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# Effects of Lentil Flour on the Quality of Gluten-free Muffins

## Mercimek Unu Kullanımının Glutensiz Kek Kalitesi Üzerine Etkileri

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### Abstract

The purpose of this study was to develop a gluten-free muffin recipe containing lentil flour. The lentil flour was added at different levels (10, 20 and 30%) and various characteristics of muffin samples were investigated compared to two different controls with and without gluten. Quality characteristics of muffins were determined by analyzing proximate composition, batter properties (pH, density, and specific volume), physical properties (cooking loss, cake yield, color, texture, volume, symmetry and uniformity indices) and sensory properties. As a result of lentil flour addition, protein content of muffins increased by 1.6 times compared to gluten-free control samples. While pH and specific volume were decreased, density increased which led to decrease in air incorporation into batter and reduced final cake volume. Addition of lentil flour led to increase in yellowish color in crumb of muffins. Besides, values of browning index increased in both crumb and crust of muffins. Lentil flour addition modified textural properties of muffins in such a way that adhesiveness, cohesiveness and springiness decreased. Hardness decreased with lentil flour while increased by addition of rice flour and corn starch. Overall, all muffin samples were scored at acceptable level, and all samples had similar scores. In conclusion, results of physical, chemical and sensorial analyses indicated that formulating gluten-free muffins containing 30% lentil flour could be a valuable alternative for consumers who cannot tolerate gluten.

***Keywords:*** *Bakery products , Food quality, Gluten-free, Legume, Lentil, Muffin*

### Öz

Bu çalışmanın amacı, mercimek unu kullanılarak glutensiz kek reçetesi geliştirmektir. Mercimek unu kek formulasyonuna %10, 20 ve 30 oranlarında eklenmiş ve ürünlerin çeşitli özellikleri hem birbirleri arasında hem glutenli ve glutensiz iki farklı kontrol numunesi ile karşılaştırılmıştır. Bu keklerin kalite özellikleri besin öğeleri kompozisyonlarının, hamur özelliklerinin (pH, yoğunluk ve özgül), fiziksel özelliklerinin (pişirme kaybı, kek verimi, renk, doku, hacim, simetri ve homojenlik indeksleri) ve duyusal özelliklerinin analizleri yapılarak belirlenmiştir. Analizler sonucunda keklerin protein miktarı glutensiz kontrole göre 1.6 kat kadar artmıştır. Kek hamurunda pH ve özgül hacim azalırken, yoğunluğun arttığı, bunun da hamurun içine daha az hava girmesine ve son üründeki kek hacminin azalmasına neden olduğu görülmüştür. Mercimek unu ilavesi kekin içinde daha sarımsı bir renge sahip olmasına neden olmuştur. Ayrıca esmerleşme indeksi hem kekin kabuğunda hem de içinde artmıştır. Yapısal olarak, keklerin yapışkanlık, iç yapışkanlık ve elastikiyet değerleri azalmış, çiğnenebilirlik ve sertlik değerleri de mercimek unuyla azalırken, pirinç unu ve mısır nişastası ilavesiyle artmıştır. Genel olarak, kek numunelerinin tümü duyusal özellikleri açısından kabul edilebilir bir puan almış ve bütün çalışmalar yakın sonuçlar almıştır. Sonuç olarak, fiziksel, kimyasal ve duyusal analizlerin sonuçları %30 mercimek unu içeren keklerin gluten hassasiyeti bulunan tüketiciler için alternatif bir ürün olabileceğini göstermektedir.

***Anahtar Kelimeler:*** *Baklagiller, Gıda Kalitesi, Glutensiz, Kek, Mercimek, Unlu mamüller*

## 1. Introduction

People can suffer from gluten which is found in most grains due to genetics and age factors. Reaction to gluten consumption can arise with three different forms; allergy (wheat), autoimmune (celiac disease, dermatitis herpetiformis and gluten ataxia) and immune mediated (gluten sensitivity) [1]. Celiac disease is a genetic autoimmune disorder affecting the digestion system because of occurring intolerance to definite arrangement of amino acids found in prolamin part of wheat (gliadin), rye (secalin) and barley (hordein) [2, 3]. The general symptoms of celiac disease are malabsorption, diarrhea, weight loss, osteoporosis, fatigue, abdominal discomfort, and arthralgia; besides, iron and folic acid deficiency can be incomprehensible symptoms [4]. About 1-2% of world population is suffering from celiac disease [5] and it is believed that most patients have not been yet diagnosed. For now, the only treatment is removing gluten containing foods from the diet [4]. However, removing of gluten from food products leads to decrease of palatability and nutritional value [6]. Gluten-free market products generally contain more carbohydrates and fats, and less protein [7]. However, legumes have a great amount of protein, complex carbohydrates (starch and fiber), vitamins and minerals, and also, they contain low amount of fat and no cholesterol [8,9]. Legume proteins have high level of lysine and low level of sulphur containing amino acids (methionine and cysteine), while cereal proteins have high amount of sulphur containing and low amount of lysine amino acids. According to that, a more balanced essential amino acid profile can be obtained by consumption of cereals and legumes together [10]. Lentil proteins contain essential amino acids and are rich in lysine, leucine, arginine, aspartic and glutamic acid whereas they are limited in sulphur containing amino acids and tryptophan, therefore; they are required to be used in combination with other plant protein sources to achieve a balanced amino acid composition [11]. Also, lentils are known as poor man's meat due to their relatively low price and high protein content (21-31 g / 100 g) [12]. In addition to these, legumes are reported to have other beneficial effects including prevention and control of diabetes, prevention of cardiovascular diseases and some types of cancer [9].

Lentil consumption has a great importance in nutrition in many regions of the world. Lentils are a great source of minerals (iron, phosphorous), vitamins (thiamine, vitamins B and C, folic acid), starch, dietary fibers, proteins and antioxidants whereas they do not have cholesterol and contain low saturated fat and sugar. Lentils have been reported to be effective in controlling type-2 diabetes due to their low glycemic index (<55) which results in lower blood glucose levels compared to several carbohydrate containing foods. The low glycemic effect is observed even though combining with cereals. Additionally, lentil flour does not contain any gluten; therefore, it provides a nutritious alternative to wheat for celiac patients [13].

Due to providing mild taste, functionality (e.g., solubility, emulsification, gelation, foaming properties, water and oil absorption capacities) and nutritional properties, use of lentils in the food industry is increasing rapidly within products such as gluten-free novel foods, bakery products, extruded products, dressings, dairy and meat products. In a recent study, a bread formulation was developed by mixing of lentil flour into wheat flour up to 24% which resulted in good volume, texture and taste [12]. Besides, gluten is an important protein that helps forming of structure and affects viscoelasticity of dough. Because of elimination of gluten from food recipes, some quality degradation occurs such as low volume, bad texture and crumb structure. There are various recent studies on replacement of gluten in bakery products, and the addition of gums, emulsifiers, gluten-free grains and different flours have been provided improving quality of the gluten-free bakery products [14].

Muffin is one of the most preferred sweet baked goods due to its good taste and soft texture. General recipe of muffin contains wheat flour, sugar, vegetable oil, egg and milk, therefore, the celiac patients are unable to consume these food products. Therefore, nutritional value of gluten-free muffins can be improved for these patients [15]. Use of legume-based ingredients in cakes is easier compared to bread due to the fact that gluten network is not essential to obtain these products with desired characteristics, but also incorporation of legumes can impact negatively the final quality of product, therefore; a percentage of wheat flour or other gluten-free flours were replaced with legume flours in many studies [16]. Generally, the main ingredients of gluten-free muffins are rice flour or various starches including corn, potato, rice and wheat [17]. In addition to these, legumes are the important source of protein and carbohydrates for these type food products and combination with cereals provides completion of amino acid composition. Also, there are limited studies related with legume-based gluten-free muffins [15].

The main goal of this study was to develop alternative muffin recipes for consumers who do not tolerate or prefer consuming wheat. The muffin recipes were prepared with addition of lentil flours at different levels (10, 20 and 30%) and to investigate the effects of lentil flour addition on quality characteristics of muffins. Also, two different controls were used. One of the controls was prepared only with wheat flour to compare cake recipes with gluten-free formulations and to indicate effects of gluten in the cake recipe, and second one was prepared to demonstrate lentil flour effects on gluten-free muffins. To determine quality attributes, proximate composition, batter properties (pH, density and specific volume physical properties (cooking loss, color, texture, volume, symmetry and uniformity indices) and sensory properties were analyzed.

## 2. Material and Method

### 2.1. Materials

Raw materials for muffin preparation were supplied from a local market in Istanbul. Sinangil wheat flour (11.6% protein, 0.8% fat, 72.0% carbohydrate), Kenton precooked yellow lentil flour (26.0% protein, 0.7% fat, 53.0% carbohydrate), Dr. Oetker gluten-free rice flour (6.2% protein, 1.5% fat, 85.5% carbohydrate), and Ege gluten-free corn starch (0% protein, 0% fat, 86% carbohydrate) were used. Sunflower oil, egg, full fat milk, glycerol, crystal sugar, gluten-free baking powder, vanilla, xanthan gum (Tito) and distilled monoglyceride were also used. Distilled monoglyceride was supplied by Dupont and used as an emulsifier.

### 2.2. Methods

#### 2.2.1. Muffin preparation

Muffin formulation and preparation methods were developed based on previous reports from literature [7,14,18,19,20,21]. Formulations of control muffins with gluten (C1) and without gluten (C2), muffins with lentil flour in the proportions of 10 (L1), 20 (L2) and 30 (L3) % are shown in Table 1 based on g/100 g flour or starch. The first step of the batter preparation was the mixing of liquid ingredients (egg, milk, oil and glycerol) for 1 min at low speed using a hand mixer (Philips, HR 1492/A, Holland). Then, sugar was added to the liquid mixture and mixed for 2 min at high speed. In the final step, dry raw materials (flour, baking powder, vanilla, xanthan gum and emulsifier) were added and mixed for 5 min at high speed. After that, the batter was weighed in the muffin tray with between 35-36 g for each and baked for 67.5 min in an oven (Luxell, LX-3580, Turkey) at 180 °C.

#### 2.2.2. Sample Preparation

Baked muffins were cooled at room temperature for an hour, then they were removed from pans [5]. For color and texture analyses, 3 muffins were separated for each. Other muffins were cut into small pieces by a blender (Touch me, A356, Pacific Access Ltd., China). Moisture content of the samples was measured immediately after sample preparation. The remaining samples were frozen at -18 °C for further analysis. Batter analyses were performed immediately after preparation of batter. For sensory analysis, all

**Table 1.** Formulation of muffins based on g/100g flour or starch.

**Tablo 1.** Keklerin g/100g un veya nişastaya göre reçeteleri

| Ingredients | C1 | C2 | L1 | L2 | L3 |
|---|---|---|---|---|---|
| Wheat flour | 100 | 0 | 0 | 0 | 0 |
| Lentil flour | 0 | 0 | 10 | 20 | 30 |
| Corn starch | 0 | 50 | 45 | 40 | 35 |
| Rice flour | 0 | 50 | 45 | 40 | 35 |
| Baking powder | 4 | 4 | 4 | 4 | 4 |
| Vanilla | 2 | 2 | 2 | 2 | 2 |
| Xanthan gum | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| Sugar | 90 | 90 | 90 | 90 | 90 |
| Sunflower oil | 30 | 30 | 30 | 30 | 30 |
| Whole eggs | 50 | 50 | 50 | 50 | 50 |
| Milk | 60 | 60 | 60 | 60 | 60 |
| Emulsifier | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 |
| Glycerol | 3 | 3 | 3 | 3 | 3 |
| Total | 341.3 | 341.3 | 341.3 | 341.3 | 341.3 |

samples were prepared on the same day and were tested after waiting overnight, and volume and symmetry indexes were calculated by using samples prepared for sensory analysis. All analyses were performed in triplicate.

### 2.2.3. Proximate composition

The ash, lipid, crude protein (N x 6.25), and moisture contents of muffins were determined according to Association of Official Analytical Chemists methods [22]. Carbohydrate content was calculated by subtraction of moisture, protein, fat and ash contents from 100. Energy value of the samples were calculated using multiplication factors of 4 kcal/g for both protein and carbohydrates, and 9 kcal/g for fat [23].

### 2.2.4. Batter Properties

The density of the cake batter was measured by using graduated cylinder according to relation between weight of the batter and same volume of distilled water [24]. The specific volume of batter was determined by dividing volume of water by weight of the same volume of batter [25]. Also, the pH of batter was measured in triplicate by a pH meter (Hanna Instruments, HI 221, USA).

### 2.2.5. Physical properties

#### 2.2.5.1. Cake yield and cooking loss

The muffins were weighed before and after baking and 1 h cooling to room temperature [17]. The cake yield was measured by dividing cake weight by batter weight and multiplying with 100. The result was subtracted from 100 to obtain percentage of cooking loss [26].

#### 2.2.5.2. Symmetry, volume and uniformity indices

The muffins were cut through their center, and placed on milimeter paper. The values in Figure 1 were used for calculation of symmetry, volume and uniformity indices with following equations 1, 2 and 3 [27]. The B and D values are middle of the edge and center of muffin (C) [25].

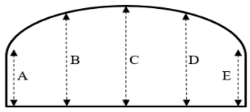


**Figure 1.** Cross section of muffin with the values used for physical indices [27].

**Şekil 1.** Fiziksel indeksler için kullanılan değerlerle kek kesiti [27].

$$\text{Symmetry index} = 2\text{C} - \text{B} - \text{D} \quad (1)$$

$$\text{Volume index} = \text{B} + \text{C} + \text{D} \quad (2)$$

$$\text{Uniformity index} = \text{B} - \text{D} \quad (3)$$

#### 2.2.5.3. Color analysis and browning index

The crumb and crust color of the muffin were determined by a colorimeter (Konica Minolta, CR-400, Japan). Three muffins for each type of formulations were analysed 1h after baking. The color analysis was performed according to CIELAB color system. A color is represented by $L*$, $a*$ and $b*$ values. $L*$, $a*$ and $b*$ indicate lightness, red/green value and yellow/blue value, respectively [28]. The total color difference ($\Delta E*$) between control and muffin with lentil flour was calculated according to equation 4 [29].

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \quad (4)$$

For the equation, $\Delta L*$, $\Delta a*$ and $\Delta b*$ are differences between $L*$, $a*$ and $b*$ values of the control and samples with lentil flour, respectively [30]. The $\Delta E*$ value can evaluated according to below 1, between 1 and 3, and more than 3. Less than 1 means that there are no obvious differences while more than 3 show obvious color differences for human eye. Color differences between 1 and 3 are not appreciated by human eye [29]. The browning index (BI) indicates purity of brown color and it is a significant value related with browning. According to CIELAB parameters, the browning index was calculated according to equation 5 [14].

$$\text{BI} = \frac{\left[100\left(\frac{a^*+1.75L^*}{5.645L^*+a^*-3.012b^*} - 0.31\right)\right]}{0.17} \quad (5)$$

#### 2.2.5.4. Texture analysis

Texture of muffins were analysed 1h after baking by using texture analyser (LLOYD Instruments, TA plus, UK). The crumb of the muffins were cut into cubes with the length of the side of 20 mm. The analysis was made with using 25 mm cylindirical probe, and with applying double compression test to compressed by 50% of initial height of crumbs at 2 mm/s speed [21]. The trigger was 1 N for each sample and 3 cake samples were used for each formulations. According to test, adhesiveness, cohesiveness, chewiness, hardness and springiness were obtained.

### 2.2.6. Sensory analysis

The sensory analysis was carried out with 11 panelists within the age range of 20 and 50 years while the number of female and male participants were 6 and 5, respectively. Muffin samples were evaluated the next day after baking for appearance (color, volume, symmetry), flavor (odour and taste), texture (softness and moistness) and overall acceptability. The evaluation was performed according to the hedonic scale method on a 1 to 9 scale, and the samples were served randomly to the panelists. The scores indicated dislike extremely for score 1 and like extremely for score 9 while the score of 5 was the lowest limit of acceptance [31].

### 2.2.7. Statistical analysis

All analyses were performed in triplicate and cakes were prepared in two replicate batches and mean values and standart deviations were indicated. Statistical significance of the differences were determined by a one-way analysis of variance (ANOVA). The normality of data was determined by using z-values of skewness [32] and homogeneity of variances was determined by levene statistic. Comparison between the results were performed by Tukey's post-hoc test with 95% confidence. In case of nonhomogeneous samples, Brown-Forsythe and Games-Howell tests were applied as robust test and post hoc test, respectively. All statistical analyses were performed using SPSS Statistics (SPSS 2019, IBM, USA) [33].

## 3. Results

### 3.1. Proximate composition

The proximate composition of muffin samples are shown in Table 2. According to results, there were not any significant differences for fat values ($p$>0.05) while significant differences were observed for other components ($p$<0.05). The highest protein content was observed in sample with C1 and L3, the highest amount of ash observed in sample with lentil flours. Sample with wheat flour had highest moisture while highest lentil flour containing sample had the lowest moisture level. The lowest carbohydrate content was observed in sample with gluten and the highest energy value was observed in sample with the highest amount of lentil flour.

### 3.2. Batter properties

The results of batter properties are shown in Table 3. All samples showed significant differences in all batter properties ($p$<0.05). The highest pH was obtained sample with C2 and L1. The highest density and specific volume were obtained in sample with gluten while this sample shown lowest specific volume.

**Table 2.** Proximate composition and energy values of muffin samples with and without lentil flour.

**Tablo 2.** Mercimek unlu ve mercimek unsuz keklerin besin ögeleri kompozisyonları ve enerji değerleri.

| Sample | Protein (g/100g) | Moisture (g/100 g) | Fat (g/100 g) | Ash (g/100 g) | Carbohydrate (g/100 g) | Energy (kcal/100 g) |
|---|---|---|---|---|---|---|
| C1 | 6.14±0.40$^{a}$ | 21.14±0.24$^{a}$ | 10.37±1.83$^{a}$ | 1.17±0.01$^{c}$ | 61.17±2.02$^{b}$ | 362.63±9.83$^{b}$ |
| C2 | 4.17±0.14$^{c}$ | 16.59±0.18$^{bc}$ | 11.36±0.24$^{a}$ | 1.12±0.01$^{c}$ | 66.76±0.47$^{a}$ | 385.95±1.23$^{a}$ |
| L1 | 5.21±0.15$^{b}$ | 16.06±0.49$^{cd}$ | 10.66±0.21$^{a}$ | 1.23±0.01$^{b}$ | 66.83±0.54$^{a}$ | 375.15±14.74$^{ab}$ |
| L2 | 5.53±0.14$^{b}$ | 17.02±0.41$^{b}$ | 11.70±0.23$^{a}$ | 1.23±0.01$^{b}$ | 64.52±0.39$^{a}$ | 385.50±2.64$^{a}$ |
| L3 | 6.58±0.14$^{a}$ | 15.58±0.27$^{d}$ | 11.59±0.11$^{a}$ | 1.30±0.04$^{a}$ | 64.95±0.40$^{a}$ | 390.40±0.74$^{a}$ |

Data were shown as mean ± standart deviation (n=3) and different superscripts within a column indicate sigfnificant difference ($p$<0.05).

**Table 3.** Batter properties of muffin samples with and without lentil flour.

**Tablo 3.** Mercimek unlu ve mercimek unsuz keklerin hamur özellikleri.

| Sample | pH | Density (g/mL) | Specific volume (mL/g) |
|---|---|---|---|
| C1 | 6.92±0.02$^{c}$ | 1.04±0.03$^{a}$ | 0.97±0.03$^{d}$ |
| C2 | 7.13±0.03$^{a}$ | 0.79±0.02$^{c}$ | 1.26±0.03$^{a}$ |
| L1 | 7.13±0.03$^{a}$ | 0.98±0.07$^{ab}$ | 1.03±0.08$^{cd}$ |
| L2 | 7.03±0.006$^{b}$ | 0.87±0.02$^{bc}$ | 1.15±0.02$^{ab}$ |
| L3 | 7.06±0.01$^{b}$ | 0.90±0.03$^{bc}$ | 1.11±0.04$^{bc}$ |

Data were shown as mean ± standart deviation (n=3) and different superscripts within a column indicate sigfnificant difference ($p$<0.05).

### 3.3. Physical properties of cake

#### 3.3.1. Cake yield and cooking loss

The results of cake yield and cooking loss are presented in Table 4. Any significant differences for cooking loss and cake yield were not observed ($p$>0.05).

**Table 4.** Cooking loss and cake yield of muffin samples with and without lentil flour.

**Tablo 4.** Mercimek unlu ve mercimek unsuz keklerin pişirme kaybı ve kek verimi.

| Sample | Cooking Loss (%) | Cake Yield (%) |
|---|---|---|
| C1 | 11.8±1.7$^{a}$ | 88.3±1.7$^{a}$ |
| C2 | 17.2±2.3$^{a}$ | 82.8±2.3$^{a}$ |
| L1 | 17.1±2.7$^{a}$ | 82.9±2.7$^{a}$ |
| L2 | 14.8±2.4$^{a}$ | 85.2±2.4$^{a}$ |
| L3 | 16.3±2.5$^{a}$ | 83.7±2.5$^{a}$ |

Data were shown mean ± standart deviation (n=3) and different superscripts within a column indicate sifnificant difference ($p$<0.05).

#### 3.3.2. Symmetry, volume and uniformity indices

The symmetry and uniformity indices of muffins were not significantly different while volume index of muffins had a significant difference and the results are shown in Table 5.

**Table 5.** Symmetry, volume and uniformity indices of muffin samples with and without lentil flour.

**Tablo 5.** Mercimek unlu ve mercimek unsuz keklerin simetri, hacim ve homojenlik indeksleri.

| Sample | Symmetry Index (cm) | Volume Index (cm) | Uniformity Index (cm) |
|---|---|---|---|
| C1 | 0.57±0.25$^{a}$ | 12.53±0.12$^{a}$ | 0.03±0.06$^{a}$ |
| C2 | 0.37±0.06$^{a}$ | 11.23±0.32$^{b}$ | -0.03±0.06$^{a}$ |
| L1 | 0.30±0.10$^{a}$ | 11.40±0.44$^{b}$ | 0.03±0.15$^{a}$ |
| L2 | 0.33±0.15$^{a}$ | 11.07±0.15$^{b}$ | 0.00±0.10$^{a}$ |
| L3 | 0.30±0.10$^{a}$ | 11.00±0.26$^{b}$ | -0.03±0.15$^{a}$ |

Data were shown mean ± standart deviation (n=3) and different superscripts within a column indicate significant difference ($p$<0.05).

#### 3.3.3. Color analysis and browning index

The results of color analysis and browning indices are shown in Table 6. All of the $L^*$, $a^*$, $b^*$ values were not significantly different ($p$>0.05), except $b^*$ value of crumbs of muffins and the highest results were observed in samples L2 and L3. The highest browning indices were observed in crumb of sample L3 and crust of samples L2 and L2. The results of color differences ($\Delta E^*$) are shown in Table 7 and samples with lentil flour compared with controls with wheat flour and with rice flour and corn starch, seperately. The biggest difference was observed between crust of C1 and L3 ($p$<0.05).

#### 3.3.4. Texture analysis

The results of texture analysis parameters are shown in Table 8. All values were found to be significantly different ($p$<0.05), except chewiness. The lowest hardness and the highest adhesiveness, cohesiveness and springiness were observed in sample with gluten.

### 3.4. Sensory analysis

The results of sensory characteristics of the muffins are shown in Table 9. Only results of taste and moistness were found to be significantly different ($p$<0.05). The lowest results of taste and moistness were observed in sample with 10% lentil flour.

**Table 6.** Color parameters of muffin samples with and without lentil flour.

**Tablo 6.** Mercimek unlu ve mercimek unsuz keklerin renk parametreleri.

| Sample | Crumb Color | | | | Crust Color | | | |
|---|---|---|---|---|---|---|---|---|
| | *L** | *a** | *b** | Crumb Browning Index | *L** | *a** | *b** | Crust Browning Index |
| C1 | 65.04±0.81$^{a}$ | -2.08±0.15$^{a}$ | 18.24±0.32$^{b}$ | 29.59±1.23$^{c}$ | 57.54±3.74$^{a}$ | 5.45±2.00$^{a}$ | 23.04±1.02$^{a}$ | 57.20±4.79$^{b}$ |
| C2 | 65.28±1.07$^{a}$ | -2.50±0.40$^{a}$ | 17.10±0.16$^{c}$ | 26.65±0.77$^{c}$ | 52.30±2.45$^{a}$ | 7.63±0.53$^{a}$ | 22.08±0.97$^{a}$ | 64.48±1.54$^{ab}$ |
| L1 | 66.32±3.43$^{a}$ | -2.61±0.51$^{a}$ | 20.75±0.10$^{abc}$ | 33.48±1.15$^{b}$ | 51.15±4.05$^{a}$ | 8.02±0.83$^{a}$ | 21.87±1.58$^{a}$ | 66.27±2.68$^{ab}$ |
| L2 | 63.64±0.97$^{a}$ | -2.52±0.41$^{a}$ | 21.26±0.10$^{a}$ | 36.44±1.20$^{b}$ | 51.19±5.48$^{a}$ | 7.95±1.56$^{a}$ | 21.90±1.96$^{a}$ | 66.38±4.79$^{a}$ |
| L3 | 63.87±1.20$^{a}$ | -1.94±0.20$^{a}$ | 22.51±0.85$^{a}$ | 39.83±1.56$^{a}$ | 48.31±3.32$^{a}$ | 8.81±0.65$^{a}$ | 21.08±1.76$^{a}$ | 69.54±1.31$^{a}$ |

Data were shown mean ± standart deviation (n=3) and different superscripts within a column indicate sifnificant difference ($p$<0.05).

**Table 7.** Color differences of muffin samples with lentil flour compared to controls.

**Tablo 7.** Mercimek unlu keklerle kontrol keklerin arasındaki renk farklılıkları.

| Sample | Comparison with Control 1 | Comparison with Control 2 |
|---|---|---|
| Crumb | | |
| L1 | 2.87 | 3.80 |
| L2 | 3.36 | 4.47 |
| L3 | 4.43 | 5.62 |
| Crust | | |
| L1 | 6.98 | 1.23 |
| L2 | 6.92 | 1.17 |
| L3 | 10.02 | 4.29 |

## 4. Discussion and Conclusion

### 4.1. Proximate composititon

The differences observed in proximate composition were determined based on 95% significance level. According to protein content of muffin samples the highest protein value was obtained with using 30% of lentil flour which was higher than gluten-free control samples with about 1.6 times of its protein content ($p$<0.05). This finding was compatible with the estimations; because, lentil flour contains higher amount of protein compared to wheat flour, rice flour and corn starch. However, there was not significant differences in protein content of 10% and 20% of lentil flour added samples ($p$>0.05). Increased protein content was also observed in other studies due to relatively higher protein content of legumes.

**Table 8.** Textural properties of muffin samples with and without lentil flour.

**Tablo 8.** Mercimek unlu ve mercimek unsuz keklerin dokusal özellikleri.

| Sample | Hardness (N) | Adhesiveness (N) | Cohesiveness | Chewiness (N) | Springiness |
|---|---|---|---|---|---|
| C1 | 3.51±0.19$^{b}$ | -0.0017±0.00$^{a}$ | 0.22±0.02$^{a}$ | 4.62±0.44$^{a}$ | 4.40±0.18$^{a}$ |
| C2 | 5.36±1.53$^{ab}$ | -0.0013±0.00$^{ab}$ | 0.20±0.04$^{ab}$ | 6.56±3.31$^{a}$ | 3.60±0.54$^{ab}$ |
| L1 | 6.99±1.79$^{a}$ | -0.0007±0.00$^{b}$ | 0.16±0.02$^{ac}$ | 7.40±4.30$^{a}$ | 3.17±0.49$^{ab}$ |
| L2 | 3.89±1.18$^{ab}$ | -0.001±0.00$^{b}$ | 0.12±0.02$^{bc}$ | 2.50±1.86$^{a}$ | 2.95±0.46$^{b}$ |
| L3 | 4.26±0.85$^{ab}$ | -0.0006±0.00$^{b}$ | 0.11±0.04$^{c}$ | 2.59±1.80$^{a}$ | 2.58±0.58$^{b}$ |

Data were shown mean ± standart deviation (n=3) and different superscripts within a column indicate sifnificant difference ($p$<0.05).

**Table 9.** Sensory properties of muffin samples with and without lentil flour.

**Tablo 9.** Mercimek unlu ve mercimek unsuz keklerin duyusal özellikleri.

| Sample | Appearance | | | Flavor | | Texture | | Overall Acceptability |
|---|---|---|---|---|---|---|---|---|
| | Color | Volume | Symmetry | Odour | Taste | Softness | Moistness | |
| C1 | 6.45±1.63$^{a}$ | 6.55±2.11$^{a}$ | 7.27±1.95$^{a}$ | 6.36±1.91$^{a}$ | 6.18±2.09$^{ab}$ | 5.09±2.47$^{a}$ | 5.73±1.62$^{ab}$ | 6.55±1.44$^{a}$ |
| C2 | 6.55±1.37$^{a}$ | 6.91±1.64$^{a}$ | 6.64±1.43$^{a}$ | 7.10±2.02$^{a}$ | 6.73±2.20$^{a}$ | 6.64±1.63$^{a}$ | 5.00±1.84$^{ab}$ | 6.45±1.44$^{a}$ |
| L1 | 6.18±2.04$^{a}$ | 5.64±1.86$^{a}$ | 5.73±1.79$^{a}$ | 5.00±2.28$^{a}$ | 4.27±1.79$^{b}$ | 6.00±2.05$^{a}$ | 4.36±1.69$^{b}$ | 5.45±1.37$^{a}$ |
| L2 | 6.18±1.33$^{a}$ | 6.27±1.35$^{a}$ | 5.91±1.45$^{a}$ | 6.64±1.43$^{a}$ | 6.09±1.30$^{ab}$ | 4.91±1.38$^{a}$ | 6.09±1.38$^{ab}$ | 5.91±0.70$^{a}$ |
| L3 | 6.00±1.26$^{a}$ | 5.45±1.63$^{a}$ | 5.73±1.79$^{a}$ | 6.73±1.62$^{a}$ | 6.55±1.57$^{a}$ | 6.64±1.69$^{a}$ | 6.82±1.66$^{a}$ | 6.45±1.63$^{a}$ |

Data were shown mean ± standart deviation (n=11) and different superscripts within a column indicate sifnificant difference ($p$<0.05).

In a study with different legume flours (chickpea, pea, lentil and bean), protein content of all cake samples were increased by replacing half of the rice flour with legume flour. For the lentil flour added samples, the amount of increase was almost 1.5 times of control with rice flour [20]. In another cake study with pea protein incorporation, using 30% or more protein led to lower acceptability due to lower scores in odor and taste; therefore, flour substitution was advised to prepare high protein cakes. Moreover, preparations with rice flour and mixture of pea, whey and egg proteins can increase acceptability compared to using pea protein alone [16]. The control with wheat flour had the highest moisture content while the gluten-free samples with 30% of lentil flour had the lowest moisture content. Decreasing of moisture was not significant until the addition of 30% lentil flour compared to gluten-free control, and replacement of wheat flour with rice flour, corn starch and/or lentil flour decreased the moisture content of muffins. According to studies and containing high amount of protein and dietary fiber of legumes led to increase the water holding capacity which also increased the moisture content [15,34]. However, in this study, moisture content decreased with addition of legume flour. It could be due to using pre-cooked lentil flour which can affect the final moisture content of the product.

The fat content was not found to be significantly different between samples ($p$>0.05). In a study with gluten-free muffins, replacement of half of the rice flour with different legume flours (chickpea, pea, lentil and bean) was reported to increase the fat content of muffins. Sample with chickpea flour had the highest fat content [20]. This finding was attributed to the higher fat content of chickpea flour compared to lentil flour [35,36]. The similar fat content for all samples can be due to amount of lentil flour added, and using higher amounts of lentil flour can led to increase in fat content.

There was significant differences in ash content among samples ($p$<0.05), and it was increased with addition of lentil flour. The lowest ash content was observed in gluten-free control sample. In other studies, the ash content (minerals) were also increased with addition of legume flours compared to muffin with wheat flour or rice flour [15,20]. The increasing of ash content is due to having more minerals in legume flours than wheat and rice flours.

Carbohydrate content was significantly different between samples and the lowest value was observed in control sample with wheat flour ($p$<0.05). Carbohydrate content increased with addition of gluten-free flours while it did not change with addition of lentil flour. In a different study, the amount of carbohydrate in muffins decreased with the replacement of rice flour with different legume flours [20]. It could be related with percentage of added lentil flour, increasing of amount of lentil flour can led to decrease in carbohydrate content.

The energy values were significantly different among samples ($p$<0.05). In a study with different legume flours, energy values were decreased with changing of half of the rice flour with legume flours [20]. Due to similar results in fat content of muffins, it did not affect energy values. Containing more carbohydrate in sample with 30% of lentil flour than sample with wheat flour and containing high amount of protein led to increase in energy value.

### 4.2. Batter properties

The differences observed in batter properties were determined with 95% significance level. Control with wheat flour had the lowest pH and significantly different than other samples without gluten. Addition of lentil flour by 20 and 30% led to a significant reduction of pH ($p$<0.05). A study indicated that addition of about 15% lentil flour into formula had the same pH with gluten-free control which contains only rice flour, and both pH values were 7.5 [20]. In another study, the pH of cake with wheat flour was 7.2 while pH values of batter with navy bean flour were ranged from 6.6 to 6.9 with different protein levels of flour. It was shown that addition of the navy bean flour decreased the pH of cake batter, and protein content affected the pH value of muffins [37]. Also, in this study, the pH values were decreased after a certain increase in protein content within gluten-free samples.

Control with wheat flour had the highest density while gluten-free control samples had the lowest density, and the densities of gluten-free samples were slightly increased with addition of lentil flour with no significant differences among each others, and replacement of wheat flour led to decrease in density of batter. In a study with different legume flours, the batter density was decreased significantly by replacement of rice flour with lentil and bean flours while pea and chickpea flours were not affected significantly to batter density [20]. High batter density is linked with the less air incorporation into batter that lead to lower cake volume [37]. Besides, some other factors affect cake characteristics such as amount of gas from mixing step or chemical leavening, the gas incorporated into batter and retained during baking [10]. In this study, using lentil flour instead of rice flour and corn starch led to increase of batter density and result in less air incorporation into batter, but it was not the only factor affecting cake characteristics.

The highest specific volume was observed in gluten-free control and all gluten-free samples had higher specific volume than the sample with wheat flour, and addition of lentil flour led to decrease in specific volume. Increase in specific volume indicated an increase in incorporated air into batter. Increasing specific volume was also reported for layer cakes by using of pea or chickpea flour instead of wheat flour in different studies. Also, differences according to flour type or ratio were not observed [19].

### 4.3. Physical properties of cake

#### 4.3.1. Cooking loss and cake yield

The cooking loss and cake yield values were found to be similar ($p$>0.05). The cooking loss can be related with moisture loss during baking. In a study, replacement of 10% wheat flour by legume flours (lentil, chickpea and pea) led to less loss of moisture. The possible reason of this finding could be attributed to the higher water holding capacity of legume flours. In other studies, water holding capacity was increased while moisture loss was decreased with addition of soy flour into cake. High water holding capacity of legume flours was related with containing high amount of protein and fiber [38]. In another study, significant differences in cake weight was also not observed by using chickpea flour instead of wheat flour in sponge cake at the ratio of 50 and 100%. Hence, the substitution was not found to affect the water retention capacity [10].

#### 4.3.2. Symmetry, uniformity and volume indices

The symmetry index provides information on gas retention of cakes with high results generally indicating the rising of cakes from their center, besides; the negative results show that colapsing volume of cakes at the end of baking step [10]. The differences observed in results of symmetry, uniformity and volume indices were determined based on 95% significance level. The symmetry of muffin samples did not show any significant differences ($p$>0.05). Better gas retention property of gluten can lead to high symmetry and changing with gluten-free flours and using legume flours led to decrease in symmetry. In a different study, using chickpea flour instead of wheat flour led to decrease in symmetry both in layer and sponge cakes [10]. Also, in a similar study conducted with lentil flour, cake symmetry indices were decreased and negative results were obtained with 50 and 100% by using different type of lentil flours instead of wheat flour [8].

There was a significant difference between volume index of control with gluten and the other muffin samples ($p$<0.05). Also, similar to the findings observed for symmetry, using chickpea flour instead of wheat flour led to decrease in both volume of layer and sponge cakes. Lower gas retention capacity of chickpea flour compared to wheat flour was indicated as the possible reason of this observation [10]. Additionally, volume of layer cakes decreased with replacing wheat flour with lentil flour and increasing amount of lentil flour also led to more decrease in the volume of cakes [8]. Decreasing symmetry and volume indices of muffins with addition of gluten-free flours could be mostly related with changing of amino acid composition of final product; therefore, related with gas retention capacities of these flours which resulted in changes in cake physical properties.

The uniformity index indicates the cake symmetry while symmetry index shows the surface contour of muffins [39]. The high results in uniformity index indicated uneven surfaces [40]. Also, for achieving a good product quality, cake uniformity index should be close to zero [41].

#### 4.3.3. Color analysis and browning index

Color is an important characteristic for evaluation of bakery products [38] and the color of the ingredients and colored compounds produced during baking affect~~s~~ the final product [7]. The differences observed in color parameters were determined based on 95% significance level. The decrease in ligthness was observed in another study with 50 and 100% replacement of wheat flour with yellow or orange lentil flour in layer cakes [8]. In other study, the lightness of layer cake crumbs was also sligthly decreased with addition of chickpea flour [10]. The lightness of muffin crust also was not significantly changed. In different studies also, partially or fully replacement of wheat flour with native corn starch decreased lightness of the sponge cake crusts while using of lentil flour instead of rice flour did not significantly affect cake crusts [20,42].

Regarding to red/green value, the crumb of muffins showed negative $a^*$ values indicating greenish color while the crust of muffins showed positive $a^*$ values indicating reddish color. In different studies, the reddish color of layer cake crumbs was increased with addition of yellow or orange lentil flour and the orange lentil flour was more increased the reddish color [8] while the replacement of rice flour with lentil flour was not found to significantly affect the cake color [20]. The crust redness of layer cake was also increased with addition of yellow or orange lentil flour [8]. Using native corn starch instead of wheat flour was also reported to increase the $a^*$ value of sponge cake crusts [42] and replacement of rice flour with lentil flour increased the $a^*$ value of cake crusts [20].

For blue/yellow color, the $b^*$ values were positive for all crumbs and crusts of samples which indicates yellowish color. The $b^*$ values of muffin crumbs were significantly different within each others ($p$<0.05). While rice flour and corn starch decreased the $b^*$ value of crumbs compared to wheat flours, the addition of 20 and 30% lentil flour increased the yellowness of crumbs. The sample with 10% added lentil flour were similar with other samples ($p$>0.05). In a similar study with different legumes, the $b^*$ value increased with addition of lentil and bean flour in the crumb color of the gluten-free cakes [20]. In the layer cake, yellow color was increased with addition of lentil flour. Maillard and caramelization reactions do not occur in the cake crumb; therefore, the main reason of the crumb color is the color of the used ingredients. The $b^*$ values of muffin crusts were not changed significantly. In the crust of layer cakes, Maillard and caramelization reactions occur and affect the color of the muffin crust. In a study, any significant changes in crust color were not observed with addition of lentil flour although lentil flour has different amino acid and sugar composition compared to wheat flour. Only the $b^*$ value was reported to slightly decrease in layer cakes [8]. In addition, replacement of wheat flour with native corn starch decreased the $b^*$ values of sponge cake crusts. The decrease in yellowish color could be the promoting Maillard reaction by increasing amount of carbohydrates [42].

The browning indices of muffin crumb and crust increased with addition of lentil flour, and the biggest differences were observed between controls and 30% of lentil flour added muffins ($p<0.05$). Maillard reaction leads to browning of baked goods during baking. Additionally, hydrocolloids have a lightening effect in crumbs which can be based on its water distribution property [14]. Increasing browning index both in crumb and crust could be due to changing the amino acid composition especially for lysine content and its effect on Maillard reaction.

It has been indicated that color differences should be higher than 3 to observe by human eye [29]. When the crust color of muffins compared with gluten-free control muffin, color differences were not found to be high enough to be perceived by human for 10 and 20% lentil flour added muffins, although there was an obvious change for 30% lentil flour added samples. When the crust color compared between control with wheat flour and lentil flour added muffins, all of them were obviously different and can be perceived by human eye. For crumb color, comparison with gluten-free control showed visible difference in all lentil proportions. Muffins with 20 and 30% of lentil flour showed visible differences. On the other hand, color differences in muffins with 10% lentil flour were not high enough to be perceived by the human eye compared to the control with gluten.

The highest and the lowest differences were reported in crust color compared to the control samples with and without gluten, respectively. This finding can indicate that the color of the samples was not only affected by addition of lentil flour, but also rice flour and corn starch can significantly affect the color of the samples.

#### 4.3.4. Texture analsis

The results of texture parameters are calculated based on 95% significance level. Hardness is defined as the maximum force during first compression which is required for biting, mastication and swallowing of the food products [43]. The lowest hardness was obtained in the control sample with wheat flour. The use of rice flour and corn starch instead of wheat flour increased the hardness of muffins while the addition of lentil flour slightly decreased the hardness of muffins. Increase in hardness was also reported in different studies using legumes such as chickpea and was indicated to be related with the reduced number and size of the air bubbles which increased the required force for compression [14]. Reduced amount of gluten and higher water absorption capacity due to higher amounts of protein and fiber led to reduced formation of gluten network and decreased capability of enclosing air into muffin; therefore, denser structure was formed [15]. Furthermore, hardness was reversely related with volume of the cakes and lower volume indicates harder structure [38]. The control sample with wheat flour showed lower hardness compared to 10% lentil flour added samples; however, there was not any significant changes in volume all samples.

Adhesiveness is expressed as attraction forces between the food and the mouth cavity. For inert and non-sticky products, adhesiveness value is zero [43]. Replacement of wheat flour with lentil flour decreased the adhesiveness of muffin crumbs in this study while the amount of lentil flour was not found to have a significant effect. On the other hand, in another study using chickpea flour, adhesiveness was reported to increase with increasing amount of chickpea flour in both layer and sponge cakes [10].

Cohesiveness is a parameter describing the structural integrity of a product [42]. It allows to hold the components of the cake together and it helps shaping of the food in molding [43]. Cohesiveness of muffin crumbs decreased by replacement of wheat flour and addition of lentil flour. The lowest result was obtained in 30% of lentil flour addition. Decrease in cohesiveness was also reported by replacing wheat flour with chickpea flour [10]. Similar results were obtained by complete or partial replacement of wheat flour with lentil flour [8]. Cohesiveness was also reported to be negatively related to cake crumbliness [7]. Producing gluten-free products and addition of lentil flour were reported to increase the crumbliness of cakes and the most significant effects were observed in 30% lentil flour added cake samples.

The springiness is related with fresh, aerated and elastic structures while cohesiveness is related with the denseness and required energy for chewing of samples. Increased springiness and cohesiveness indicates more aerated structure due to more organized and stronger structure of gluten [15]. Springiness was observed to decrease when the wheat flour was replaced by rice flour and corn starch, and addition of lentil flour. The lowest springiness was observed in 30% of lentil flour addition into formula. Springiness and cohesiveness were also found to be higher in control with wheat flour compared to legume flour containing samples in other muffin applications. Decrease in springiness can be attributed to the the nonuniform flour blends, and high springiness and cohesiveness value with wheat flour can be an indication of stronger and more organized gluten structure [15]. Springiness was also decreased by using different types of lentil flour in the layer cake [8]. However, it was observed that springiness increased by addition of lentil and bean flours into gluten-free cake [20].

Chewiness of the products is associated with easiness to chew [7], and is indicated by multiplications of hardness, cohesiveness, springiness values [42]. In a previous study, increased chewiness was reported by addition of chickpea, pea and bean flours into rice flour based cake formulation while the chewiness was not changed by lentil flour addition [20].

### 4.4 Sensory analysis

The all sensory parameters are calculated according to 95% significance level and performed with 11 panelists with preparing one sample for each panelist. The color parameters measured were also found to be similar (Table 6, $p>0.05$). However when the browning index was considered, the lowest values were observed with control samples and the indices were found to increase with increasing amount of lentil flour (Table 7). In a similar study, addition of legume flour into muffins was reported to lead to a decrease in preferability of color in sensory analysis [15]. When volume and symmetry scores were found to be similar with their analyses, but only volume of muffin with wheat flour was found to be different in its analysis. However, it did not affect response of panelists.

All odour scores of the muffins were found to be at the acceptable level. According to taste results, only 10% lentil flour added samples were scored under acceptability level. The other samples were found to have scores higher than the acceptability level and the top three samples were gluten-free control, 30% lentil flour added samples and the control with gluten, in descending order. In another study, addition of legume flour into muffin recipe mostly led to decrease in taste and odour scores, which was attributed to the characteristic beany taste of legumes [15].

Any significant differences were not observed in softness of muffins ($p<0.05$). Regarding the moistness of samples, the lowest score was obtained with 10% lentil flour added samples which was under accebtable level, and the highest score was obtained for the 30% lentil flour added samples. A possible reason behind this finding could be addition of glycerol to obtain optimum moistness level in lentil flour added samples while the control sample with gluten had a relatively high moisture level which was unfavorable by panelists. Also, in a previous study, texture of legume-based gluten-free muffins were more favorable compared to control samples [15]. Consequently, based on overall acceptability, all results were higher than 5 points which means all can be regarded as acceptable by the panelists. No significant differences were observed in overall acceptability of the samples ($p>0.05$).

### 4.5. Conclusion

Effects of lentil flour addition on various quality characteristics of gluten-free muffins were investigated to develop a recipe with higher nutritous level for celiac patients and people who cannot consume gluten. To determine characteristic properties and obtain gluten-free muffins similar structure with muffins based on wheat flour; analysis of proximate composition, batter, physical, textural and sensorial properties are performed. Incorporation of 30% lentil flour into gluten-free muffin recipe, protein content was increased by 1.6 times compared to gluten-free control, also ash contents were increased due to relatively higher mineral content of lentils while energy values increased. According to batter quality, lentil flour addition led to decrease in pH and specific volume of the batter while increase in density was observed.

These findings indicate that less air was incorporated into batter and it affected the final cake volume. Cooking loss and cake yields were not affected.

The yellowish color of crumbs was found to increase with addition of lentil flour. Additionally, browning index of both crumb and crust increased. Addition of lentil flour led to decreases in adhesivness, cohesiveness and springiness which resulted in less aerated and more crumble structure. Hardness was observed to increase by addition of rice flour and corn starch while they decreased by addition of lentil flour. All muffin samples were found to be at acceptable levels, and based on overall acceptability all samples were found to be similar. Furthermore, these recipes can be improved by addition of some flavorings, chocolate and fruit pieces. Overall, results of physical, chemical and sensorial analyses indicated that formulating gluten-free muffins with 30% lentil flour addition could be a valuable alternative for consumers who cannot tolerate gluten.

### 4.6. Sonuç

Bu çalışmayla, çölyak hastaları ve glüten tüketemeyen kişiler için besin değeri daha yüksek bir reçete geliştirilerek, mercimek unu ilavesinin glütensiz keklerin kalite özelliklerine etkileri araştırılmıştır. Glütensiz hazırlanan keklerin karakteristik özelliklerinin buğday unuyla hazırlanan keklere yakın olmasını sağlamak ve keklerin karakter özelliklerini belirlemek için; besin ögeleri kompozisyonları, kek hamuru özellikleri ve kekin fiziksel ve duyusal özellikleri incelenmiştir. Glütensiz kek reçetesine %30 oranında mercimek unu ilavesiyle protein miktarı glütensiz hazırlanan kontrole göre 1.6 kat kadar artmış ve enerji değeri yükselmiştir, ayrıca mercimeğin daha yüksek mineral içeriğinden dolayı kül miktarı artmıştır. Hamurun kalite özellikleri incelendiğinde; mercimek unu ilavesinin hamurun pH'sının düşmesine ve özgül hacmin azalmasına neden olduğu, aynı zamanda hamurun yoğunluğunu artırdığı gözlemlenmiştir. Bu bulgular hamura daha az hava katıldığını ve son kek hacmini etkilediğini göstermektedir. Pişirme kaybı ve kek verimi etkilenmemiştir.

Mercimek unu ilavesiyle kek içlerinin sarımsı renginin arttığı görülmüştür. Ayrıca, esmerleşme indeksi hem kek içinde hem de kekin kabuğunda artmıştır. Mercimek unu ilavesi keklerin yapışkanlığının, iç yapışkanlığının ve elastikiyet değerlerinin azalmasına neden olmuş ve sonucunda da kek daha az hava içermiş ve daha çok ufalanan bir yapıda olmuştur. Pirinç unu ve mısır nişastası ilavesiyle sertlik değerinin arttığı gözlemlenirken; mercimek unu ilavesiyle bu değer azalmıştır. Tüm kek numunelerinin kabul edilebilir seviyede olduğu ve genel kabul edilebilirlik düzeyinde tüm numunelerin benzer olduğu bulunmuştur. Geliştirilen bu formulasyonların bazı aroma vericiler, çikolata ve meyve parçaları gibi ilavelerle iyileştirilmesi mümkündür. Fiziksel, kimyasal ve duyusal analiz sonuçlarına göre, %30 mercimek unu ilavesiyle hazırlanmış glütensiz keklerin glüten tüketemeyen kişiler için önemli bir alternatif olabileceği gösterilmiştir.

"Hazırlanan makalede etik kurul izni alınmasına gerek yoktur."

"Hazırlanan makalede herhangi bir kişi/kurum ile çıkar çatışması bulunmamaktadır."

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