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Farklı Kavuzsuz Arpa Çeşitlerinin Bisküvinin Teknolojik, Tekstürel ve Besin Değerleri Üzerine Etkisi

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ÖZ

Kavuzsuz arpa, biyoaktif bileşikler ve önemli besin maddeleri bakımından zengin bir tahıldır. Bu çalışmada, iki kavuzsuz arpa (cv. Özen ve cv. Yalın) unu, kabul edilebilir duyusal kaliteyi korurken gelişmiş diyet lifi, fenolik bileşikler, β-glukan ve antioksidan içeriği de dahil olmak üzere yüksek besin değerine sahip bisküvi üretme olanaklarını araştırmak için buğday (cv. Çetinel 2000) unu ile değişen oranlarda (%0, %25, %50, %75 ve %100) karıştırılmıştır. Hammadde olarak kullanılan buğday ve arpa unlarının kimyasal, fizikokimyasal ve besinsel içeriği belirlenmiş ve bisküvilerin fonksiyonel ve kalite özellikleri analiz edilmiştir. Kavuzsuz tam arpanın tüm katkı seviyelerinde bisküvi üretiminde fonksiyonel bir gıda bileşeni olarak kullanılabileceği tespit edilmiştir. Buğday ununa arpa eklenmesi kurabiyelerin çapını ve yayılma oranını azaltırken kalınlıklarını artırmıştır. Kurabiyelerin sertlik değerleri 20,64 N ile 30,45 N arasında değişmiş, en yüksek yayılma oranı kontrol örneğinden elde edilirken, bu değer %100 Özen arpa unu ile yapılan bisküvilerde 5,24'e, %100 Yalın arpa unu ile yapılan bisküvilerde ise 5,27'ye düşmüştür. Tekstür özellikleri incelendiğinde, sertlik değerlerinin katım oranı ile arttığı tespit edilmiştir. Arpanın, fonksiyonel gıdalarda potansiyel uygulamalara sahip olabilecek zengin bir biyoaktif bileşen kaynağı olduğu belirlenmiştir.

Anahtar kelimeler: β-glukan, kavuzsuz arpa, bisküvi kalitesi, tekstür, diyet lif

Effect Of Different Hull-Less Barley Varieties On The Technological, Textural, And Nutritional Properties Of Cookies

ABSTRACT

Hull-less barley is a crop abundant in bioactive compounds and substantial nutrients. In this study, two hull-less barley (cv. Ozen and cv. Yalin) flour was blended with wheat (cv. Cetinel 2000) flour at varying ratios (0%, 25%, 50%, 75%, and 100%) to explore the possibilities of producing cookies with high nutritional value, including enhanced dietary fiber, phenolic compounds, β-glucan, and antioxidant content, while maintaining acceptable sensory quality. The chemical, physicochemical, and nutritional content of the wheat and barley flours used as raw materials were determined, and the functional and quality characteristics of the cookies were analyzed. It was found that hull-less whole barley can be used as a functional food ingredient in cookie production at all supplementation levels. Adding barley to wheat flour decreased the diameter and spread ratio of the cookies while increasing their thickness. The hardness values of the cookies ranged between 20.64 N and 30.45 N., the highest spread ratio was obtained from the control sample, while this value decreased to 5.24 in the cookies made with 100% Ozen barley flour and to 5.27 in the cookies made with 100% Yalin barley flour. The texture properties were found that the hardness values increased with the incorporation ratio. It has been shown that barley is a rich source of bioactive components, which may have potential applications in functional foods.

Keywords: β-glucan, hull-less barley, cookie quality, texture, dietary fiber

INTRODUCTION

Researchers indicate that functional foods significantly reduce the risk of developing certain types of cancer, particularly those related to the digestive and cardiovascular systems. These foods also regulate blood pressure and lower cholesterol and blood sugar levels (Erbaş, 2006). Barley adapts better to environmental conditions than other cereals and can be cultivated under diverse circumstances. Its composition and properties vary depending on the variety, cultivation conditions, and environmental factors, making it a versatile raw material for developing various products. While barley was initially cultivated for human consumption, today it is primarily grown for use in animal feed and the brewing industry (Akdeniz et al., 2004).

Cultivated barley grains are categorized into two primary types depending on their structure: hulled and hull-less. The seed coat and hull stay affixed to the grain in hulled barley. During the latter stages of the grain-filling cycle, certain sticky compounds develop between the hull and the grain, inhibiting their separation. Post-harvest, the hull and seed coat stay affixed to the grain during threshing. In hull-less barley, the hull can be readily detached from the grain during threshing. The lack of de-hulling in processing enhances the value of hull-less barley. The absence of hull in barley is governed by a single recessive gene, 'nud,' situated on the long arm of chromosome 7H (Köksel, 2016).

Hull-less barley has high digestible protein and energy content and is suitable for blending in bread production. Recent studies demonstrated its ability to reduce plasma cholesterol due to its β-glucan and high soluble fiber content, drawing considerable attention to hull-less barley. Beta-glucan is an important dietary fiber in cereal products, mainly barley, oats, and mushrooms (Ahmad et al., 2012). β-glucan is a linear polysaccharide composed of glucose monomers linked by β(1→4) and β(1→3) bonds, primarily located in the endosperms of barley and oats. It is water-soluble and exhibits high viscosity even at low concentrations. The physiological benefits of β-glucan stem from its effects on lipid and postprandial glucose metabolism. Numerous researchers have reported an inverse relationship between β-glucan consumption and cholesterol levels (Lattimer & Haub, 2010).

The concentration of β-glucan in grains fluctuates based on pre- and post-harvest practices, growing circumstances, genetic determinants, and environmental factors (Simsekli and Doğan, 2015). Although β-glucan is predominantly found in the cell walls of the endosperm, the aleurone cell walls also contain small amounts of β-glucan. Compared to other cereals, barley and oats have higher β-glucan content, ranging from 3% to 11% and oats from 4% to 6%. The cell walls of barley contain approximately 70% high-molecular-weight mixed-linkage (1-3) (1-4) β-glucan (Saldamlı, 2014).

Numerous phenolic compounds vary in quality and quantity and are secondary metabolites in plant metabolism. These compounds help plants defend themselves against certain pests (Saldamlı, 2014). The primary role of antioxidants in nutrition is to prevent oxidative stress that arises from the metabolism of macromolecules (carbohydrates, proteins, and fats) during the digestive process (Güleşci and Aygül, 2016). Phenolic compounds, ascorbic acid (vitamin C), tocopherols and tocotrienols (vitamin E), and carotenoids are among the most significant antioxidant chemicals found in foods (Perera and Yen, 2007; Meral et al., 2012). Barley has been observed to possess higher vitamin E levels than other cereals. In research, the vitamin E concentration of 25 barley genotypes varied from 8.5 to 31.5 μg/g. This indicates that barley may have potential uses in functional foods as a source of vitamin E. Furthermore, barley comprises tocotrienols, isomers of tocopherols, which function as natural antioxidants. Tocotrienols and tocopherols have shown efficacy in alleviating the adverse effects of cholesterol. Recognizing that hull-less barley possesses substantial quantities of valuable constituents, numerous recent research and development studies have concentrated on its application in cereal products (Hatami Golzari, 2015; Blandino et al., 2015; Malcolmson et al., 2014; Skrbic and Cvejanov, 2011; Hatcher et al., 2005; Erkan et al., 2006).

In this study, various hull-less barley flour was blended with wheat flour at specific ratios to explore the possibilities of producing cookies with high nutritional value, including enhanced dietary fiber, phenolic compounds, β-glucan, and antioxidant content while maintaining acceptable sensory quality.

This study aimed to furnish information for creating hull-less barley foods using several Turkish varieties, which might be extensively employed in developing diverse barley-based functional foods.

MATERIALS and METHODS

Material

Two types of hull-less barley (cv. Ozen and cv. Yalin) from the Ankara Field Crops Central Research Institute and a cookie wheat variety (cv. Cetinel 2000) from the Eskişehir Transition Zone Agricultural Research Institute were used in the study. The Ozen cultivar is a two-rowed, hull-less, awned, medium-long spiking plant with white-amber grain coloration and a medium-short stature. Yalin is a two-rowed, hull-less, awned, medium-long spiking, white-amber grain-colored, and medium-tall plant type. After physical analyses of the wheat sample, it was tempered to the appropriate moisture content (15.5%) based on the pearling index value. The wheat was then milled using a Bühler laboratory mill (Bühler MLU 202, Uzwil, Switzerland) according to the International Approved Methods of the American Association of Cereal Chemists (AACCI) Method No: 26-50 to obtain cookie flour (Anonymous, 2010).

The hull-less barley varieties were milled using an ultra-centrifugal grinder (Retsch ZM 200, Germany) with a 500 µm sieve and incorporated into the cookie formulation as whole grain flour. Local stores provided the other ingredients used in the cookie recipe.

The cookie samples were made from blends in which hull-less whole barley flour was added to wheat flour at varying ratios (0%, 25%, 50%, 75%, and 100%).

Methods

Physical and Chemical Properties of Wheat and Hull-less Barley

The thousand kernel weight analysis for wheat and hull-less barley was conducted using a grain counter (Numigral II, France) according to the method described by Ozkaya and Ozkaya (2005). The hectoliter weight analysis was performed using a hectoliter measurement device (Ohaus, Chicago, USA) following the method Ozkaya and Ozkaya (2005) described. The moisture content of the cereals was determined according to AACCI Standard Method No: 44-15A, while the ash content was measured using AACCI Standard Method No: 08-01 (Anonymous, 2010). The protein content of refined wheat flour and hull-less whole barley flour was determined using the Dumas method with a nitrogen analyzer (Velp Scientifica NDA 701, Italy), according to AACCI Method No: 46-30 (Anonymous, 2010). The nitrogen-to-protein conversion factor was set at 5.7 for wheat samples and 6.25 for hull-less barley samples. The ash content of the samples was determined according to AACCI Standard Method No: 08-01 (Anonymous, 2010).

Physicochemical and Rheological Properties of Wheat Flour

The wet gluten content and gluten index values of the wheat samples were assessed following AACCI Method No: 38-12A (Anonymous, 2010). The gluten index value was determined by centrifuging the wet gluten, acquired using gluten washing equipment (Glutomatic® 2200, Perten, Sweden), in a gluten index device (Centrifuge 2015, Perten, Sweden). The wet gluten extracted from the wheat samples was subjected to drying for 5 minutes in a gluten drier (Glutork 2020, Perten, Sweden), thereafter chilled, and weighed to ascertain the dry gluten content (Ozkaya and Ozkaya, 2005). The Zeleny Sedimentation values of the flour samples were determined according to AACCI Standard Method No: 56-61A, while the Falling Number values were measured using the Falling Number device (Perten FN 1500, Huddinge, Sweden) according to AACCI Standard Method No: 56-81B (Anonymous, 2010). The samples' Farinograph properties were determined according to AACCI Standard Method No: 54-21, while the Alveograph properties were measured according to AACCI Standard Method No: 54-50 (Anonymous, 2010).

Preparation of Cookies

The cookie samples were prepared by modifying the AACCI Standard Method No. 10-54 (Anonymous, 2010), incorporating hull-less whole barley flours (Ozen and Yalin) into cookie wheat flour (Cetinel 2000) at proportions of 0%, 25%, 50%, 75%, and 100%." The formulation comprised 40.0 g of flour (at 13% moisture), 16.8 g of powdered sugar, 16.0 g of shortening, 0.6 g of high-fructose corn syrup, 0.5 g of salt, 0.4 g of non-fat dry milk, 0.4 g of sodium bicarbonate, 0.2 g of ammonium bicarbonate, and 8.8 mL of water.

The dry ingredients (powdered sugar, non-fat dry milk, salt, and sodium bicarbonate) were added to the shortening and combined using a Kitchen Aid mixer (St. Joseph, Michigan, United States). Thereafter, HFCS and ammonium bicarbonate were solubilized in water and integrated into the mixture to yield a uniform cream. Ultimately, a blend of wheat flour or a combination of wheat flour and hull-less barley flour was used, and the mixture was amalgamated to create the dough. The dough is thereafter rolled to a consistent thickness of 6 mm and cut into circles with a diameter of 60 mm. The cookies were baked at 205°C for 11 minutes.

Physical Characteristics of Cookies

The diameter (mm) and thickness (mm) of the cookie samples were evaluated following AACCI Standard Method No: 10-54 (Anonymous, 2010). The spread factor of the cookies (W/T) was determined by dividing the diameter by the thickness.

Nutritional Properties of Wheat, Hull-less barley and Cookies

The β-glucan content in the samples was enzymatically determined using the β-glucan test kit from Megazyme, following a modified version of the methods developed by McCleary and Glennie-Holmes (1985), McCleary and Codd (1991), and McCleary and Mugford (1992). This approach involves degrading glucose units generated by treating the sample with lichenase and β-glucosidase, utilizing the GOPOD (glucose oxidase-peroxidase) reagent. The resultant color is quantified for absorbance at 510 nm via a spectrophotometer (HITACHI U-1800, Tokyo, Japan).

The total dietary fiber content of the samples was determined using the Megazyme total dietary fiber kit, following AOAC Method No: 991.43 (Anonymous, 2000). The total phenolic content of the samples was determined using the Folin-Ciocalteu method, as described by Singleton and Rossi (1965) and Gao et al. (2002). The total antioxidant activity of the samples was determined using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity assay, according to the method of Brand-Williams et al. (1995).

Textural and Color Characteristics of Cookies

The textural parameters of the cookie samples (hardness and brittleness) were assessed using a texture analyzer (TA-XT plus, Stable Micro Systems, UK) following AACCI Standard Method No: 74-09 (Anonymous, 2010). The breaking force (hardness) values were determined utilizing the three-point bend rig method (load cell: 30 kg, pre-test speed: 1.0 mm/s, test speed: 3.0 mm/s, post-test speed: 10.0 mm/s, distance: 5 mm, trigger force: 50 g). The color values of the cookies were quantified using a Hunterlab MiniScan XE Plus colorimeter (USA) as follows: L* value [(0) black – (100) white], a* value [(+) red – (-) green], and b* value [(+) yellow – (-) blue]. The equation presented below (Peressini and Sensidoni, 2009) computes the total color difference (ΔE*) by deducting the L*, a*, and b* values of barley flour-enriched cookies from those of the control cookies.

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

Statistical analysis

The data obtained from the analyses were evaluated using One-Way ANOVA (single-factor analysis of variance) with SPSS v.20 software (IBM, Armonk, NY, USA), and the differences between sample means were examined at a significance level of $p<0.05$.

RESULTS and DISCUSSION

Physical and Chemical Properties of Wheat and Hull-less Barley Kernel and Flour

The hectoliter weight and thousand kernel weights of the Çetinel 2000 wheat were 77.8 kg/hl and 34.4 g, respectively. For the barley samples, the hectoliter weight and thousand kernel weight were 77.1 kg/hl-32.3 g for the Ozen variety and 80.1 kg/hl-46.0 g for the Yalın variety, with the Yalın variety showing higher values. In the study conducted by Nohutcu and Soylu (2018), it was reported that the thousand kernel weights of bread wheat genotypes developed for use in the cookie industry ranged from 34.74 g to 50.13 g, and their hectoliter weights varied between 73.19 kg/hl and 80.78 kg/hl, showing a similar variation to this study.

Table 1. Physical and chemical properties of wheat and hull-less barley

Analysis	Wheat (Cetinel 2000)	Refined Wheat Flour (Cetinel 2000)	Hull-less barley (Ozen)	Hull-less barley (Yalin)
1000 Kernel Weight * (g)	77.8±1.7	-	77.1±0.9	80.1±1.3
Hectolitre Weight (kg/hl)	34.4±0.4	-	32.3±0.2	46.0±0.3
Moisture Content(%)	-	12.98±0.02	9.84±0.08	10.68±0.1
Protein Content* (%)	-	10.20±0.03	17.1±0.09	15.8±0.05
Ash Content* (mg/100g)	-	0.50±0.01	1.95±0.02	1.83±0.03

*dry basis

It has been reported that hull-less barley contains higher crude protein content than hulled barley (Mitchall et al., 1976). A research by Edney et al. (1992) on 11 hull-less barley samples indicated that the protein content varied from 12.5% to 17.2%. When examining the protein content of the varieties used in the study, it was observed that the protein content of Ozen and Yalın whole barley flours was 17.1% and 15.8%, respectively, while Çetinel wheat flour contained 10.2% protein. The protein and ash content of whole barley flour were higher than wheat flour's.

Table 2. Physicochemical and rheological properties of wheat flour

Analysis	Wheat (Cetinel 2000) Flour
Wet Gluten Content* (%)	26.2±0.13
Dry Gluten Content* (%)	8.1±0.1
Gluten Index (%)	35±0.4
Falling Number*** (s)	390±2.5
Sedimentation Value** (ml)	22±0,5
Farinograph	
Water Absorption (%)	51.3±1.3
Development Time (min)	1.3±0.02
Stability (min)	2.5±0.07
Softening Degree (BU)	112±3.7
Alveograph	
Energy Value (10^{-4} Joule)	90±1.3
/L Ratio	0.5±0.04

*dry basis, **based on 14% moisture, ***based on %15 moisture, BU: Brabender unit

Physicochemical and Rheological Properties of Wheat Flour

Table 2 presents the values related to the flour properties obtained in the study. The wheat flour utilized in this investigation exhibits wet gluten at 26.2%, dry gluten at 8.1%, a gluten index of 35%, and zeleny sedimentation values of 22 ml. Zeleny sedimentation is considered an indicator of protein quality and is widely used by industry professionals. A low sedimentation value (<30) is desired for flour intended for use in the cookie industry. Wheat with low protein content and weak gluten properties, which is unsuitable for bread making, is preferred for cookie production.

In a study by Demir (2015) on the use of whole wheat flour and its blends in cookie production, the ash, protein, wet gluten, gluten index, and zeleny sedimentation values of cookie wheat flour were found to be 0.672%, 9.01%, 23.5%, 81.4, and 20.5 ml, respectively.

The falling number value provides information about the amylase activity in flours. The flour used in the study had a high falling number value (390 s).

Water absorption, development time, and stability values are expected to be low in flours with low protein content used for cookies (Doğan and Uğur, 2004). The study identified them as 51.3%, 1.3, and 2.5 minutes, respectively. The extent of softening is anticipated to be significant. Upon examining the alveograph values, the W (energy) value of Cetinel flour was determined to be 90 x 10^{-4} Joules. The W energy value plays an important role, particularly in evaluating the bread-making quality of flour. In a study investigating the quality parameters of wheat flour, the W value for cookie wheat flour was reported to be similar to this study, with an average of 119.6 x 10^{-4} J (Arslan, 2018).

Nutritional Properties of Flour

The nutritional contents of the wheat and hull-less whole barley flours used in the study are presented in Table 3. When examining the total β-glucan contents of the flours, it is observed that whole barley flours contain significantly higher amounts of β-glucan, dietary fiber, and phenolic compounds than wheat flour.

Table 3. Nutritional properties of wheat and hull-less barley flour

Analysis	Refined Wheat Flour (Cetinel 2000)	Hull-less barley Flour (Ozen)	Hull-less barley Flour (Yalin)
β-glucan content(%)	0.23±0.01	5.10±0.1	5.11±0.1
Total Dietary Fiber* (g/100g)	2.74±0.07	17.87±0.09	18.05±0.1
Total Phenolic Content* (mgGAE/kg)	817.30±1.2	2306.24±23.4	2413.51±25.8
Total Antioxidant Activity* (µmolTE/100g)	98.73±4.9	859.30±5.2	979.20±7.5

*dry basis, GAE: Gallic acid equivalent, TE: Trolox equivalent

The total dietary fiber contents of Cetinel wheat flour and hull-less barley flours (Ozen and Yalin) were found to be 2.74%, 17.87%, and 18.05%, respectively, with the highest amount obtained from Yalin barley flour. The total phenolic content of the barley flours was found to be 2306.24-2423.51 mg GAE/kg for Ozen and Yalın, while the antioxidant activity values were 859.30-979.20 µmol TE/100 g, with the highest values observed in Yalin whole barley flour.

Physical Characteristics of Cookies

Table 4 presents the diameter (W), thickness (T), and spread factor (W/T) characteristics of cookies made by incorporating Ozen and Yalin hull-less whole barley flours in different ratios into Cetinel 2000 flour.

The control sample exhibited a diameter of 71.24 mm, a thickness of 10.54 mm, and a spread factor of 6.76. The control sample exhibited the largest spread ratio, which diminished to 5.24 in cookies prepared with 100% Ozen barley flour and to 5.27 in those manufactured with 100% Yalin barley flour. The elevated dietary fiber and β-glucan levels in the cookie formulation result in enhanced water absorption, hence diminishing the cookies' spread factor (Sharma and Gujral, 2014).

The decrease in diameter and the increase in thickness values of the cookies were statistically significant for all supplementation ratios ($p<0.05$).

Table 4. Physical characteristics of cookies

Cookie Samples	Supplementation level (g/ 100 g)	Diameter (W) (mm)	Thickness (T) (mm)	Spread Factor (W/T)
Ozen Hull-less Barley	0	71.24^{e}	10.54^{a}	6.76^{e}
	25	70.67^{d}	11.42^{b}	6.19^{d}
	50	69.19^{c}	11.75^{c}	5.89^{c}
	75	66.76^{b}	12.45^{d}	5.36^{b}
	100	66.20^{a}	12.63^{e}	5.24^{a}
Yalin Hull-less Barley	0	71.24^{e}	10.54^{a}	6.76^{e}
	25	68.36^{d}	11.05^{b}	6.19^{d}
	50	67.65^{c}	12.06^{c}	5.61^{c}
	75	66.37^{b}	12.23^{d}	5.43^{b}
	100	65.18^{a}	12.38^{d}	5.27^{a}

The letters 'a-e' within the same column indicate that the differences between the means of different incorporation levels of the same barley flour are statistically significant ($p<0.05$).

Table 5. Nutritional properties of cookies

Cookie Samples	Supplementation level (g/ 100 g)	β-glucan Content* (%)	Total Dietary Fiber* (%)	Total Phenolic Content* (mg GAE/kg)	Total Antioxidant Activity* (μmol TE/100g)
Ozen Hull-less Barley	0	0.11[a]	1.89[a]	522.59[a]	81.88[a]
	25	0.75[b]	4.13[b]	694.45[b]	175.70[b]
	50	1.34[c]	6.25[bc]	881.58[c]	265.85[c]
	75	1.54[d]	7.98[c]	1161.05[d]	361.70[d]
	100	2.41[e]	11.62[d]	1293.97[e]	412.60[e]
Yalin Hull-less Barley	0	0.11[a]	1.89[a]	522.59[a]	81.88[a]
	25	0.73[b]	4.28[b]	698.39[b]	187.30[b]
	50	1.39[c]	6.65[c]	968.12[c]	292.70[c]
	75	1.66[d]	8.51[d]	1256.27[d]	383.55[d]
	100	2.45[e]	12.68[e]	1303.43[d]	447.50[e]

*dry basis, GAE: Gallic acid equivalent, TE: Trolox equivalent.
The letters 'a-e' within the same column indicate that the differences between the means of different incorporation levels of the same barley flour are statistically significant ($p<0.05$).

Nutritional Properties of Cookies

The β-glucan, total dietary fiber, phenolic content, and total antioxidant activity values of cookies made by incorporating different ratios of Ozen and Yalin hull-less whole barley flours into Cetinel 2000 flour are presented in Table 5. The table shows that the β-glucan and total dietary fiber content of the cookies made by adding Ozen and Yalin barley flours to Cetinel flour increased with the incorporation ratio ($p<0.05$). The highest β-glucan content (2.45%) and total dietary fiber content (12.68%) were found in the 100% Yalin barley flour cookie.

In a comparable study, various plants served as sources of active components for functional cookie creation, wherein hull-less barley flour was blended with wheat flour in varying proportions (5%, 10%, 15%, 20%, 30%) to create cookies. It was found that the total dietary fiber content in cookies with 30% hull-less barley flour increased by 183.85% compared to the control sample. The study also reported that the β-glucan content of cookies with 30% hull-less barley was 1.82% and that a 100g serving of this cookie could meet 60.67% of the FDA's recommended daily intake of β-glucan (3 g) (Hassan et al., 2012).

In a study conducted by Verardo et al. (2010), the total dietary fiber content of a cookie prepared by incorporating 60% coarse barley fraction into refined wheat flour was found to be 28.3%, while the total dietary fiber content of the control sample (100% refined wheat flour) was reported to be 4.5%.

Table 5 indicates that the control sample exhibited a total phenolic content of 522.59 mg GAE/kg and a total antioxidant activity of 81.88 μmol TE/100g. The cookies produced by integrating hull-less barley flour with Cetinel flour had the highest values when composed entirely of Yalın flour, with a total phenolic content of 1303.43 mg GAE/kg and an antioxidant activity of 447.50 μmol TE/100g.

In cookies made with barley flour, barley flour increased the total phenolic content and total antioxidant activity in proportion to the supplementation ratio. This increase was statistically significant for all supplementation levels ($p<0.05$). In a study by Sharma and Gujral (2014), barley contained higher amounts of phenolic compounds and antioxidant activity than more commonly consumed grains such as wheat and rice. In the same study, the total phenolic content of cookies made by adding varying amounts of dehulled barley flour (0%, 25%, 50%, 75%, 100%) to wheat flour ranged from 656 to 2154 μg FAE/g, with an increase in phenolic content and antioxidant activity observed as the proportion of barley flour increased.

Textural and color characteristics of cookies

The texture and color characteristics of cookies made by incorporating different ratios of Ozen and Yalin hull-less whole barley flour into Cetinel flour are presented in Table 6. As shown in the table, the hardness values of the cookies ranged between 20.64 N and 30.45 N, with the highest hardness value observed in the cookie made with 100% Yalin barley flour. The brittleness values of the cookies ranged between 38.50 mm and 42.86 mm, with the highest value again obtained from the cookie made with 100% Yalin barley flour. The increases in the hardness values of cookies with barley flour addition were significant (p<0.05). In contrast, the supplementation ratio did not significantly affect the brittleness values.

Table 6. Textural and color characteristics of cookies

Cookie Samples	Supplementation level (g/ 100 g)	Hardness (N)	Brittleness (mm)	L*	a*	b*	ΔE*
Ozen Hull-less Barley	0	20.64^{a}	40.48^{a}	70.74^{e}	3.91^{a}	19.00^{e}	-
	25	21.31^{a}	41.85^{b}	66.54^{d}	4.17^{b}	17.53^{d}	4.46
	50	25.60^{b}	41.86^{bc}	64.52^{c}	4.48^{c}	17.06^{c}	6.54
	75	27.31^{c}	42.51^{c}	62.74^{b}	4.77^{d}	16.96^{b}	8.30
	100	28.28^{c}	42.06^{bc}	61.28^{a}	4.83^{e}	16.82^{a}	9.75
Yalin Hull-less Barley	0	20.64^{a}	40.48^{a}	70.74^{e}	3.91^{a}	19.00^{e}	-
	25	25.64^{b}	42.77^{c}	64.97^{d}	4.07^{b}	17.07^{d}	6.09
	50	25.69^{b}	42.68^{b}	64.38^{c}	4.22^{c}	17.05^{c}	6.66
	75	28.62^{c}	42.78^{c}	61.76^{a}	4.50^{e}	16.86^{b}	9.25
	100	30.45^{d}	42.86^{c}	62.11^{b}	4.34^{d}	16.25^{a}	9.07

The letters 'a-e' within the same column indicate that the differences between the means of different incorporation levels of the same barley flour are statistically significant (p<0.05).

In a study by Škrbic and Cvejanov (2011), cookies were made by adding hull-less barley flour at different ratios (0%, 30%, 50%) to refined and whole wheat flour. It was reported that the hardness values increased with the incorporation ratio of hull-less barley flour for both types of wheat flour. The hardness values of the cookies made with refined wheat flour were 9.38, 9.63, and 11.7 kg, respectively, while those made with whole wheat flour were 11.8, 18.1, and 20.2 kg, respectively.

A further study examining the quality attributes of fiber-enriched cookies with different fiber ratios (0%, 5%, 10%) revealed that the hardness values of the cookies ranged from 13.53 N to 21.6 N. The hardness values rose with increased fiber content (Laguna et al., 2014).

The L* (lightness) and b* (yellowness) values were reduced by the addition of barley flour, while the a* (redness) value was increased in proportion to the incorporation ratio of barley flour, as observed during the examination of color characteristics of the cookies.

Table 6 indicates that the control sample exhibited L*, a*, and b* color values of 70.74, 3.91, and 19.00, respectively. The control sample exhibited the highest L* and b* values, whereas the cookie formulated with 100% Ozen barley flour yielded the highest a* value. The decrease in L* and b* values in the barley flour cookies was found to be significant for the incorporation ratios (p<0.05). In contrast, the change in a* value was not statistically significant (p>0.05). In a study conducted by Frost et al. (2011), when barley flour was incorporated into wheat flour at different ratios (0%, 30%, 50%, 60%, 70%) to make cookies, an increase in the a* (redness) value occurred with the addition of barley flour, while decreases were observed in the L* (lightness) and b* (yellowness) values. As the proportion of whole barley flour increased, the ΔE* value also increased, indicating a greater color difference. The most significant color difference from the control sample was observed in the cookie made with 100% Ozen barley flour.

CONCLUSION

This study used hull-less barley, a rich source of β-glucan, which contains high levels of protein, dietary fiber, phenolics, and antioxidants, all of which have clinically validated health benefits. The applicability of hull-less whole barley flour in cookie manufacturing was examined. To achieve this objective, two distinct kinds of hull-less barley (Ozen and Yalın) were milled as whole grain and included into cookie wheat flour at designated ratios (0%, 25%, 50%, 75%, 100%) to formulate flour blends utilized in cookie production. The chemical, physicochemical, and nutritional properties of the wheat and barley flours utilized as raw materials were assessed, and the functional and qualitative attributes of the cookies were examined. Hull-less whole barley flours possess markedly elevated levels of protein, β-glucan, dietary fiber, phenolic compounds, and antioxidants compared to wheat flour.

In the cookies produced, the control sample was selected as the cookie made with 100% refined wheat flour, and the effect of hull-less whole barley flour addition on the characteristics of the cookies was evaluated. Adding hull-less whole barley flour increased the cookies' β-glucan, dietary fiber, phenolic compound content, and antioxidant activity values in proportion to the additional levels. Adding hull-less whole barley flour reduced the diameter and spread ratio of the cookies while increasing their thickness. When examining the texture properties, it was found that the hardness values increased with the incorporation ratio of hull-less whole barley flour. However, incorporating hull-less whole barley did not significantly affect the brittleness. In terms of color, the cookies' L* (lightness) and b* (yellowness) values decreased with increasing supplementation ratios. In contrast, adding hull-less whole barley flour increased the a* (redness) value.

Cookies enriched with hull-less barley maintained enhanced nutritional content and potential health benefits. In conclusion, hull-less barley has been demonstrated to serve as a functional food ingredient in cookie manufacture across all supplementation levels. Additional research is advised to investigate the possibilities of hull-less barley in other functional food products. Our research provides valuable insights into the development of nutritious, functional foods with whole-grain flour from hull-less barley.

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