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Comparison of quality characteristics of muffins produced with einkorn, whole grain and white wheat flours

Siyez, tam buğday ve beyaz buğday unları ile üretilen muffin keklerin kalite karakteristiklerinin karşılaştırılması

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Abstract

In this study, the chemical, physical and sensory properties of muffin cakes produced with 100% white wheat flour (WWF), 100% whole grain einkorn flour (EF), a 50/50 blend of whole grain einkorn flour/whole grain wheat flour (E-WGWF), and 100% whole grain wheat flour (WGWF) were determined. The total and insoluble dietary fiber content, Ca, K, P, Mg and Mn content, total antioxidant activity values and total phenolic content of the muffins were increased by using EF and WGWF instead of white wheat flour. The muffins produced with EF had the highest protein content; the crumb color of the control muffin (C) was the lightest and yellowest, while the crumb color of the muffin produced with 100% WGWF (WGM) was the darkest and reddest. Volume index values, specific volumes, symmetry indexes and uniformity indexes of all muffins were similar. Muffins having 100% einkorn flour (EM) had the highest chewiness, gumminess, and hardness values. According to SEM micrographs, the WGM, EM and muffins produced with E-WGWF (E-WGM) had larger sized pores due to the higher amount of dietary fiber. While the C formulation received the highest scores for all sensory characteristics, the odor, flavor, and overall acceptability scores of all muffins were statistically (p>0.05) similar.

Keywords: Einkorn, white and whole grain wheat flours, Muffin, Chemical composition, SEM, Texture.

Öz

Bu çalışmada, %100 beyaz buğday unu (WWF), %100 tam tahıllı siyez unu (EF), 50/50 tam tahıllı siyez unu/tam tahıllı buğday unu (E-WGWF) ve %100 tam tahıllı buğday unu (WGWF) ile üretilen muffin keklerinin kimyasal, fiziksel ve duyusal özellikleri incelenmiştir. Beyaz buğday unu yerine EF ve WGWF unu kullanılmasıyla muffinlerin toplam ve çözünmeyen diyet lifi, Ca, K, P, Mg, Mn miktarları, toplam antioksidan aktivite değerleri ile toplam fenolik madde içeriklerinin arttığı tespit edilmiştir. EF ile üretilen keklerin en yüksek protein içeriğine sahip olduğu; kontrol kekin (C) iç rengi en açık ve en sarı iken, %100 WGWF (WGM) ile üretilen kekin iç renginin en koyu ve en kırmızı olduğu saptanmıştır. Tüm keklerin hacim indeks değerleri, spesifik hacimleri, simetri ve tekdüzelik indeksleri benzer bulunmuştur. %100 siyez unu (EM) içeren keklerin en yüksek çiğnenebilirlik yapışkanlık ve sertlik değerlerine sahip olduğu tespit edilmiştir. SEM mikrograflarında;, EM, WGM ve E-WGWF ile üretilen (E-WGM) keklerin, daha yüksek miktarda diyet lifi nedeniyle daha büyük boyutlu gözeneklerine sahip oldukları görülmüştür. Duyusal değerlendirmede, en yüksek puanları C örneği almış olsa da koku, tat ve genel kabul edilebilirlik bakımından tüm kekler istatistiksel olarak benzer (p>0.05) bulunmuştur.

Anahtar kelimeler: Siyez, beyaz ve tam tahıllı buğday unları, Muffin, Kimyasal kompozisyon, SEM, Tekstür.

1 Introduction

An ancient wheat einkorn (*Triticum monococcum*) has been cultivated for centuries in the North-Africa, Europe, Middle-East, and Central Asia. Today it still grows in marginal parts of Turkey, Europe, and the Caucasus. In recent years, it has gained popularity due to its resistance to disease and pests, its putative low allergenicity, its useful nutritional compound content of proteins, lysine, carotenoids and tocols [1],[2].

Einkorn grain has more proteins (10.3-25.2g/100 g), minerals (particularly calcium (170.0-1302.5 mg/kg), magnesium (369.1-1706.1 mg/kg), potassium (2493.0-6571.2 mg/kg)) and carotenoids (2.8-12.4mg/kg) compared to modern wheats [1],[3]-[6]. It also contains fewer α-amylase inhibitors than bread and durum wheat, and so its starch is consequently easier to digest and assimilate [2],[7]. Ancient wheat einkorn is a diploid-hulled wheat, having only the A genome. Triticum aestivum is a hexaploid species with three genomes (A, B and D), and species that have the D genome of wheat appear to exhibit average higher reactivity than wheats such as einkorn, emmer, and durum, to celiac disease [8],[9].

Einkorn is not safe for celiacs, but it may be less toxic than modern varieties for patients with gluten sensitivity or allergies. The studies for less toxic and/or naturally detoxified, ancient grains has garnered great interest due to their potential for use in diet, and for the prevention of disease in those at high risk of developing gluten intolerance [10],[11].

Although several studies have indicated that einkorn is a promising candidate for improving of foods, such as baked goods, pasta, and baby foods with high dietary fiber, carotenoids and tocol content, EF is often thought to have poor dough and baking qualities [1],[11]-[15]. The baking quality of wheat flour is mostly associated with its gluten quantity and quality [16]. The low gluten quality of einkorn flour is attributed to the disproportional 2:1 gliadin/glutenin ratio of einkorn wheats, while common wheat has a ratio of 1:1 [16],[17].

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Scientific studies have demonstrated that the regular consumption of whole grains and their products is related to a reduced risk of various types of chronic disease, such as some cancers, type 2 diabetes, and cardiovascular disease. Therefore, dietary modification through the increased daily consumption of a wide variety of whole grains, vegetables, and fruits can be considered a practical approach to the optimization of health and the reduction of the risk of chronic diseases [18],[19]. Whole grain wheat flour offers specific nutritional benefits compared to refined white wheat flour. Because some nutrients, such as fibers, proteins, vitamins, and minerals are retained in the germ and bran during milling [18],[20]. Using whole grain wheat flour instead of white wheat flour, however, can lead to undesirable problems in some properties, especially the rheological and color properties, of bakery products.

Nowadays consumer interest in bakery goods that offer health benefits as a result of their bioactive components is continuing. Beneficial results have been recorded in some studies of the use of einkorn flour and whole grain modern wheat flour in bakery products [11]-[15],[21], while there have been a lack of studies investigating the effects of using only EF or WGWF in muffins. In the present study, we use 100% EF and 100% WGWF in the production of muffin cakes to determine the influence of the different flours on certain chemical, physical and sensory properties of cakes. The cake is a commonly consumed bakery good, in which WWF, fat/oil, sugar, eggs, and baking powder are the main constituents [22]. If sensory acceptable muffin cakes enriched with bioactive components are obtained in the study, the use of only EF or only WGWF over WWF may be suggested to manufacturers for the production of products that meet the interests of consumers.

2 Material and methods

2.1 Materials

White wheat flour (*Triticum aestivum*) (Sinangil un), whole grain einkorn flour (*Triticum monococcum*) (Doğalsan), whole grain wheat flour (*Triticum aestivum*) (Bemtat un), sugar, eggs, baking powder, milk, and corn oil were obtained from markets in Denizli, Turkey.

2.2 Methods

2.2.1 Muffin cake production

Table 1 shows the muffin cake formulations. The production process of the muffins was carried out as reported previously by Topkaya and Isik [22].

Table 1. Muffin cake formulations.

Ingredients (g)	C	EM	E-WGM	WGM
WWF	100.0	-	-	-
EF	-	100.0	50.0	-
WGWF	-	-	50.0	100.0
Egg	78.1	78.1	78.1	78.1
Sugar	66.7	66.7	66.7	66.7
Corn oil	47.0	47.0	47.0	47.0
Milk	20.0	20.0	20.0	20.0
Baking powder	5.7	5.7	5.7	5.7

WWF: White wheat flour, EF: Whole grain einkorn flour, WGWF: Whole grain wheat flour, C: Control muffin cake having 100% white wheat flour, EM: Muffin cake having 100% einkorn flour, E-WGM: Muffin cake having 50% einkorn flour and 50% whole grain wheat flour, WGM: Muffin cake having 100% whole grain wheat flour.

Firstly, eggs and sugar were whipped into a cream in a kitchen robot (Kenwood KMM060, UK) with a mixer function at a maximum speed for 5 min. Then, corn oil and milk were added and mixed for 1 min. at a medium speed. At last, flour and baking powder were added, and the mixture was whipped at minimum speed for a minute. 50g of this cake batter was poured into nonstick muffin pans and baked at 170°C for 23 min in an oven (Ozkoseoglu Oven, Turkey).

2.2.2 Proximate analysis

The ash (Method 942.05), protein (Method 988.05), fat (Method 954.02) and moisture (Method 934.01) contents were measured by AOAC approach [23]. The total dietary fiber (TDF) analysis was conducted using a Megazyme TDF kit (Megazyme Int., Ireland) in line with the AACC Method 32-07 [24] and AOAC Method 991.43 [25] approaches.

Carbohydrate content and caloric values were calculated using the following equations:

$$Carbohydrate\ (\%) = 100 - (Moisture + Protein + Fat + Ash + TDF)$$

$$Caloric\ Value\ (kcal/100g) = (Carbohydrates \times 4) + (Proteins \times 4) + (\ Fat \times 9)$$

2.3 Mineral matter composition

The mineral matter compositions were determined according to Turk Aslan and Isik [26]. 6 mL of HNO_3 and 2 mL of H_2O_2 were added to 0.5 g of samples. The mixture was left to stand for 30 minutes and in microwave method of wet decomposition was fulfilled. Samples burnt in microwave were filtered through filter paper and the mineral elements (P, K, Ca, Mg, Mn, Zn, Fe) in filtrate were analyzed by an ICP-OES (Perkin Elmer, Optima 2100 DV, Massachusetts, US).

2.3.1 Total antioxidant activity and total phenolic content

The phenolic compounds of the flours and muffins were extracted according to Ozgoren et al. [27]. For the extraction of phenolic compounds, 1 g homogenized sample was weighed. After adding 10 ml methanol (70:30 v/v), the mixture was sonicated for 10 min in an ultrasonic bath (E 60 H Model, Elma Co., Germany) and shaken in a mechanical shaker (WiseShake SHO-1D, Wertheim, Germany) for 15 min. Then, the mixture was centrifuged (NF 1200 R, Nuve, Turkey) at 8500g at 4 °C for 20 min. After centrifugation, the supernatant was collected for the total phenolic content and antioxidant activity analysis.

The total phenolic content was analyzed in accordance with the approach described by Singleton et al. [28] using a Folin-Ciocalteu assay. 1 mL of extract was mixed with 5 mL of 1:10 (v/v) Folin-Ciocalteu reagent: water mixture and then 4 mL of 75g/L Na_2CO_3 was added. Then the mixture was vortexed and incubated for 2 hours in the dark at room temperature. After incubation, the absorbance of the mixture was measured by a spectrophotometer (T80 UV/VIS Spectrometer, PG Instruments Ltd., Leicestershire, United Kingdom) at 760 nm. Gallic acid was used as a standard to produce the calibration curve.

2.2-Diphenyl-1-picrylhydrazyl (DPPH) method was used for the total antioxidant activity measurement [29]. The stock solution was prepared by dissolving 24 mg DPPH with 100mL methanol. The working solution was obtained by mixing stock solution with methanol to obtain an absorbance of 1.10± 0.02 units at 515 nm using the spectrophotometer. Sample extracts (150µL) were mixed with 2850µL of the DPPH working solution and incubated for 1 h in the dark at room temperature.

Then the absorbance was taken at 515 nm. Trolox was used as a standart to produce the calibration curve.

2.3.2 Physical properties

A Hunter Lab Miniscan XE colorimeter (Hunter Associates Laboratory, Reston, VA) was used to measure the crumb and crust colors of the muffins. The color values were expressed as L^* (whiteness/darkness), a^* (redness/greenness) and b^* (yellowness/blueness).

And also, the total color differences (ΔE) were calculated as follows;

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2} + (\Delta b)^2$$

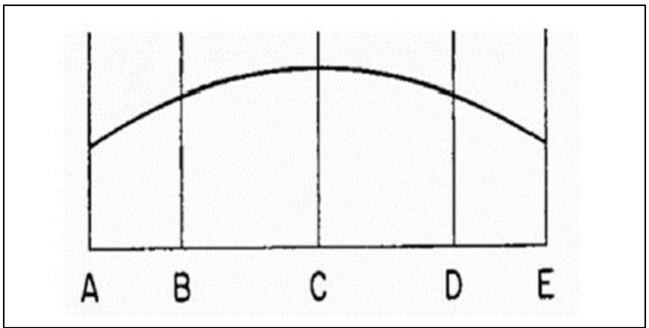
$$Where;$$

$$\Delta L = L * sample - L * control$$

$$\Delta a = a * sample - a * control$$

$$\Delta b = b * sample - b * control$$

The volume of the muffin samples was identified through the rapeseed displacement method, while the specific volume was determined from the cake volume/weight ratio. The volume, symmetry and uniformity index were measured using a plastic measuring template, following AACC method 10-91 [30]. These index values were determined using the following equations:



$$Volume\ index = B + C + D; Symmetry\ index = 2C - B - D$$

$$Uniformity\ index = B - D$$

Brookfield CT3 Texture Analyzer (Brookfield Engineering Laboratories Inc., USA) was used for texture profile analysis (TPA). 2 Hours after baking, cakes with a diameter of 60 mm were cut parallel to the ground at a height of 20 mm. A 38.1 mm diameter cylindrical probe (TA4/1000) was used to determine the hardness, chewiness, gumminess, cohesiveness, springiness, and adhesiveness values of the muffin cakes. Muffin cakes were compressed to 50% of their original height. The texture analyzer was set at trigger load, pre-test speed and test speed of 4.5 g, 2 mm/s and 1mm/s, respectively.

2.3.3 Microstructure properties

Freeze-dried muffin cake samples were coated with gold palladium and microstructure was monitored as described by Ozgoren et al. [27]. Micrographs were taken at 250x magnification.

2.3.4 Sensory properties

The muffin cakes were evaluated for crust color, crumb color, pore structure, odor, flavor, chewiness and overall acceptability by 48 untrained panelists (10 male; 38 female) from Pamukkale University using a 7-point hedonic scale (1= dislike extremely, 7= like extremely).

2.3.5 Statistical analysis

All data were analyzed with a one-way ANOVA in IBM SPSS Statistics (Version 22.0. Armonk, NY: IBM Corp.). Duncan's multiple range test was used to determine the differences among the treatment means at $p<0.05$.

3 Results and discussion

3.1 Chemical and physical properties of raw materials

The chemical, nutritional and physical properties of WWF, EF and WGWF are given in Table 2.

According to the results, EF has the highest values for protein, fat, soluble dietary fiber, ash, P, Ca, Mg, Zn, total antioxidant activity and total phenolic content; WGWF has the highest insoluble dietary fiber, total dietary fiber, K, Mn and Fe content; and WWF has the highest moisture and carbohydrate content and energy value. In previous studies on EF, it was reported that EF contains 10.30-25.20% protein, 2.80-4.20% fat, 1.70-2.80% ash and 8.20-11.00% total dietary fiber [1],[11],[15],[16],[31]. The protein and fat results in the present study were similar to those reported in literature, while our ash and total dietary fiber results were a little lower. The small differences can be attributed to such factors as genetic composition, agricultural practices (such as fertilization), climate, geochemistry, and geography [32].

The results of other studies [2],[33] also reveal EF and WGWF to have higher mineral matter and total phenolic content, and higher antioxidant activity values than WWF, concurring with the results of the present study. The production of commercial WWF from kernels implies the elimination of bran and germ, thus lowering the mineral and natural antioxidant content [21],[34].

It has been stated [2],[31] that einkorn grain has a lower total and insoluble dietary fiber content than other cultivated wheats, and the results of the present study concur, indicating that WGWF produced from cultivated wheat has higher insoluble and total dietary fiber content than EF. The present study also revealed that EF had a higher insoluble and total dietary fiber content than WWF, which can be attributed to the low bran content of WWF, which is a refined flour, and the high bran content of EF, which was ground in a stone mill in Turkey. The L^* (lightness) value of WWF was higher than that of other flours, followed by EF and WGWF, respectively, while WGWF had the highest a^* value and WWF had the highest b^* value (Table 2). The difference in the color in the flours is linked primarily to the type and content of pigment compounds present, as well as on the ratio of endosperm to bran [35]. Consistent with this study Hidalgo et al. [36] also found that whole grain einkorn flour (*Tr. monococcum*) had higher L^* and b^*, lower a^* values than whole grain bread wheat flour (*Tr. aestivum*).

3.2 Chemical properties of muffin cakes

3.2.1 Proximate compositions of muffin samples

Table 3 presents some chemical properties of the muffin samples. Although there were differences in the crude fat, soluble dietary fiber, carbohydrate content and caloric values of the cakes, the differences were not statistically significant ($p>0.05$). The C sample contained significantly ($p<0.05$) lower insoluble and total dietary fibers than the other samples, most likely because the WWF used in the C had lower insoluble and total dietary fiber contents (Table 2).

Table 2. Some properties of WWF, EF and WGWF.

	WWF	EF	WGWF
Moisture (%)	10.46±.08^{a}	8.16±0.22^{b}	8.01±0.19^{b}
Crude protein (%)[1]	9.67±0.08^{c}	13.31±0.07^{a}	10.05±0.05^{b}
Crude fat (%)[1]	1.50±0.26^{b}	2.94±0.06^{a}	2.50±0.03^{a}
Total dietary fiber (%)[1]	2.59±0.27^{c}	6.95±0.30^{b}	10.26±0.09^{a}
Soluble dietary fiber (%)[1]	1.25±0.07^{b}	2.85±0.08^{a}	2.74±0.08^{a}
Insoluble dietary fiber (%)[1]	1.34±0.20^{c}	4.10±0.22^{b}	7.52±0.17^{a}
Crude ash (%)[1]	0.45±0.07^{c}	1.34±0.01^{a}	1.09±0.01^{b}
Carbohydrate (%)[1]	75.34±0.63^{a}	67.32±0.22^{b}	68.11±0.11^{b}
Caloric value (kcal/100g) [1]	353.48±0.18^{a}	348.96±0.08^{b}	335.12±0.51^{c}
Mg (mg/kg) [1]	273.74±12.42^{c}	970.36±17.08^{a}	885.19±15.20^{b}
Ca (mg/kg) [1]	190.86±6.35^{c}	396.05±7.00^{a}	365.73±10.08^{b}
K (mg/kg) [1]	1428.01±59.10^{b}	3174.49±38.81^{a}	3308.76±71.81^{a}
P (mg/kg) [1]	1326.51±53.23^{c}	3243.17±57.86^{a}	3011.40±86.27^{b}
Mn (mg/kg) [1]	2.74±0.13^{b}	11.68±0.69^{a}	12.07±0.21^{a}
Zn (mg/kg) [1]	2.42±0.03^{b}	10.59±0.94^{a}	8.77±0.64^{a}
Fe (mg/kg) [1]	15.68±1.21^{b}	53.05±2.80^{a}	60.71±2.96^{a}
Total phenolic content (mg GAE/100g) [1]	56.20±2.32^{b}	66.98±1.34^{a}	62.82±3.82^{ab}
Total antioxidant activity values (µmol TE/100g) [1]	2.15±0.16^{c}	49.45±6.17^{a}	23.29±5.06^{b}
Hunter color values			
*L**	91.33±0.63^{a}	90.12±0.25^{a}	83.83±1.03^{b}
*a**	4.13±0.13^{b}	5.94±0.37^{a}	6.02±0.69^{a}
*b**	5.33±0.18^{a}	4.88±0.23^{a}	4.69±0.37^{a}

WWF: White wheat flour, EF: Whole grain einkorn flour, WGWF: Whole grain modern wheat flour.[1]: In wet basis. The same superscript letters within the same row are not statistically different(p>0.05).

Table 3. Basic chemical compositions of muffins.

Parameter	C	EM	E-WGM	WGM
Moisture	20.34±0.42 ^{a}	16.55±0.30 ^{b}	15.60±0.26 ^{b}	16.45±0.47 ^{b}
Crude protein (Nx5.7) (%)[1]	6.64±0.17 ^{c}	8.66±0.01 ^{a}	7.98±0.13 ^{b}	7.36±0.08 ^{b}
Crude fat (%)[1]	21.91±1.13 ^{a}	23.96±2.32 ^{a}	23.65±1.48 ^{a}	23.24±2.46 ^{a}
Total dietary fiber (%)[1]	2.19±0.24 ^{c}	4.48±0.46 ^{b}	5.32±0.44 ^{ab}	6.21±0.53 ^{a}
Soluble dietary fiber (%)[1]	1.15±0.07 ^{a}	1.90±0.21 ^{a}	1.83±0.21 ^{a}	1.77±0.28 ^{a}
Insoluble dietary fiber (%)[1]	1.04±0.31 ^{c}	2.58±0.25 ^{b}	3.49±0.23 ^{ab}	4.44±0.25 ^{a}
Crude ash (%)[1]	1.51±0.06 ^{b}	1.70±0.06 ^{a}	1.66±0.01 ^{a}	1.62±0.04 ^{ab}
Carbohydrate (%)[1]	47.41±1.68 ^{a}	44.65±2.11 ^{a}	45.79±1.92 ^{a}	45.12±1.78 ^{a}
Caloric Value (kcal/100g) [1]	413.39±2.77 ^{a}	428.94±12.47 ^{a}	427.97±4.59 ^{a}	419.14±16.46 ^{a}

C: Control muffin cake having 100% WWF, EM: Muffin cake having 100% EF, E-WGM: Muffin cake having 50% EF and 50% WGWF, WGM: Muffin cake having 100% WGWF.[1]: In wet basis. The same superscript letters within the same row are not statistically different (p>0.05)

Goranova et al. [12] found that sponge cake made with 50% einkorn wholemeal flour contained larger quantities of insoluble and total dietary fiber than the control cake produced with white wheat flour. Similarly, Van Boxstael et al. [37] reported that bread produced with whole grain wheat (*Tr. aestivum*) flour had a greater insoluble and total dietary fiber content than bread produced with whole grain einkorn wheat flour, while similar fiber content changes were reported for some cereal foods by Sidhu et al. [33] and Karnopp et al. [38].

Rich dietary fiber intake reduces the risk of developing the diseases such as; obesity, gastrointestinal disorders, stroke, coronary heart disease, hypertension, and diabetes. The dietary fiber intake recommendations for adults generally fall in the range of 20-35 g/day [22]. Assuming that a person should take 27.5 g of dietary fiber per a day, the consumption of 100 g of EM, E-WGM or WGM would satisfy 18.28%, 19.38% or 22.55% of their daily needs, respectively, while a person consuming 100g of C muffin cake would satisfy 8.00% of these needs. It can thus be concluded that the consumption of cakes containing EF and WGWF will better fulfil dietary fiber requirements.

EM had a significantly higher protein content than the other muffins in the study, most likely because EF has a higher protein content than WWF and WGWF (Table 2). Proteins are the most important components of tissues in animals and humans and are an essential part of a healthy diet [39]. Their function in nutrition is to supply sufficient quantities of the amino acids required for the metabolism, and so the consumption of bakery products with a high protein content contributes to health. In the present study, the EM samples had the highest protein content, 1.30, 1.09 and 1.18 times that of C, E-WGM and WGM respectively. Products prepared with einkorn flour with a higher protein content than those prepared with white wheat flour were also reported in Van Boxstael et al. [37] and Levent [15].

3.2.2 Mineral compositions of muffin samples

Minerals are essential for both physiologic and metabolic processes for human including acid base balance of the blood, nerve impulse conduction, enzyme activation, muscle contraction, bone health, normal heart rhythm, oxidative phosphorylation, oxygen transport, antioxidant activity and immune function [40]. Significant (p <0.05) increases were found for Ca, K, Mg, P, Mn and Fe contents of muffin cakes due to the usage of EF and WGWF in the formulation (Table 4).

An adult needs approximately 800 mg P, 2000 mg K, 1000 mg Ca, 370 mg Mg, 9 mg Fe and 2 mg Mn per day [39]. According to our calculations, the consumption of 100g of C, EM, E-WGM and WGM meets 3.2, 4.4, 4.3 and 4.1, % of daily adult Ca needs, respectively.

Table 4. Mineral contents of muffins.

Minerals (ppm)[1]	C	EM	E-WGM	WGM
Ca	316.31±8.91 [b]	440.19±15.03 [a]	429.79±24.14 [a]	406.44±17.51 [a]
K	1311.32±30.12 [b]	2234.98±201.92 [a]	1922.55±106.87 [a]	2106.27±275.96 [a]
Mg	285.40±31.68 [c]	588.75±53.78 [a]	464.70±45.47 [b]	441.60±24.81 [b]
P	2226.90±179.46 [c]	3823.45±112.92 [a]	3523.85±173.74 [ab]	3299.35±88.60 [b]
Mn	2.91±1.27 [b]	9.15±1.06 [a]	8.05±0.78 [a]	8.63±0.81 [a]
Zn	3.82±2.97 [a]	6.50±2.69 [a]	4.60±1.70 [a]	4.65±1.91 [a]
Fe	14.01±2.83 [b]	28.70±3.25 [a]	24.65±2.47 [a]	22.70±1.13 [a]

C: Control muffin cake having 100% WWF, EM: Muffin cake having 100% EF, E-WGM: Muffin cake having 50% EF and 50% WGWF, WGM: Muffin cake having 100% WGWF. [1]: in wet basis, The same superscript letters within the same row are not statistically different (p>0.05).

Other mineral calculations of C, EM, E-WGM and WGM are as follows, respectively: 6.6%, 11.2%, 9.6%, and 10.5% for K; 7.7%, 15.9%, 12.6% and 11.9% for Mg; 27.8%, 47.8%, 44.0% and 41.2% for P; 14.5%, 45.5%, 40.0% and 43.0% for Mn; and 15.6%, 31.9%, 27.3% and 25.2% for Fe. Based on the results, the samples produced with EF and WGWF better meet the mineral needs of consumers other than for Zn.

Similar results were found for the other studies that mineral compositions of products prepared with supplementation of einkorn flour studied. In Levent [15]; Ca, Fe, Cu and Mg contents of noodle samples increased 1.41, 3.27, 1.45 and 2.66 times at 100% einkorn flour compared to control sample prepared with white flour. Van Boxstael et al. [37] determined that breads produced with whole grain einkorn flour had higher K, Ca, Mg, P, Fe, and Zn contents than breads produced with modern whole grain flour. In the present study, EM had significantly ($p<0.05$) higher Mg, and P contents than WGM, in addition their other mineral contents were similar.

3.2.3 Total phenolic contents and antioxidant activity values of muffin samples

In the present study, EM, E-WGM and WGM recorded significantly ($p<0.05$) higher antioxidant activity values and total phenolic contents than C (Table 5), which is thought to be related to the higher antioxidant activity values and total phenolic content of EF and WGWF (Table 2). As known, EF and WGWF used in the study were whole grains, and whole grains include many antioxidants like trace minerals, vitamins, phenolic acids, phytoestrogens, lignans, phytic acid, etc. [34]. Li et al. [41] found that noodles and steamed breads made from whole and partially debranned wheat flours of different colored wheats had higher total phenolic contents, total flavonoid contents and antioxidant activities than products made from white wheat flour. Levent [15] prepared noodles after replacing white wheat flour with einkorn flour in different ratios (0, 20, 40, 60, 80, 100%) and found that the total phenolic content and antioxidant activity values of the noodles increased with the increasing einkorn flour levels.

In Yu et al. [42], total phenolic contents of breads prepared with whole grain flours were between 1.50-1.65 mg equivalent of ferulic acid/g while total phenolic contents of breads prepared with white flour were between 0.79-1.03 mg equivalent of ferulic acid/g. In the study, whole wheat flour breads also showed significantly ($p<0.05$) higher antioxidant activity values than white flour, which concurs with the results of the present study.

3.3 Physical properties of muffin samples

3.3.1 Color values of muffin samples

In general, the crumb color of cakes is affected by the ingredients in the formulation, and the crust color is affected by the Maillard and caramelization reactions that occur during baking [43]. In the present study, the crumb color of C was the lightest and yellowest, while the crumb color of WGM was the darkest and reddest (Table 6), and these results are compatible with the color values of the flours used in the muffins (Table 2). Compatible with the highest crumb b^* value, C had also the highest crust b^* value, while in contrast to the lowest crumb a^* value, C recorded the highest crust a^* value (Table 7). The highest crust a^* value of C may be related to its greater exposure to the Maillard reaction and sugar caramelization during baking due to the highest carbohydrate content (Table 2) of WWF [22],[43]. Majzoobi et al. [44] reported that their control cake had a higher crumb and crust a^* and L^* values than the cakes containing oat fiber, and as the amount of oat fiber increased, the a^* and L^* values decreased. In contrast to this result, b^* value was increased by the increase in oat fiber content in the study. Singh et al. [45] found that increasing the corn bran content in cake formulations decreased the crust a^* and b^* values and reported out corn bran did not interfere in the Maillard reaction responsible for crust color.

According to Yamauchi [46], ΔE values of the crumb colors of E-WGM and WGM can be classified as "another color group" while the classification of the crumb color of EM and crust color of all muffins were "large difference in the same color group".

3.3.2 Specific volume, and uniformity, symmetry, volume index values of muffin cakes

The specific volume, uniformity, symmetry, and volume index values all give information about degree of swelling of muffin doughs, and the volumes and shapes of the produced muffins. In the present study, in spite of the higher specific volume and volume index values of the C sample, the muffins recorded statistically similar ($p>0.05$) specific volume, uniformity, symmetry, and volume index values (Table 8). These results indicate that the use of EF and WGWF can be used successfully in terms of the resulting volume and shape of the cakes. Schmiele et al. [20] found that replacing wheat flour with whole grain wheat flour and wheat bran decreased the specific volume in bread production, which the researchers attributed to the dilution of the gluten and weakening of the formed gluten network. This contradicts findings of the present study, which is thought to be attributable to the egg used in the formulation of the cakes. The contradicts findings of Schmiele et al. [20] with this study is thought to be attributable to the egg used in the formulation of the cakes.

Table 5. Total antioxidant activity and total phenolic content of muffins.

Sample	Total antioxidant activity (µmol TE/ 100g)[1]	Total phenolic content (mg GAE/ 100g)[1]
C	6.05±1.15 b	35.82±3.17 b
EM	21.89±0.64 a	59.94±1.16 a
E-WGM	21.40±4.36 a	57.96±2.18 a
WGM	19.13±2.53 a	54.35±3.61 a

C: Control muffin cake having 100% WWF, EM: Muffin cake having 100% EF, E-WGM: Muffin cake having 50% EF and 50% WGWF, WGM: Muffin cake having 100% WGWF. [1]: In wet basis. The same superscript letters within the same column are not statistically different (p>0.05).

Table 6. Crumb color values of muffins.

Sample	Crumb color			
	L*	a*	b*	ΔE
C	78.00±0.28 a	9.41±0.41 b	29.47±0.73 a	
EM	70.48±0.74 b	9.61±0.46 b	26.88±1.28 ab	8.09±0.22c
E-WGM	66.30±0.06 c	11.04±0.36 a	25.08±1.27 b	12.66±0.91b
WGM	63.28±0.73 d	11.89±0.50 a	23.81±0.98 b	16.01±0.18a

C: Control muffin cake having 100% WWF, EM: Muffin cake having 100% EF, E-WGM: Muffin cake having 50% EF and 50% WGWF, WGM: Muffin cake having 100% WGWF. The same superscript letters within the same column are not statistically different (p>0.05).

Table 7. Crust color values of muffins.

Sample	Crumb color			
	L*	a*	b*	ΔE
C	54.02±1.44 ab	23.77±0.10 a	35.52±0.61 a	
EM	56.83±2.23 a	19.07±0.20 c	30.40±0.07 b	7.51±0.85a
E-WGM	53.52±0.04 ab	19.27±0.18 bc	29.63±0.30 b	7.50±0.98 a
WGM	50.34±0.64 b	19.61±0.10 b	30.04±0.69 b	7.88±1.88 a

C: Control muffin cake having 100% WWF, EM: Muffin cake having 100% EF, E-WGM: Muffin cake having 50% EF and 50% WGWF, WGM: Muffin cake having 100% WGWF. The same superscript letters within the same column are not statistically different (p>0.05).

Table 8. Volume and shape characteristics of muffins.

Sample	Specific volume (mL/g) *	Uniformity index (mm)	Symmetry index (mm)	Volume index (mm)
C	2.46±0.03 a	2.40±0.85 a	8.70±2.41 a	132.00±5.66 a
EM	2.44±0.06 a	2.00±0.01 a	11.00±2.83 a	127.00±1.41 a
E-WGM	2.44±0.01 a	3.00±0.71 a	14.00±4.24 a	126.00±2.83 a
WGM	2.43±0.04 a	2.75±0.35 a	10.50±2.83 a	124.00±1.41 a

C: Control muffin cake having 100% WWF, EM: Muffin cake having 100% EF, E-WGM: Muffin cake having 50% EF and 50% WGWF, WGM: Muffin cake having 100% WGWF. The same superscript letters within the same column are not statistically different (p>0.05).

In the production of cakes, egg proteins play an important role alongside gluten in the volume characteristics of cakes. Egg proteins (ovomucin, ovalbumin, ovotransferrin, globulins, lysozyme, etc.) are the essential components to gain foam formation and stabilization in cake mix through the immediate conformational regulation and following film formation around the gas cells. Interactions between the different egg white proteins, such as lysozyme-ovomucin or ovotransferrin-ovalbumin interactions can also enhance foam stability. During the final stages of baking, the liquid batter transforms into a solid foam as a result of both starch gelatinization and egg protein coagulation [47].

Similar results were found by Gómez et al. [48] for specific volume and volume index values. In Gómez et al. [48], cakes produced with whole grain wheat flour had statistically similar specific volume and volume index values with cakes produced with white wheat flour. But in contrary to our result, cakes produced with white wheat flour had statistically higher symmetry index value than the cake produced with whole wheat flour.

3.3.3 Textural properties of muffin samples

In texture analysis, EM sample had a significantly higher hardness value (Table 9) than the other samples, one reason for which may be the higher protein content of EM (Table 3) and its interaction during dough development and baking. During baking of the cakes, the structure is formed by the result of protein network formation and starch gelatinization [43],[49]. Another reason for the highest hardness value being recorded for EM may be related to the high dietary fiber content of the resulting cakes. Dietary fiber can impart some functional properties into foods, such as increasing oil and water holding capacity and encouraging emulsification and/or gel formation, and modify the textural properties of bakery goods, dairy products, soups, meats and jams [50]. The use of WGWF also increased hardness value in muffins due to its higher dietary fiber content than WWF.

Gumminess is calculated by multiplying cohesiveness and hardness. Chewiness is calculated by multiplying springiness and gumminess, and it gives the energy amount needed to masticate a food. There was a linear relationship between the gumminess, chewiness and hardness values of the samples. The C sample prepared with WWF had significantly lower values than the muffins produced with whole grain flours, and these results concur with the findings of Gómez et al. [48],[51]. In Gómez et al. [48] whole grain (wheat, rye, triticale, barley, tritordeum) flour cakes recorded higher hardness and chewiness values than white flour cakes, while Gómez et al. [51] reported that sponge cakes produced with chickpea whole flours had higher hardness, gumminess and chewiness scores than those produced with white wheat flour. In Ateş and Elmacı [52], substitution (20, 25, 30%) of wheat flour by coffee silverskin, a by-product which has high fiber content, also increased hardness and chewiness values of cakes.

Table 9. Textural properties of muffins.

Muffin Cake Sample	Hardness (g)*	Springiness (mm)	Adhesiveness (mJ)	Cohesiveness	Gumminess (g)	Chewiness (mJ)
C	1259.5±135.8 [c]	8.08±0.11 [a]	0.04±0.01 [a]	0.52±0.04 [a]	647.1±48.15 [d]	51.20±5.40 [d]
EM	2498.0±5.66 [a]	8.30±0.17 [a]	0.05±0.03 [a]	0.56±0.06 [a]	1370.43±49.25 [a]	111.55±4.52 [a]
E-WGM	1854.3±109.6 [b]	8.34±0.11[a]	0.03±0.01 [a]	0.57±0.03 [a]	1040.95±23.26 [b]	85.13±2.43 [b]
WGM	1415.13±79.7 [c]	8.07±0.06 [a]	0.02±0.01 [a]	0.60±0.02 [a]	842.23±72.58 [c]	66.50±5.35 [c]

C: Control muffin cake having 100% WWF, EM: Muffin cake having 100% EF, E-WGM: Muffin cake having 50% EF and 50% WGWF, WGM: Muffin cake having 100% WGWF flour. The same superscript letters within the same column are not statistically different (p>0.05).

In addition, in the study of Singh et al. [45] in which wheat flour was substituted by corn bran in various ratios (5- 30%) during cake production, the samples with corn bran ratios higher than 20% had significantly higher hardness values than the control group. In Aydogdu et al. [53] hardness of cakes increased as fiber (oat, pea, apple, lemon) concentrations (5%, 10%) substituted to wheat flour increased.

3.4 SEM results

Scanning electron microscopy micrographs provide a detailed image of the internal geometrical structures and surface structures of foods [27],[54]. Scanning electron microscopy micrographs of the internal cross-sectional area of the muffin samples are presented in Figure 1.

In the cross-section micrograph of the C sample, a gelatinized starch and continuous gluten matrix were observed, as reported also by Kaur and Kaur [55]. Starch acts as a filler in the gluten matrix and it plays a crucial role in the structure of dough. The gluten matrix of muffins was disrupted with the addition of whole grain flours. As seen in the EM, WGM and E-WGM micrographs, the samples contain larger pores due to the greater amount of dietary fiber, and similar results have been observed in previous studies in which flaxseed and fruit pomaces were included in the cake formulation [55],[56].

3.5 Sensory properties

Sensory evaluation results give information about consumer preference, and they are very important for the studies on product development. The odor, flavor and overall acceptability scores of the cakes were statistically similar (p>0.05). The C sample had significantly (p<0.05) the highest crust color, pore structure and chewiness scores, and received the highest crumb color score, although it was statistically similar (p>0.05) to the EM and E-WGM samples (Figure 2). In other studies, about developing bakery products with einkorn flour, the products got also the scores above moderate level in general.

In Levent and Aktaş [14], cakes in which wheat flour was substituted with 10, 20 and 30% einkorn flour recorded similar taste, texture and chewiness scores as the control cake. Furthermore, those containing 20 and 30% einkorn flour also recorded higher (p<0.05) overall acceptability scores than the control cakes. Goranova et al. [12] compared the sensory properties of cakes produced with wheat flour by the cakes whose wheat flour had been replaced by 35% of cocoa husks powder, 20% of Jerusalem artichoke powder and 50% of einkorn wholemeal flour. The highest overall acceptability score was taken for the cake produced with 50% einkorn wholemeal flour. In Nakov et al. [57], biscuits made from 100% wheat flour scored the highest for quality (4.46/5.00), and the scores decreased as the einkorn flour percentage in the formulation increased. The biscuits containing 100% einkorn flour scored 3.97/5.00 in terms of quality. Lomolino et al. [58] found that the flavor and color parameters of breads prepared with einkorn flour were more intense than those prepared with wheat flour. In Levent [15], traditional Turkish noodles were produced by the substitution of wheat flour with einkorn wheat flour at 0, 20, 40, 60, 80 and 100% levels, and the sensory characteristics of uncooked and cooked noodles were determined. In the study, it was found that the appearance, surface smoothness, speck, and overall acceptability scores of uncooked noodles had been decreased with 80% and 100% einkorn wheat flour supplementation. For the cooked noodles; odor, taste, stickiness, and overall acceptability scores were similar up to 100% einkorn wheat flour substitution. But chewiness score of the cooked sample having 100% einkorn wheat flour was statistically different and lower from control sample.

4 Conclusions

In the study, EF and WGWF usage improved the dietary fiber and total phenolic content, as well as the total antioxidant activity, K, Ca, Mg, P and Mn of the muffin samples. The addition of EF also improved protein content. In spite of the changes noted in some physical properties, such as increases in hardness, gumminess and chewiness, and decreases in the volume index and the brightness of the crumb color with the addition of EF and WGWF, these cakes were liked similarly in terms of odor, flavor and overall acceptability in the sensory evaluation. It can be concluded from the results of this study that 100% EF, 100%WGWF and 50/50% EF-WGWF may be used instead of WWF for the production of muffin cakes enriched with bioactive components.

5 Sonuçlar

Çalışmada, EF ve WGWF kullanımının muffin kek örneklerinde diyet lifi ve toplam fenolik madde içeriğinin yanı sıra toplam antioksidan aktivite, K, Ca, Mg, P ve Mn içeriklerini de arttırdığı tespit edilmiştir. EF'nin eklenmesi ayrıca protein içeriğini de yükseltmiştir. EF ve WGWF ilavesi ile keklerin fiziksel özelliklerinden sertlik, yapışkanlık ve çiğnenebilirlikte artış ile hacim indeksi ve iç renk açıklık değerlerinde azalma tespit edilmiş olsa da duyusal analizde kekler koku, lezzet ve genel kabul edilebilirlik açısından benzer bulunmuşlardır. Bu çalışmanın sonuçlarından biyoaktif bileşenlerle zenginleştirilmiş muffin keklerinin üretiminde WWF yerine %100 EF, %100WGWF ve %50/50 EF-WGWF’nun kullanılabilecekleri sonucuna varılabilir.

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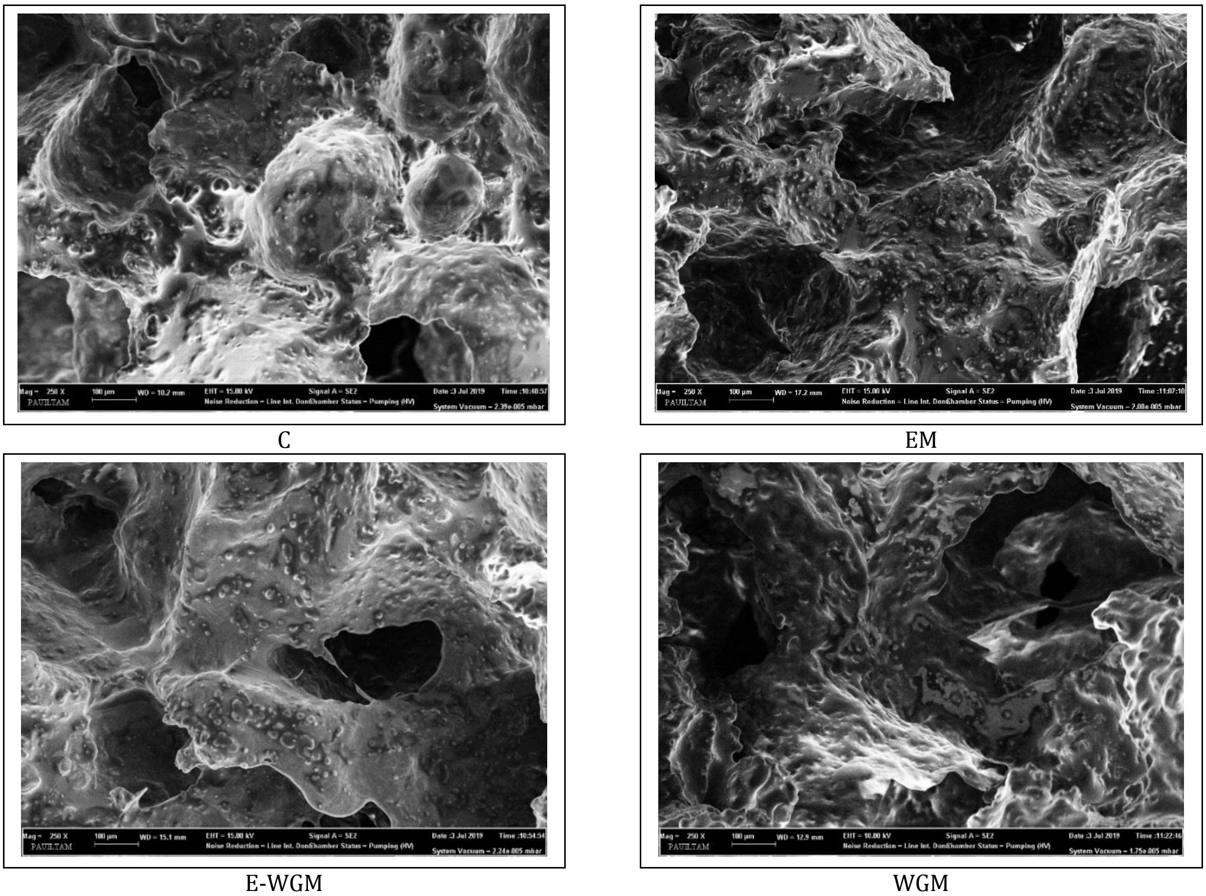
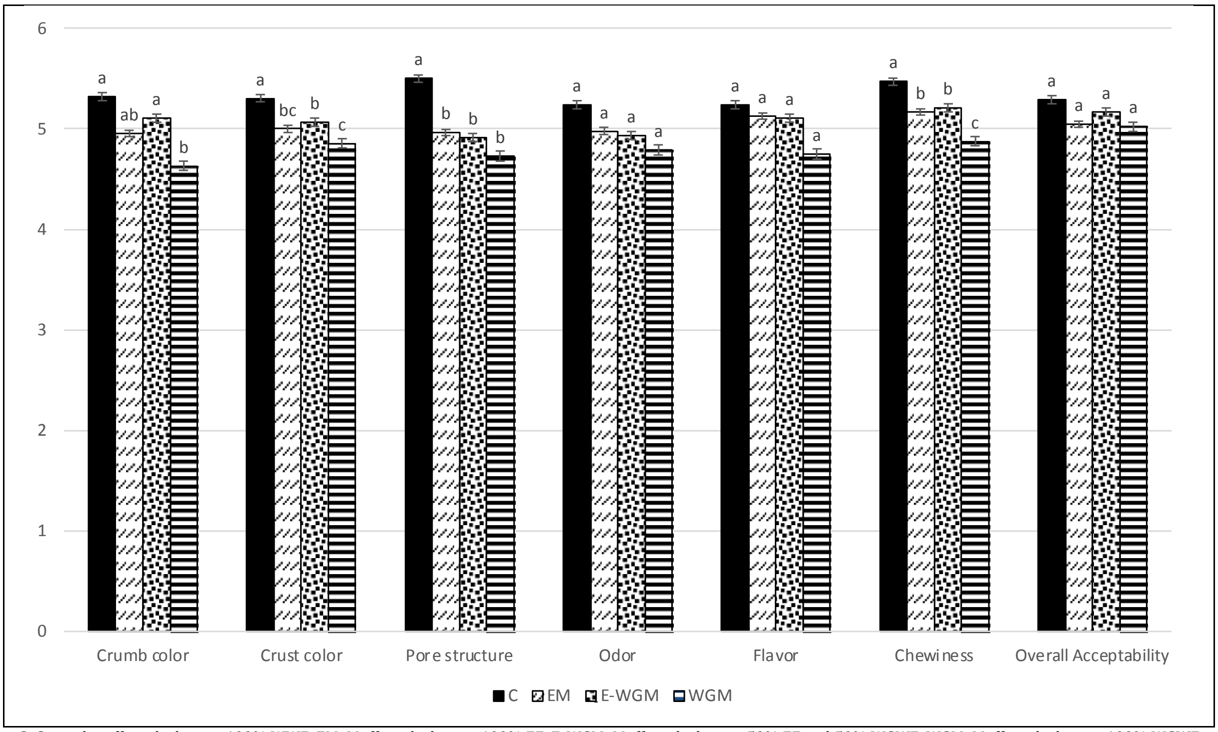


C: Control muffin cake having 100% WWF, EM: Muffin cake having 100% EF, E-WGM: Muffin cake having 50% EF and 50% WGWF, WGM: Muffin cake having 100% WGWF flour.

Figure 1. SEM micrographs of muffin samples at 250x magnification.



C: Control muffin cake having 100% WWF, EM: Muffin cake having 100% EF, E-WGM: Muffin cake having 50% EF and 50% WGWF, WGM: Muffin cake having 100% WGWF flour. The same superscript letters are not statistically different (p>0.05).

Figure 2. The sensory scores of muffin cake samples.

7 Author contributions

Fatma ISIK, Project administration, writing - original draft (lead), methodology, writing-review & editing, laboratory analysis. Ezgi OZGOREN, Writing-original draft, software, data curation, laboratory analysis. Yagmur SOLA, Production of muffins, laboratory analysis.

8 Ethics committee approval and conflict of interest statement

The article does not require permission from the ethics committee. There is no conflict of interest with any person/institution in the article prepared.

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