. La pulpa en polvo y la cáscara de manzana tienen el potencial de uso en la fabricación de pasteles como una buena fuente de fibra dietética.
Palabras clave: Pulpa de manzana, pastel enriquecido, Propiedades texturales, fibra dietética, cáscara de manzana.

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1. Introduction

Functional foods are produced for the purpose of providing health and nutritional value. The Food and Drugs Administration (FDA) recommends using substances such as antioxidants, phytochemicals, and dietary fibers in food compositions (1). Non-starch polysaccharides (NSP) are recognized as dietary fibers (2). A fiber-rich diet is characterized by biological benefits such as improving colon health, lowering the risk of chronic diseases, and protecting the cells from oxidative damage. Additionally, the fermentation of the dietary fibers results in short-chain fatty acids that are beneficial to human health (3).

However, such positive biological effects are provided by certain dietary fibers which may not have the same effect and depend on fiber sources and processing methods (4). Fruit fibers contain low amounts of phytic acid and bioactive molecules such as antioxidants (5), and phenols. Characteristics such as higher water-holding capacity, solubility, and fermenting ability in the intestine have given higher qualities to fruit fibers (6).

Apple pomace is a by-product of the fruit juice industry and comprises peel, seed, stem, and pulp tissues. This by-product contains dietary fibers, polyphenols, vitamins, and organic acids that can benefit human health (7, 8) and have high potential as a dietary source (3). The main components of apple dietary fiber are pectin (5.50-11.70 %), cellulose (7.20-43.60 %), hemicelluloses (4.26-24.40 %), lignin (15.30-23.50 %), and gums (9). Apple peel (APE) and Apple pulp (APU) powders have high amounts of soluble and insoluble dietary fiber; therefore, they can be used to enrich food products.

Baked products are well-known food types to humans and have a key role in feeding people worldwide. Among most of them, wheat flour usually is the main ingredient in processing. However, can be replaced with partially dietary fibers to produce enriched products. Nowadays, enriched products such as bread, cakes, and biscuits are available in stores. Some of the criteria that consumers consider when choosing foods include taste, convenience, price, and other characteristics, such as health (10). Replacing a part of wheat flour with functional ingredients to produce enriched products can change properties such as stability, texture, and taste (11, 12).

Sing *et al*. produced high-quality enriched muffins using 6 % concentrate of black carrot dietary fiber and 0.5 % xanthan gum (13). O'Shea *et al*. utilized orange juice pomace (up to 8 %) to increase the dietary fiber content of bread (14). Using carrot pomace powder to produce cakes resulted in a product with optimal density, hardness, and sensory scores (15). Also, the application of apple pomace in biscuits showed low glycemic index levels as a partial substitution of wheat flour in cake elaboration and produced a healthy food product (16).

2. Materials and methods

2.1. Materials

Apple peel and pulp, separately produced as residual wastes of juicing, were dried for 3 hours in the oven (60 °C). The dried pulp and peel were ground and sieved using a 60 µm mesh. Then, the samples were placed into plastic lid packages and stored in a refrigerator at 4 °C. The packages were kept at room temperature for 12 hours before use.

2.2. Methods

2.2.1. Chemical analysis

The moisture and ash content of the APE, APU, and wheat flour were determined according to methods 6540:1980 and 5984:2002 (17). The lipid content was tested according to the Soxhlet method (18), and the protein content was determined following the modified Lowry method (19). The fiber content was assessed upon method 32–07.01 (20).

2.2.2. Water holding capacity

The Sudha *et al.* methods, with some modifications, were used to quantify the water-holding capacity of the powders (21). One gram of each sample was dissolved in 15 ml of distilled water in a 50 ml falcon tube. Next, the samples were kept at room temperature for water absorption. After 24 hours, the samples were centrifuged at 15,000 *g* for 20 minutes. Next, the upper clear liquid phase was removed. The lower part was weighted to determine the water-holding capacity (g/g) by measuring the weight difference between the sample residue and the initial sample.

2.2.3. Oil absorption capacity (OAC)

OAC was analyzed based on the methods developed by Ktenioudaki *et al.* with slight modifications (22). One gram of each powder was mixed with 15 ml sunflower oil in a 50 ml falcon tube. Next, the samples were kept at room temperature to absorb the oil. After 24 hours, the samples were centrifuged at 15,000 g for 20 minutes. By removing the upper oil phase and weighting the residue, the oil absorption capacity was determined by calculating the weight difference.

2.2.4. pH

One gram of each APE and APU powders were dissolved and homogenized in 200 ml water using a mixer. Next, the mixture was filtered using a filter, and the pH was determined at 24.0 ± 0.3 °C using a pH meter (Jenway-3020-UK) with method 02-52 (20).

2.2.5. Bulk density

Fifty grams of each sample was poured into a 250 ml graduated cylinder with slight shaking to measure the sample volume (20).

2.2.6. Cake production

APU and APE powders were used separately in three levels (10, 20, and 30 %) to prepare the cake samples. Another cake sample was produced with only wheat flour as a control. The used amounts are shown in Table 1. The cake samples were made by blending ingredients, including sugar, milk, egg, and commercial emulsifier, and using an electric mixer for 4 minutes under fast speed to reach a foam-like mixture. Next, flour and baking powder were slowly added to the compound at a slow mixer speed. After 1 minute, the generated dough was poured into a cake pan and placed in the oven at 180 °C for 20 minutes.

Table 1. Formulation of prepared cakes

Ingredients	Control	APU-10	APU-20	APU-30	APE-10	APE-20	APE-30
Wheat flour	100	90	80	70	90	80	70
Apple powder	0	10	20	30	10	20	30
Egg	130	130	130	130	130	130	130
Sugar	60	60	60	60	60	60	60
Emulsifier	4	4	4	4	4	4	4
Baking powder	2.8	2.8	2.8	2.8	2.8	2.8	2.8

Based on weight (g)

2.2.7. Specific volume

The cake volume was calculated using colza seeds based on the displacement principle. Subsequently, weight (g) and specific volume (cm3/g) were determined (20).

2.2.8. Colorimetry

Three colorimetric parameters, including *a**, *b**, and *L**, were investigated. Parameter *a** indicates the green to the red color range, *b** delineates the blue to the yellow color range, and *L** represents cake lightness. The crust and crumb of the cakes were separated, and the samples were placed in an imaging box with 10 lamps to prepare the samples for the test. Imaging was carried out using a digital camera (Canon, EOS 450D). Also, the measurement of color parameters was done using the Image processing toolbox in MATLAB (v 9.4, 2018a) software (23).

2.2.9. Textural analysis

The texture analysis was conducted using the reference method (20) with a texture analyzer (Brookfield CT3-10 kg, US) equipped with an aluminum probe (36 mm diameter) and a loading weight of 5 kg. The cake crust was separated, and then the crumb was examined by slicing 2×2×2 cm cubes to analyze the texture. The required pressure to compress the cubes to 40 % of the original height was calculated using the device in the following conditions: pre-test speed = 1 mm/s; speed during the test = 1.7 mm/s; post-test speed = 10 mm/s.

2.2.10. Sensory analysis

Seventeen trained panelists carried out sensory analyses of the cakes on a five-point hedonic scale (1 dislike very much to 5 like very much). The parameters to evaluate were aroma, texture, taste, odor, and appearance; an overall quality score was computed as the average of the five traits. Mean score values for sensory evaluations of cakes were used (24).

2.2.11. Statistical analysis

One-way ANOVA and Duncan's multiple-range tests (significance level at $p<0.05$) were used to analyze the obtained data in SPSS v24 statistical software. All the tests in this research were performed in triplicate.

3. Results

3.1. Chemical analysis of powder

In the chemical analysis results (Table 2), it was found that all three samples showed statistically significant differences ($p<0.05$). The wheat flour had higher moisture, 13.42±0.18 %, than APU and APE, but the ash content was less than in other samples. APU and APE had 3.27±0.05 % and 1.58±0.04 % protein which were significantly lower than the wheat flour ($p<0.05$). The insoluble fiber of the wheat flour (5.89±0.05 %), significantly lower than APE (38.12±0.04 %), and APU (33.71±0.05 %) ($p<0.05$). The dietary soluble fiber of APE and APU were 19.24±0.07 % and 13.89±0.03 %, respectively.

Table 2. Chemical composition of wheat flour, APU and APE powders (DWB).

Chemical composition (%)	Moisture	Ash	Protein	Fat	Insoluble dietary fiber	Soluble dietary fiber

wheat flour	13.42±0.18 [a]	0.63±0.01 [c]	10.11±0.08 [a]	1.08±0.12 [c]	5.89±0.05 [c]	2.32±0.00 [c]
APU	8.81±0.11 [b]	1.62±0.06 [b]	3.27±0.05 [b]	2.43±0.08 [b]	33.71±0.05 [b]	13.89±0.03 [b]
APE	7.70±0.09 [c]	1.97±0.02 [a]	1.58±0.04 [c]	4.25±0.14 [a]	38.12±0.04 [a]	19.24±0.07 [a]

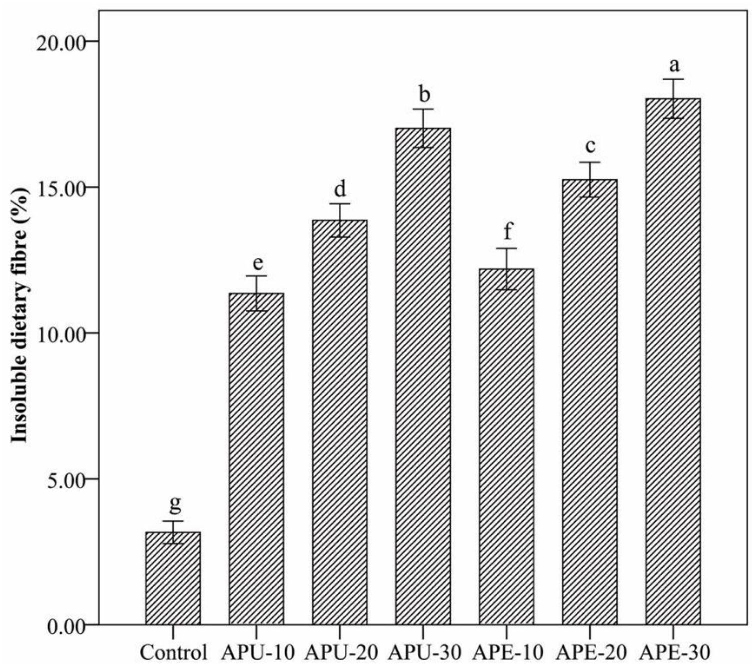
DWB = Dry weight basis

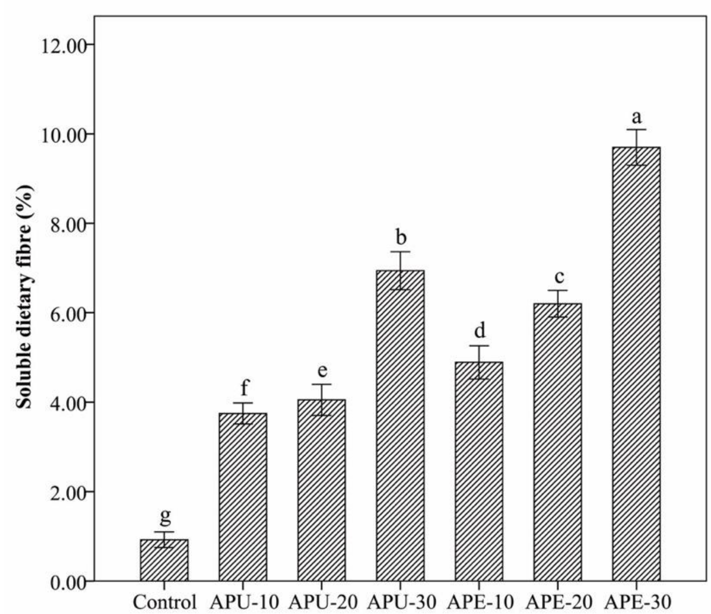
Values in the same column with the same letter are not significantly different ($p<0.05$).

3.2. Dietary fiber analysis of cakes

In this research, seven treatments of the samples (three different levels of percentage replacement of APU and APE powders and a control sample) were prepared and examined for chemical properties. Figure 1 shows that replacing the wheat flour with APU and APE powders significantly affected the amount of soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) in the cakes ($p<0.05$). Data comparison showed that the control sample contained the lowest amount of SDF (1.03±0.12 %), IDF (3.58±0.21 %), and total fiber, while APE-30 had the highest SDF (9.87±0.53 %) and IDF (17.64±0.79 %). However, by increasing the percentage of APE or APU powder in the cakes, the amounts of IDF and SDF were significantly increased from 11.61±0.81 to 17.64±0.79 % and 3.84±0.44 to 9.87±0.53 %, respectively ($p<0.05$).

A.





B.

Figure 1. A. Insoluble dietary fiber (IDF), and B. Soluble dietary fiber (SDF) content of the cakes prepared with increasing quantities of APU and APE (0 %, 10 %, 20%, 30%). Error bars represent the standard deviation. Columns with different letters are significantly different ($p<0.05$).

3.3. Functional and physiochemical properties of APU and APE powders

The wheat flour, APE, and APU powders were analyzed using a pH meter (Table 3). According to the results, the APE contained a lower pH level (4.31±0.02) than the APU powder (4.97±0.01). Additionally, the pH levels of both powder types were significantly lower than the wheat flour (6.35±0.02) ($p<0.05$).

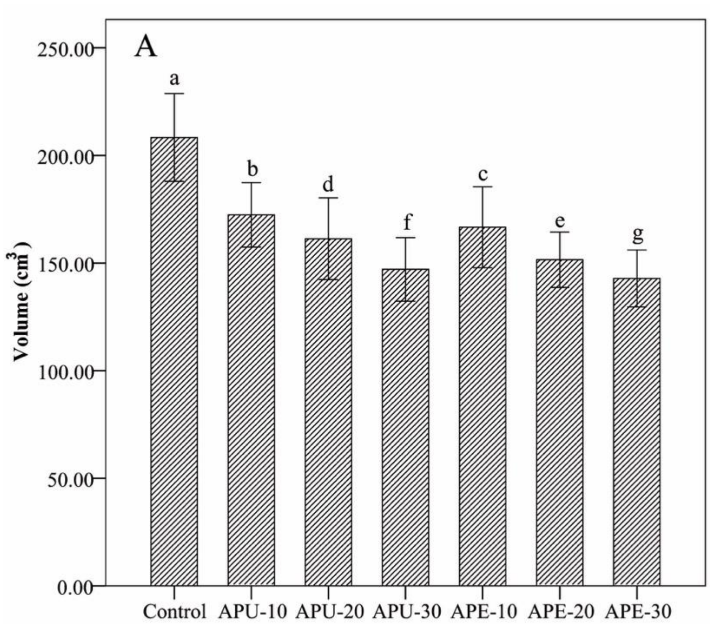
Table 3. Functional and physicochemical properties of Wheat flour, APU, and APE powders.

Sample	pH	Water absorption capacity (g/g)	Oil absorption capacity (g/g)	Bulk density (g/l)
wheat flour	6.35±0.02 ^{a}	4.71±0.12 ^{c}	1.14±0.09 ^{c}	503.4±2.5 ^{a}
APU	4.97±0.01 ^{b}	6.69±0.10 ^{b}	2.19±0.07 ^{b}	438.6±3.7 ^{b}
APE	4.31±0.02 ^{c}	7.26±0.13 ^{a}	2.32±0.03 ^{a}	421.1±4.9 ^{c}

Water absorption capacity (WAC) is a practical parameter in food products such as bread, cakes, and macaroni. Table 3 shows that APE with 7.26 ± 0.13 (g/g) contained the highest value, and the wheat flour with 4.71±0.12 (g/g) had the lowest. The Oil absorption capacity (OAC) of the APE and APU powders were 2.32±0.03 (g/g) and 2.19±0.07 (g/g), respectively, and significantly higher than wheat flour ($p<0.05$) (Table 3). The obtained bulk density for the wheat flour, APU, and APE were 503.4±2.5 (g/l), 438.6±3.7 (g/l), and 421.1±4.9 (g/l), which were significantly different ($p<0.05$).

3.4. Physical characteristics

Figure 2 shows the physical characteristics of the control and enriched cakes. As the data indicates in Figure 2A, the volume of the samples were reduced significantly with the addition of APE and APU powder levels compared to the control ($p<0.05$). As can be seen in figure 2, the volume of the APU and APE samples ranged from 141 cm^3 to 168 cm^3, which were lower than that of the control sample ($p<0.05$). By increasing the APU or APE powder content in the cake formula (Figure 2B), the density of the samples was higher than the control sample ($p<0.05$).



A.

B.

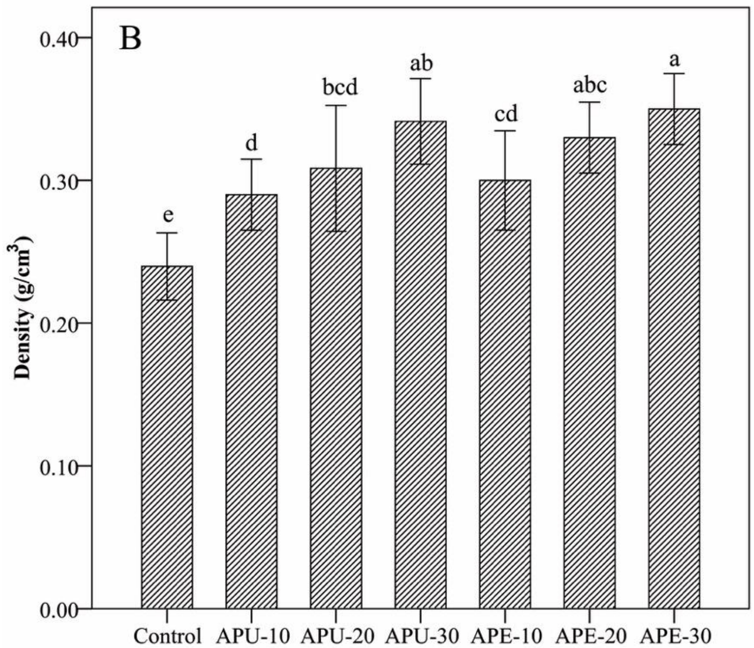


Figure 2. Effect of different levels of APU and APE powders on volume (A) and density (B) of enriched cakes.

3.5. Colorimetry

The effects of adding APU and APE powders on the cake color have been separately presented in Table 4. The highest lightness level of the cake core and crust were observed in the control sample; these parameters were 81.23±5.88 and 52.21±3.12, respectively. Among the enriched samples, the APU-10 sample showed no significant difference compared to the control ($p>0.05$). Evaluation of the cake crust showed that increasing the enrichment level did not significantly affect the lightness of the cake enriched with APU ($p>0.05$). The *a** index demonstrates the color range of the samples from green to red. By increasing APU and APE, *a** values increased from 1.38±0.16 to 3.01±0.22 and 1.59±0.18 to 3.82±0.25, respectively, in the cake core ($p<0.05$). The cake core in APE samples also showed higher *a** index levels. The highest level of redness in the cake core was found in the APE-30 (3.82±0.25). Evaluation of the cake crust showed that the control sample had the highest redness with a value of 5.99±0.23. With the addition of APU and APE powders, the redness of the samples was reduced compared to the control sample ($p<0.05$). The *b** index demonstrates the color range of blue to yellow in the samples. In the evaluation of cake cores, the enriched samples had less yellowness compared to the control sample ($p<0.05$), but they had no significant difference from each other ($p>0.05$). The yellowness index cake crusts dropped from 28.14±2.73 to 24.36±2.03 and 25.66±1.57 to 18.39±1.07 with increasing the level of APU and APE, respectively.

Table 4. Effect of different level of APU and APE powders on color parameters of enriched cakes.

Sample	Core		Crust

	L*	a*	b*		L*	a*	b*
Control	81.23±5.88 ^{a}	1.02±0.11 ^{f}	29.72±1.23 ^{a}		52.21±3.12 ^{a}	5.99±0.23 ^{a}	31.22±1.98 ^{a}
APU-10	77.41±5.01^{b}	1.38±0.16 ^{e}	23.15±1.55 ^{b}		49.87±3.98 ^{ab}	5.81±0.41 ^{b}	28.14±2.73 ^{ab}
APU-20	72.29±3.95^{cd}	2.12±0.13 ^{c}	23.97±1.38 ^{b}		47.62±4.01 ^{bc}	5.63±0.39 ^{d}	27.09±1.61 ^{bc}
APU-30	69.05±4.28 ^{d}	3.01±0.22 ^{b}	21.07±2.41 ^{b}		47.35±5.28 ^{bc}	5.70±0.35 ^{c}	24.36±2.03 ^{cd}
APE-10	73.71±6.43 ^{c}	1.59±0.18 ^{d}	23.81±2.04 ^{b}		44.41±3.84 ^{cd}	4.92±0.34 ^{f}	25.66±1.57 ^{bc}
APE-20	72.08±4.80 ^{cd}	2.30±0.20 ^{c}	22.97±1.81 ^{b}		41.30±2.57 ^{de}	5.08±0.31 ^{e}	22.18±1.39 ^{d}
APE-30	65.19±7.61 ^{e}	3.82±0.25 ^{a}	21.34±0.05 ^{b}		38.97±3.91 ^{e}	4.34±0.27 ^{g}	18.39±1.07 ^{e}

Values in the same column with the same letter are not significantly different ($p<0.05$)

3.6. Textural properties

The results (Table 5) showed that hardness, gumminess, and chewiness of the samples increased significantly ($p<0.05$), which were higher in all samples compared to the control. However, in equal enrichment levels, the samples enriched with APE had higher levels of hardness, gumminess, and chewiness compared to APU. The APE-30 sample had the highest level of hardness (6.24±0.13 N), gumminess (4.48±0.16 N), and chewiness (4.44±0.10 N.mm). In the evaluation of springiness, no significant difference was found between the enriched and control samples. However, the springiness of APU-30 and APE-30 samples were 1.08±0.13 (mm) and 1.07±0.12 (mm), which had a significant difference compared to the other samples ($p<0.05$). The APU-30 and APE-30 samples had the lowest cohesiveness compared to other samples ($p<0.05$).

Table 5. Effect of different level of APU and APE powders on textural parameters of enriched cakes.

Sample	Hardness (N)	Gummines s (N)	Chewiness (N.mm)	Springiness (mm)	Cohesiveness	Adhesiveness (N.s)
Control	1.61±0.06 ^{g}	1.29±0.05 ^{g}	1.31±0.11^{g}	1.01±0.06 ^{b}	0.80±0.02 ^{ab}	0.39± 0.01 ^{b}
APU-10	2.82±0.13 ^{f}	2.14±0.10 ^{f}	2.17±0.10^{f}	1.00±0.00 ^{b}	0.83±0.01 ^{a}	0.39±0.01 ^{b}
APU-20	3.32±0.17 ^{e}	2.55±0.15 ^{d}	2.70±0.10^{d}	1.02±0.03 ^{b}	0.82±0.01 ^{ab}	0.40±0.01 ^{b}
APU-30	4.54±0.15 ^{c}	3.52±0.19 ^{b}	3.42±0.13 ^{c}	1.08±0.13 ^{a}	0.79±0.00 ^{b}	0.40±0.01 ^{b}
APE-10	4.26±0.17 ^{d}	2.39±0.21 ^{e}	2.52±0.24^{e}	0.99±0.02 ^{b}	0.79±0.01 ^{b}	0.46±0.18 ^{a}
APE-20	5.39±0.26 ^{b}	3.22±0.09 ^{c}	3.79±0.11^{b}	1.02±0.02 ^{b}	0.80±0.01 ^{ab}	0.40±0.01 ^{b}
APE-30	6.24±0.13 ^{a}	4.48±0.16 ^{a}	4.44±0.10^{a}	1.07±0.12 ^{a}	0.79±0.01 ^{b}	0.40±0.01 ^{b}

Values in the same column with the same letter are not significantly different ($P<0.05$)

3.7. Sensory characteristics

The sensory evaluation showed that the cake prepared with APE-30 had the lowest score in terms of appearance, texture, taste, and odor parameters (Figure 3). The control sample obtained the highest total score (Figure 4). However, the samples prepared with APE-10 and APU-10 were not significantly different from the control sample (p>0.05).

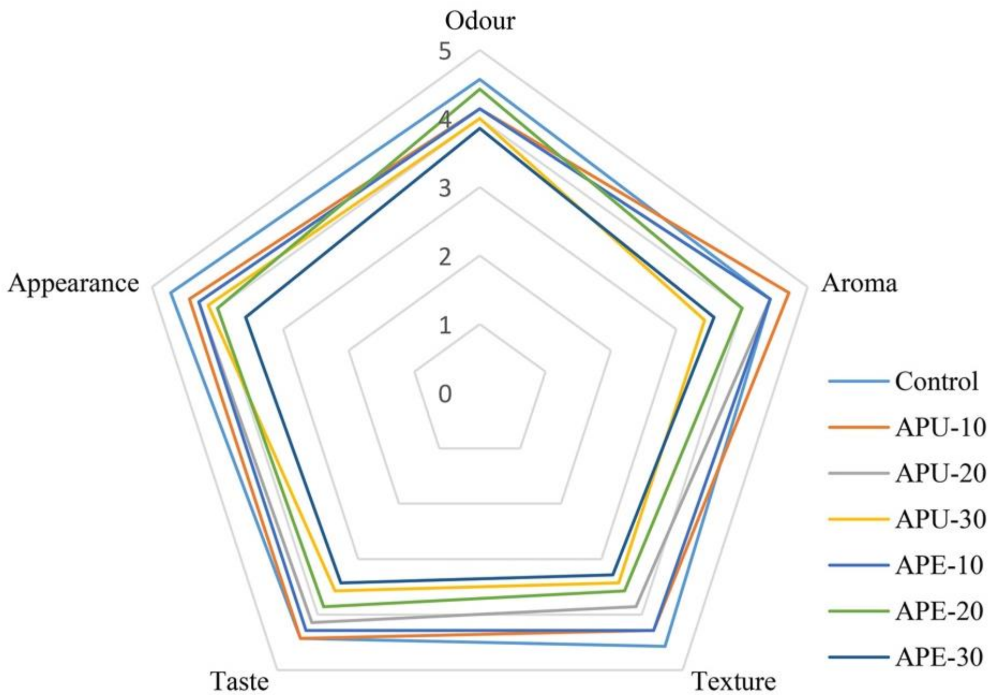


Figure 3. Sensory characteristics of seven samples prepared with increasing level of APU and APE powders, scale from 1 (extreme dislike) to 5 (extreme like).

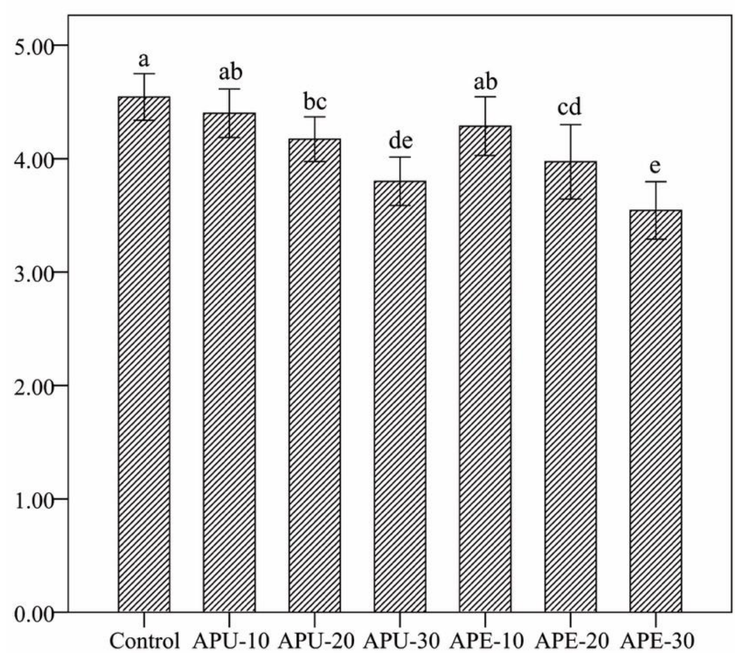


Figure 4. Overall sensorial quality of seven samples prepared with APU and APE powders.

4. Discussion

4.1. Chemical analysis of powder

Noor Aziah *et al.* (25) reported 2.65 and 5.73 % for soluble and insoluble fiber of wheat flour, respectively. In this research, the soluble and insoluble fiber content of wheat flour were 2.32±0.00 % and 5.89±0.05 %, respectively. The APU and APE powders contained a higher percentage of soluble and insoluble fiber than the wheat flour ($p<0.05$). The measured insoluble fiber in APU and APE powders were 33.71±0.05 % and 38.12±0.04 %, respectively, indicating that APE powder contains a higher percentage of insoluble dietary fiber than APU powder. The APE powder, also contained more soluble dietary fiber ($p<0.05$). In Skinner *et al.* (26) research, the content of soluble and insoluble dietary fiber in apple pomace powders were 13.5-14.6 % and 33.8-60.0 %, respectively. This broad difference in the amount of apple pomace can be associated with the difference in apple cultivars and dietary fiber extraction methods. In similar research, the content of soluble and insoluble fiber of apple pomace were 14.6 % and 36.5 % (21), respectively, which was consistent with the findings of this research as they also investigated peel and pulp powder. Regarding the function of fibers in the human diet, it can be stated that APU and APE as a source of soluble and insoluble fibers can improve the quality of food products.

4.2. Dietary fiber analysis of cakes

Kim *et al.* (27) used *Opuntiaa humifusa* powder in enriched sponge cakes, which resulted in a linear increase of fiber and a reduction of carbohydrates and calories in the produced samples. Some research has shown that the use of green banana flour (28), green tea powder (29), mango peel and pulp flours (25), and apple pomace (30, 31) also increased the fiber levels in the baked product. In this research, the samples enriched with APU contained lower amount of fiber compared to the corresponding samples that were enriched with APE ($p<0.05$).

4.3. Functional and physiochemical properties of APU and APE powders

In Moazezi *et al.* (7) research, the pH levels of wheat flour and apple pomace were reported to be 6.1 and 4.6, respectively, which was consistent with this research. Due to the higher acid content of APU and APE compared to the wheat flour, in the preparation of the enriched cakes, the pH of the dough is lower than that of ordinary cakes. Masoodi *et al.* (32) linked the pH reduction in the samples enriched with apple pomace power to the high surface area and acidity of the pomace.
Water absorption capacity (WAC) indicates the potential of a food product to bond with water (33, 34). All three samples displayed significant differences compared to each other. Kumar and Saini (35) reported WAC and oil absorption capacity (OAC) of the wheat flour at 0.46 (g/g) and 1.19 (g/g), respectively. In this research, WAC and OAC of wheat flour were 4.71±0.12 (g/g) and 1.14±0.09 (g/g). The OAC is the potential of flour proteins to make physical bonds with fat/lipids

through capillary absorption. This property is of primary importance since lipids, as preservatives of aroma and taste, can increase mouth feel sense, especially in bread and other cooked food products (36, 37). Higher OAC in APU (2.19±0.07 g/g) and APE (2.32±0.03 g/g) than the wheat flour (1.14±0.09 g/g), indicated the higher bonding potential and preservative feature of the pomace types in food products. High OAC can be due to other components present in apple peel and pulp which contribute to hydrophobicity (38). In some research on apple pomace (21, 39), the bulk density was reported at 520 (g/L) and 429.5 (g/L), respectively, which could be consistent with the present study.

4.4. Physical characteristics

The volume of the cake is influenced by the mixture of air in the dough and the capacity of the dough to retain the gases released from the baking powder system. The volume reduction in the enriched cake with APU and APE may be linked with the interference of the fibers with the process of gas capturing within the cake matrix (40). In the case of replacing flour with cellulose, several researchers stated that it weakened the capacity of the gluten matrix to contain the released gases inside the cake (32, 21). The density of the cake is an indicator of the dough capacity to contain air during mixing. Low density suggests many air bubbles within the cake texture. With the addition of APU to the cake formula (Figure 2B), the density of the samples was significantly increased from 0.29±0.04 (g/cm3) to 0.34±0.04 (g/cm3). Similarly, a decrease in volume and an increase in density were reported with the addition of fiber in the cake (21). Compared to the control, a rise in the density of the enriched samples can be due to the high level of fibers and the subsequent change in the viscosity of the dough. Proper density is associated with good aeration of the batter in mixing. An excessively low batter density also causes air to escape during the mixing and baking (41, 42). Fibers, proteins, and sugars can increase the batter density because they can disturb the aeration process (43, 44). Ayoubi *et al.* (45) reported that adding *Eleaagnus angustifolia* (senjed) powder increased the density of the cake. In the present research, APU samples had more volume than the APE samples, indicating a higher amount of fiber in the peel powder. Noor Aziah *et al.* (25) reported a specific volume reduction by replacing wheat flour with mango fiber in cakes. Similar findings concerning the volume reduction with the addition of spinach and avocado (*Persea americana*) puree (46, 47) in cakes and APE in muffins (48) were consistent with the findings of this research.

4.5. Colorimetry

The color of the food products is a determining factor in their quality and heavily influences their marketability (49). Indeed, heat exposure generates the cake color (50). As stated before, the *L** index indicates the product's lightness. Based on the color analysis results, the highest lightness level of the cake core and crust were observed in the control sample. Increasing the enrichment level from 10 to 30% led to a decrease in *L** index in the cake core. In the research of Kırbaş *et al.* (51), it was found that the addition of apple pomace powder to the cake led to a reduction of the lightness level. An increase in the darkness and redness of the samples can be associated with the presence of more sugars in apple pomace compared to the wheat flour. Hence, the Maillard reaction between amino acids and sugars, as well as the caramelization of the samples, could have occurred more intensively (52, 25, 50). Jung *et al.* (52) found similar results by adding apple pomace powder; in their research, the lightness of the cookie samples was reduced, while the redness level increased, which was explained by the darkness of apple pomace compared to the wheat flour.

The APU-10 sample showed no significant difference compared to the control sample (p>0.05). Salehi *et al.* (53) stated that the cake enrichment with apple powder led to a decrease in lightness, an increase in redness, and had no significant effect on yellowness.

4.6. Textural properties

The texture of food products is one of the most important factors that affect the acceptability of the product. Texture characteristics are influenced by cake volume, moisture level, and the interaction of different cake components (16). The texture tests are conducted either by instrumental analysis or sensory evaluation; however, the instrumental method is used frequently due to its accuracy.

Gumminess is calculated as hardness × cohesiveness (27), and chewiness is calculated as springiness × gumminess, and it is defined as the needed energy to disintegrate a food for swallowing (54). The results (Table 5) showed that with increasing the enrichment level, the hardness, gumminess, and chewiness also increased (p<0.05), which were higher than the control. Salehi *et al.* reported that adding apple powder to the cakes significantly increased cake hardness (53). According to Sudeh *et al.* (21), the dietary fiber of fruits increased the hardness of the cake core. Ayubi *et al.* (47) replaced wheat flour with senjed powder at different levels, increasing the cake texture hardness. Jung *et al.* (52) researched on cookie samples enriched with apple pomace; high enrichment percentage decreased their hardness, which was associated with a low moisture level of the pomace.

Springiness is the measurement of elasticity level by determining the recovery level between the first and second compression cycle (27). In this research, APU-30 and APE-30 had higher springiness than other samples (P<0.05). Grigelmo-Miguel *et al.* (55) found no significant difference in springiness by adding peach fiber to muffin samples. In research conducted by Kırbaş *et al.* (51), the fiber addition reduced the cake springiness; however, the amount and type of fiber did not affect springiness. Noor Aziah *et al.* (25) attributed texture changes in sponge cakes to interactions of fiber and gluten.

Cohesiveness determines the internal resistance of food structure and indicates the product's strength to stick together (54). APU-30 and APE-30 had the lowest cohesiveness in all samples (p<0.05). In the research of Salehi *et al.* (54), the enrichment of cake using carrot pomace showed a reduction in cohesiveness. However, Rocha Parra (56) found that increasing the apple pomace level led to reduce cohesiveness in bread samples. Jun *et al.* (57) found that applying apple peel flour reduced cohesiveness, whereas hardness and gumminess parameters in the samples significantly increased. Moreover, the control and three-gram enriched sample had no significant difference in adhesiveness.

Adhesiveness and cohesiveness parameters can be influenced by storage conditions, temperature, relative humidity, and packaging (58). In the present research, no significant difference was found in adhesiveness by adding pomace powders, except in the APU-30 and APE-30 samples, with the highest level of adhesiveness. This finding was consistent with the research of Kırbaş *et al.* (51) since they found no significant difference in the addition of apple pomace in terms of adhesiveness.

4.7. Sensory characteristics

Consumers usually pay special attention to the sensory and visual characteristics of foods. Sensory analysis is an effective way to assess the acceptability of new food products. Our evaluation showed that the control sample had the highest score (4.57), but there was no significant difference between that and APU-10 or APE-10. In contrast, the APE-30 had the lowest score (3.72) due to the low score of APE-30 in appearance, texture, and taste parameters. The texture is an important characteristic and indicates the acceptability of the sensory quality of cakes. Based on the results, the control sample had no significant difference with APU-10 and APE-10 in texture scores. The aroma of the cakes enriched with APU-30, APE-30, and APE-20 had significantly lower scores than other samples ($p<0.05$). However, none of the panelists felt any aftertaste in sample APE-20. No significant difference was observed in the taste of the APU-10, APU-20, APE-10, and control samples. The evaluation showed that replacing a small amount of the wheat flour with APU or APE (10%) could improve the nutritional properties without significantly reducing the overall acceptance of the cake ($P>0.05$). These findings were consistent with the findings of some researchers (21, 17, 31) in different bakery products.

4. Conclusion

The results of this research demonstrated that a partial replacement of the wheat flour with apple pomace significantly increased the dietary fibers, especially insoluble fiber, compared to the control sample. The cakes prepared with APU-10 and APE-10 received the highest sensory scores after the control sample. APU and APE had the potential to use in the cake as a good source of dietary fibers.

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Ethical Guidelines

Ethics approval was not required for this research.

Conflict of Interest

The authors declare no conflict of interest for this work.

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