GIDA
THE JOURNAL OF FOOD
E-ISSN 1309-6273, ISSN 1300-3070

Research / Araştırma
GIDA (2023) 48 (1) 94-106
doi: 10.15237/gida.GD22096

D-OPTIMAL MIXTURE DESIGN APPROACH IN THE PRODUCTION OF COOKIES ENRICHED WITH DIETARY FIBER SOURCES SUCH AS LENTIL FLOUR, BANANA FRUIT AND BANANA PEEL POWDER

Semanur Yildiz*, Eylem Karakuş, Serpil Öztürk Muti
Sakarya University, Faculty of Engineering, Department of Food Engineering, Sakarya, Türkiye

Received /Geliş: 09.10.2022; *Accepted* /Kabul 30.12.2022; *Published online*/Online baskı 18.01.2023

Yildiz, S., Karakuş, E., Öztürk-Muti, S. (2023). D-optimal mixture design approach in the production of cookies enriched with dietary fiber sources such as lentil flour, banana fruit and banana peel powder. GIDA (2023) 48 (1) 94-106 doi: 10.15237/ gida.GD22096

Yildiz, S., Karakuş, E., Öztürk-Muti, S. (2023). Mercimek unu, muz meyve ve muz kabuk tozu gibi diyet lifi kaynakları ile zenginleştirilen bisküvi üretiminde D-optimal karışım tasarımı yaklaşımı. GIDA (2023) 48 (1) 94-106 doi: 10.15237/ gida.GD22096

ABSTRACT
This study aimed to develop fiber-enriched cookies by partially replacing wheat flour (WF) with alternative fiber sources including yellow lentil flour (YLF), green lentil flour (GLF), banana powder (BP), and banana peel powder (BPP). The ratios of YLF, GLF, and WF were identified as 24.5, 10.7, and 64.8 % (flour basis), respectively, considering the mixture experimental design for an optimal breaking strength of cookies. Four types of cookies were studied: (i) wheat-based cookies (WC), (ii) lentil flour, BP and BPP-incorporated cookies (LBC), (iii) BP and BPP-incorporated cookies (BC), (iv) lentil flour-incorporated cookie (LC). LC showed a higher spread ratio and lightness than LBC and BC. Although alternative ingredients enhanced dietary fiber content compared to wheat-only cookies, the liking degree of sensory attributes was lower in LBC and BC. Overall, LC was superior to LBC and BC samples, indicating possible use of lentil flours for partial replacement of wheat flour for desired physical, chemical, and sensory attributes.
Keywords: D-optimal mixture design, cookie, lentil flour, dietary fiber, optimization, banana, texture

MERCIMEK UNU, MUZ MEYVE VE MUZ KABUK TOZU GİBİ DİYET LİFİ KAYNAKLARI İLE ZENGİNLEŞTİRİLEN BİSKÜVİ ÜRETİMİNDE D-OPTİMAL KARIŞIM TASARIMI YAKLAŞIMI

ÖZ
Bu çalışma, sarı mercimek unu (YLF), yeşil mercimek unu (GLF), muz tozu (BP) ve muz kabuğu tozu (BPP) gibi alternatif lif kaynakları kullanarak buğday unu (WF) miktarı kısmen azaltılmış ve diyet lif içeriği açısından zenginleştirilmiş bisküvi geliştirmeyi hedeflemektedir. YLF, GLF ve WF'nin un bazındaki oranları karışım deney tasarımı çerçevesinde sırasıyla %24,5, %10,7, 64,8 olarak belirlenmiştir. Dört çeşit bisküvinin kalite özellikleri üzerinde çalışılmıştır: (i) buğday unu bazlı bisküvi (WC), (ii) mercimek unu, muz meyve ve kabuk tozu katkılı bisküvi (LBC), (iii) muz meyve ve kabuk tozu katkılı bisküvi (BC), (iv) mercimek unu katkılı bisküvi (LC). LC numuneleri, LBC ve

**Corresponding author* / Yazışmalardan sorumlu yazar
: semanury@sakarya.edu.tr ✆: (+90) 264 295 5853 🖷: (+90) 264 295 5601

Semanur Yildiz; ORCID no: 0000-0002-1845-7813
Eylem Karakuş; ORCID no: 0000-0002-6441-3483
Serpil Öztürk Muti; ORCID no: 0000-0002-3493-1212

BC'den daha yüksek yayılma oranı ve açık renk özellikleri göstermiştir. Alternatif lif kaynakları, yalnızca buğday unu içeren ürüne kıyasla diyet lifi içeriğini arttırsa da LBC ve BC numunelerinin duyusal özelliklerinin beğeni derecesi daha düşük kalmıştır. Genel olarak, mercimek unu katkılı bisküvi (LC), LBC ve BC örneklerinden daha üstün nitelikler göstermiş olup istenen fiziksel, kimyasal ve duyusal özelliklerdeki bisküvi üretimini sağlamak için baklagil unu kullanımıyla buğday ununun kısmi olarak azaltılmasının mümkün olabileceğine işaret etmektedir.
Anahtar kelimeler: D-optimal deneysel tasarım, bisküvi, mercimek unu, diyet lifi, optimizasyon, muz, tekstür

INTRODUCTION

The food industry needs to make advancements in ingredients and formulations due to the growing consumer demand for functional foods that provide advantages in addition to basic nutrition (Falguera et al., 2012). Cookie-type biscuits are suitable products for designing alternative formulations for diversified nutrition due to their consumption worldwide, extended shelf life, and appealing characteristics.

Legume flours have been gaining attention to enrich cakes and cookies because of their nutritional composition and positive health effects (Bravo-Núñez and Gómez, 2021). Lentils are considered one of the alternative ingredients to enhance cookie formulations or substitute wheat flour since they are good sources of protein, fiber, iron, vitamin B, and phenolic compounds (Sen Gupta et al., 2013; Hall et al., 2017). Valorization of agricultural and industrial wastes and by-products is also a critical approach for developing value-added food products considering sustainable processing and production strategies. Currently, wastes and by-products of fruit and vegetables are highly recognized as a source of bioactive compounds, dietary fiber, polysaccharides, and proteins (Narayanan et al., 2017). Fruit peels can be utilized as an ingredient in cookie formulations since they can provide dietary fiber and bioactive compounds for the final product. Consumption of dietary fiber is associated with several health benefits, including lowering the risk of diabetes, cancer, and intestinal diseases and promoting healthy gut microflora (Weickert and Pfeiffer, 2008; He et al., 2022).

Banana is one of the most popular fruits worldwide. Banana peel contributes about 40% of the total weight of fruit (Anhwange et al., 2009). Banana fruit and banana peel are well known for their content of nutrients and dietary fiber (Sidhu and Zafar, 2018); therefore, they could be a good source to produce fiber-enriched cookies. Different dietary fiber sources have been included in the cookie formulation including cereals (Sudha et al., 2007), mango peel (Ajila et al., 2008), pumpkin and carrot pomace (Turksoy and Özkaya, 2011), pomegranate peel (Colantuono et al., 2016), raspberry and blueberry pomace (Šarić et al., 2019). Lentil flours are also suggested as a promising ingredient for the enhancement of nutritional and sensory quality of bakery products including gluten-free cookies (Hajas et al., 2022).

The incorporation of dietary fiber sources into biscuit-type cookie production system to replace wheat flour leads to changes in the rheological properties of dough as well as the physicochemical, textural, and sensory characteristics of the product (Sudha et al., 2007). Since development of new foods is directly associated with consumer approval, proper optimization actions should be considered for desired color, texture, sensory, and nutritional properties. Experimental design is important in food science because it provides crucial knowledge on the effect of ingredients and processing parameters on the quality of final products that satisfy consumers' demands. Use of the experimental design is a systematic approach to optimizing new food formulations with minimum effort, time, and resources (Montgomery, 2001). Mixture design is one of the effective data collection methods to identify optimal formulation of a specific mixture (Ellouze-Ghorbel et al., 2010).

This study aims to evaluate the possibility of using different dietary fiber sources in developing a cookie-type biscuit formulation to partially replace wheat flour with lentil flour (green and yellow), banana fruit powder, and banana peel powder. Fiber-enriched cookie formulation was developed considering mixture design methodology. The optimized cookies were compared with the standard wheat-based cookie in terms of physicochemical, textural, and sensory properties. This study contributes to product development strategies using alternative dietary fiber sources including agricultural and industrial food by-products and waste.

MATERIALS AND METHODS

Materials

Commercial yellow lentil flour (YLF) and green lentil flour (GLF) were purchased from Tito (İzmir, Turkey). All-purpose shortening (Marsa, Adana, Turkey), high fructose corn syrup (42% HFCS), fine-granulated sucrose, brown-granulated sugar, skimmed milk powder, salt (NaCl), and wheat flour (13% moisture basis) were used in this study. Bananas were purchased from a local market in Sakarya at their commercial maturity. Banana fruit and banana peel were separated, sliced into pieces, and freeze-dried by using a lyophilizer (Labconco freezone 6.0., U.K.) at 0.045 mbar for 48 hours. Dried banana fruit and banana peel pieces were ground using a Waring blender, and the banana fruit powder (BP) and banana peel powder (BPP) were then used in the cookie formulation.

Preparation of cookies

Cookies were prepared according to the approved method 10-54.01 (AACC, 2000) with slight modifications. Formulation of a standard cookie using 100 % wheat flour (WF) is given in Table 1. BP and BPP were tested at 5 and 10 % levels (on flour basis) by examining the taste and odor of the cookies (data not shown). The proportions of the BP and BPP were then set at 5 % considering the sensory characteristics of the final product. Wheat flour was partially replaced with yellow and green lentil flours based on an experimental mixture design.

Fine-granulated sucrose, brown-granulated sugar, skimmed milk powder, salt, and all-purpose shortening were mixed using a dough mixer (KitchenAid, USA) to get a uniform creamed mixture, followed by the addition of 42% HFCS and water. After the addition of flours and powders, the mixture was kneaded to obtain a uniform dough. Then the dough was rolled to 7 mm thick and shaped with a circular cookie cutter with a 6.5 cm diameter. Baking was performed at 205°C for 11 min in a rotary oven (Simsek Laborteknik, Ankara Turkey).

Table 1. Standard cookie formulation

Ingredients	Weight (g)
All-purpose shortening	32
Fine-granulated sucrose	25.6
Brown-granulated sugar	8
Salt	0.5
Nonfat dry milk powder	0.8
High fructose corn syrup (42% HFCS)	1.2
Water	17.5
Sodium bicarbonate	1
Wheat flour*	40

*13% moisture basis.

Experimental mixture design

D-optimal experimental design was used to formulate the 3-component mixture system on flour basis. A mixture design was constructed using the Design Expert (version 7.0.0, Stat-Ease, USA) software to analyze the effect of varying proportions of YLF (x_1), GLF (x_2), and WF (x_3) on the breaking strength of cookies. The relationship between the component composition and cookie textural properties (i.e., breaking strength) was evaluated by performing 18 experiments. Linear, quadratic, and special cubic mathematical equations were developed in which x_i represents the fractional constrained proportion of i^{th} ingredient, $0 \leq x_i \leq 1$, i= 1, 2, ….q.

Linear $Y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3$

Quadratic $Y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3$

Special cubic $Y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \beta_{123} x_1 x_2 x_3$

where Y represents the dependent variable (i.e., breaking strength). β_i refers to the linear and cross constituent coefficients in the models. The sum of components ($\sum_{i=1}^{3} x_i = x_1 + x_2 + x_3$) is equal to 1 or equivalent to 100% in the mixture design. The upper limit for YLF and GLF was set at 44 % while the proportion of wheat flour varied between 56% and 100 %. Triangular contour plots and 3-D surface graphs were constructed based on the selected regression model.

Physicochemical properties

Weight, diameter, thickness, and spread ratio

Weight, diameter, and thickness were measured after cooling the cookies for 24 h. Six measurements were conducted using three different cookies. The spread ratio of each cookie was calculated by dividing the average diameter by the average thickness.

Color

Instrumental color measurement was conducted using a portable colorimeter PCE-CSM 7 (Alicante, Spain). The surface color of each cookie was expressed in the CIELab coordinate system. Nine measurements were performed to estimate lightness (L*), redness-greenness (a*), and yellowness-blueness (b*) of cookies. The instrument was standardized by black and white calibration before analysis.

Moisture, ash, and total dietary fiber content

The moisture content (%) of flours, powders and cookies was measured using a moisture analyzer with infrared heating (AND MX-50) at 105 °C. Ash content was determined based on AOAC Official Method 923.03 (AOAC, 2000). The total dietary fiber contents of flours, powders and cookies were determined using the enzymatic-gravimetric method according to the approved method 32-07 (AACC, 2000).

Texture

Textural properties of cookies were identified according to the procedure of Tyagi et al. (2007) with some modifications. Stable Micro Systems TA.TX2 texture analyzer (Surrey, UK) was used to determine the breaking strength and hardness of the cookies. The breaking strength values of cookies were measured in triplicate by using HDP/BS blade set probe at a pre-test speed of 2 mm/s, test speed of 3 mm/s, post-test speed of 10 mm/s, and a distance of 5 mm. The maximum force (N) required to break the cookie samples was recorded as breaking strength. Regarding hardness, HDP/90 blade set and P/2 probe were used at pre-test speed of 2 mm/s, test speed of 0.5 mm/s, post-test speed of 10 mm/s, and a distance of 5 mm. The first peak force was recorded as hardness and all measurements were repeated four times for each cookie type.

Sensory analysis

The sensorial properties of cookies were examined by 25 semi-trained panelists who were familiar with the quality aspects of baked products and randomly selected from students and staff of the Food Engineering Department (Sakarya University, Turkey). The cookie samples were assigned three-digit codes and served to panelists on white plates. The samples were evaluated in terms of appearance, color, odor, hardness, fracturability, taste, mouth feel, after-taste, and overall acceptability on a 9-point hedonic scale (1= disliked extremely, 9= extremely liked).

Statistical analysis

Data analysis was conducted using Microsoft Excel (2016) and Minitab 16 (Minitab Inc. State College, PA). The significance of the differences was determined based on an analysis of variance using the Tukey test at a 95% confidence interval ($p<0.05$).

RESULTS and DISCUSSION

Optimization of the flour mixture components

The addition of YLF and GLF to partially replace the WF in the cookie formulation was evaluated using contour and 3-D response surface graphs obtained from the mixture experimental design (Figure 1). Based on the preliminary experiments, lower and upper limits on the proportions (w/w) of the mixture components were selected as follows:

$0.00 \leq x_1, x_2 \leq 0.44$

$0.56 \leq x_3 \leq 1$

where x_1, x_2, and x_3 correspond to YLF, GLF, and WF, respectively.
The 18-run mixture experiment design generated by Design Expert (7.0) is shown in Table 2, representing the change in the breaking strength of cookies as affected by the proportions of YLF, GLF, and WF. Breaking strength of cookie decreased as the proportion of lentil flours was increased (Figure 1).

Table 2. D-optimal experimental design to optimize flour proportions based on breaking strength of cookies

Run	Proportion of flour (%)			Breaking strength (N)
	Yellow lentil	Green lentil	Wheat	
R1	26.3	17.7	56	17.03
R2	22	0	78	20.57
R3	0	35	65	25.25
R4	44	0	56	24.04
R5	7.2	7.4	85.4	25.59
R6	14.7	14.7	70.7	26.66
R7	10.2	27.8	62	19.04
R8	0	44	56	22.34
R9	0	22	78	24.85
R10	14.7	14.7	70.7	19.94
R11	0	44	56	21.18
R12	22	0	78	25.97
R13	44	0	56	23.84
R14	14.7	14.7	70.7	25.61
R15	16.6	13.9	69.5	26.91
R16	8	21.4	70.6	26.29
R17	0	0	100	29.38
R18	0	0	100	32.36

Linear, quadratic, and special cubic models were developed in terms of actual components as follows:

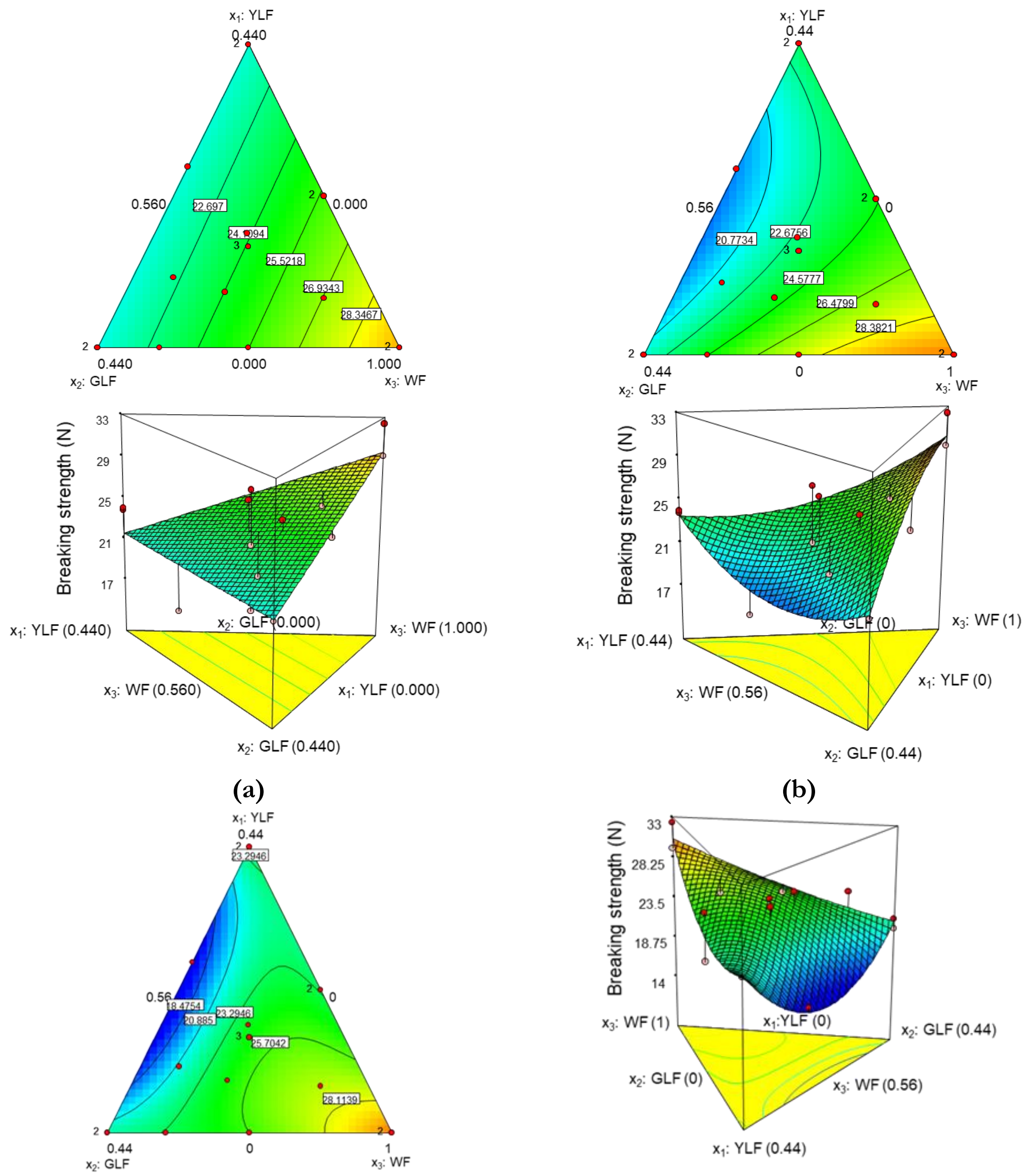
Linear $Y = 11.16x_1 + 10.50x_2 + 29.76x_3$

Quadratic $Y = 43.27x_1 - 11.53x_2 + 30.28x_3 - 74.76x_1x_2 - 50.33x_1x_3 + 39.10x_2x_3$

Special cubic $Y = 63.93x_1 + 17.63x_2 + 30.52x_3 - 908.38x_1x_2 - 85.79x_1x_3 - 11.46x_2x_3 + 1365.46x_1x_2x_3$

The coefficients of determination were 0.4887, 0.6077, and 0.7145 for linear, quadratic, and special cubic models, respectively. Variance analysis of the experimental design is given in Table 3 based on the special cubic model that is selected due to its higher R^2 value. The model was found significant ($p<0.05$) with an insignificant lack of fit ($p=0.7012$). Linear terms and the interaction of YLF (x_1) and GLF (x_2) were significant ($p<0.05$) in the model. The mixture that allowed reduction of wheat flour proportion and resulted in optimal breaking strength was identified for the final formulation on the flour basis. In this respect, 24.5 %, 10.7 %, and 64.8 % were selected for the addition of YLF, GLF, and WF to obtain lentil-based cookies (LC), respectively.

The optimized levels of flours were used with banana fruit and banana peel powders to obtain lentil- banana-based cookies. The proportions of wheat and lentil flours were selected based on the D-optimal mixture design, while banana fruit and banana peel powder were limited to 5% each on flour basis considering preliminary tests and sensorial evaluation (data not shown). Selected proportions of flours and powders are given in Table 4. WC refers to the control cookie developed using 100 % wheat flour as described in the standard cookie formulation. Lentil and banana-based cookies (LBC) comprised of the optimized lentil flour proportions (24.5 % YLF, 10.7 % GLF), 54.8 % wheat flour, 5 % banana fruit powder (BP), and 5% banana peel powder (BPP) to evaluate the incorporation of both lentil flours and banana powders. In order to differentiate the effects of BP and BPP, banana fruit and banana peel powder incorporated cookies (BC) were developed using 90 % WF, 5% BP, and 5% BPP.



(c)

Figure 1. Contour and 3-D response surface graphs for linear (a), quadratic (b), and special cubic (c) models of breaking strength of cookies as affected by the proportion of lentil and wheat flours. YLF, GLF, and WF refer to yellow lentil flour, green lentil flour, and wheat flour, respectively.

Table 3. Variance analysis of D-optimal experimental design considering a special cubic model

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	172.87	6	28.81	4.59	0.0142	significant
Linear Mixture	118.23	2	59.11	9.42	0.0041	
x_1x_2	38.93	1	38.93	6.20	0.0300	
x_1x_3	23.14	1	23.14	3.69	0.0812	
x_2x_3	0.31	1	0.31	0.049	0.8284	
$x_1x_2x_3$	25.84	1	25.84	4.12	0.0674	
Residual	69.06	11	6.28			
Lack of Fit	23.15	5	4.63	0.60	0.7012	not significant
Pure Error	45.9158	6	7.65			
Cor Total	241.925	17				

Table 4. Selected proportions of lentil flour, banana fruit, and banana peel powder

Sample	Proportion of flour and powders (%)				
	YLF	GLF	WF	BP	BPP
WC (control)	0	0	100	0	0
LBC	24.5	10.7	54.8	5	5
BC	0	0	90	5	5
LC	24.5	10.7	64.8	0	0

YLF: yellow lentil flour, GLF: green lentil flour, WF: wheat flour, BP: banana powder, BPP: banana peel powder. Control refers to wheat-only cookies (WC). LBC: lentil flour, banana fruit and banana peel powder incorporated cookies, BC: banana fruit and peel powder incorporated cookies, LC: lentil flour incorporated cookies.

Physicochemical properties of cookies

Weight, diameter, thickness, and spread ratio

The cookies prepared using the selected flour and powder proportions are shown in Figure 2. The cookie quality in terms of weight, diameter, thickness, and spread ratio is presented in Table 5. The weights of the cookies were in the range of 24.32 – 25.90 g. The diameter and thickness of cookies were in the range of 7.12 – 7.96 cm and 0.91 – 0.98 cm, respectively. Therefore, the spread ratio varied between 7.31 – 8.79, representing the ratio of the diameter and thickness of cookies. Yellow and green lentil flour incorporated cookies (LC) resulted in a higher cookie diameter and spread ratio compared to control (WC) and the banana fruit and banana peel powder incorporated cookies (LBC and BC). LBC sample had diameter, thickness and spread ratio values similar to WC sample. Similarly, Portman et al. (2019) demonstrated that cookies prepared with wheat and lentil flour blends showed flatter and wider geometry with significant increases in cookie diameter and surface area compared to the cookies prepared from 100% wheat flour. This finding was also in accordance with the study of Hajas et al. (2022).

Color attributes

The color properties of WC, LBC, BC, and LC samples are represented in Table 5 in terms of L*, a*, b* values. Lightness values were in the range of 56.99 – 72.63 which was significantly reduced by the addition of BP and BPP compared to wheat flour (WC) and lentil-incorporated (LC) cookies. This finding is attributed to the enzymatic browning reactions during cookie production in addition to the non-enzymatic browning during baking. Polyphenol oxidase is likely to be present in banana peel as a quality-degrading enzyme that could further cause a certain degree of enzymatic browning (Thipayarat, 2007). Maillard reaction, on the other hand, results in darker products because of the formation of melanoidin in the formulations with high protein and sugar content (Zucco et al., 2011). a* values varied between 8.65 – 11.92, indicating significant increases in redness of the cookies as the wheat flour was partially replaced with GLF, YLF, BP, and BPP. Redness was significantly increased with the incorporation of BP and BPP. On the other hand, b* values were significantly increased from 25.75 to 31.98 as the proportion of lentil flours increased due to the green and yellow colors originating from the lentils.

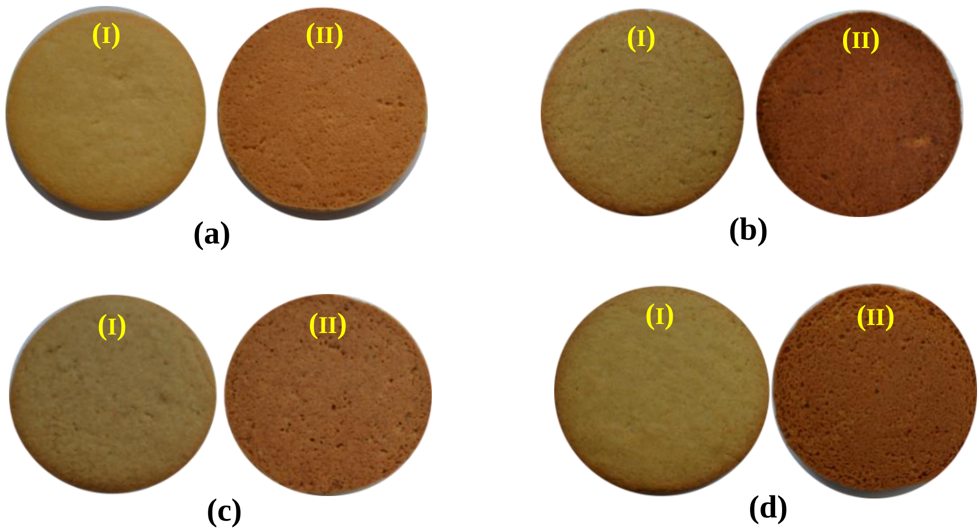


Figure 2. Picture of cookies formulated using lentil flours, banana fruit and peel powder (I) and (II) represent the front and bottom side of the cookies, respectively. a) Control: standard cookie formulation with 100% wheat flour (WC). b) Lentil flour, banana fruit and banana peel powder incorporated cookie (LBC): 24.5 % of yellow lentil flour, 10.7% of green lentil flour, 54.8 % of wheat flour, 5% of banana fruit powder, 5% of banana peel powder. c) banana fruit and banana peel powder incorporated cookie (BC): 90 % of wheat flour, 5 % of banana fruit powder, 5% of banana peel powder. d) Lentil flour incorporated cookie (LC): 24.5 % of yellow lentil flour, 10.7% of green lentil flour, 64.8 % of wheat flour.

Table 5. Physical characteristics of cookies

Sample	Diameter (cm)	Thickness (cm)	Spread ratio	Weight (g)	Color		
					L*	a*	b*
WC (Control)	7.51±0.09^{b}	0.93±0.04^{b}	8.11±0.34^{b}	25.90±1.54^{a}	72.63±0.40^{a}	8.65±0.17^{c}	25.75±0.24^{c}
LBC	7.50±0.13^{b}	0.94±0.04^{ab}	8.03±0.43^{b}	24.86±0.64^{a}	57.41±0.44^{c}	11.92±0.26^{a}	30.27±0.20^{b}
BC	7.12±0.09^{c}	0.98±0.04^{a}	7.31±0.36^{c}	25.86±0.85^{a}	56.99±1.10^{c}	11.30±0.67^{ab}	25.36±0.261^{c}
LC	7.96±0.09^{a}	0.91±0.04^{b}	8.79±0.51^{a}	24.32±1.01^{a}	68.24±2.04^{b}	9.84±1.77^{bc}	31.98±0.59^{a}

Different letters in the same column indicate significant differences among cookies ($p<0.05$). Control refers to wheat-only cookies (WC). LBC: lentil flour, banana fruit and peel powder incorporated cookies, BC: banana fruit and peel powder incorporated cookies, LC: lentil flour incorporated cookies

Moisture, ash, and total dietary fiber content

Moisture and total dietary fiber contents of flours and powders are given in Table 6. The moisture was in the range of 9.87 – 12.65 % for flours while BP and BPP had 4.31 and 7.66 % moisture, respectively. BPP had the highest fiber content (46.89 ± 1.58 %) followed by GLF (22.45 ± 0.21 %), YLF (14.66 ± 1.33 %), BP (10.77 ± 0.05 %), and WF (4.56 ± 2.15 %).

Table 6. Total dietary fiber and moisture content of flour and powders used in cookie formulation

Ingredient	Moisture content (%)	Fiber content (%)
Wheat flour (WF)	12.65±0.23	4.56±2.15
Green lentil flour (GLF)	9.87±0.11	22.45±0.21
Yellow lentil flour (YLF)	10.06±0.01	14.66±1.33
Banana powder (BP)	4.31±0.12	10.77±0.05
Banana peel powder (BPP)	7.66±0.11	46.89±1.58

Moisture levels and fiber content in ingredients have an influence on the quality properties of the final product. The chemical properties of cookies in terms of moisture, dietary fiber, and ash contents are shown in Table 7. The moisture content of cookies with substituted ingredients varied between 6.42 – 7.40 % which was not significantly different from the wheat-only control cookies. Hajas et al. (2022) recently demonstrated varying moisture levels between 8.2% and 10.0% for gluten-free cookies produced by using different lentil flour varieties. Dietary fiber content was 4.41 % in WC samples, and significantly increased to 8.83 % in LBC samples by the addition GLF, YLF, BP, and BPP. Ash contents showed a similar trend, resulting in the highest ash in LBC samples (1.56 %) followed by BC (1.27 %), LC (1.19 %), and WC (0.85 %). Thus, the addition of banana fruit powder (5%) and banana peel powder (5%) significantly increased the total dietary fiber and ash content of cookies. Portman et al. (2019) also demonstrated that the cookies containing lentil flour at a ratio of 25% and 50 % showed higher fiber content (approximately 3 – 7 %) than cookies produced with 100% wheat flour.

Table 7. Physicochemical properties of cookies

Sample	Moisture (%)	Ash (%)	Dietary fiber (%)	Hardness (N)
WC (Control)	7.19±0.09 ^{ab}	0.85±0.01^{b}	4.41±0.13 ^{b}	8.03±0.53^{a}
LBC	6.57±0.09 ^{ab}	1.56±0.29 ^{a}	8.83±0.75 ^{a}	8.51±0.74^{a}
BC	7.40±0.07 ^{a}	1.27±0.10 ^{ab}	6.14 ±0.34 ^{ab}	6.58±0.49^{b}
LC	6.42±0.41 ^{b}	1.19±0.10 ^{ab}	5.93±1.76 ^{ab}	7.92±1.04^{a}

Different letters in the same column indicate significant differences among cookies (p<0.05). Control refers to wheat-only cookies (WC). LBC: lentil flour, banana fruit and peel powder incorporated cookies, BC: banana fruit and peel powder incorporated cookies, LC: lentil flour incorporated cookies

Textural properties

The breaking strength and hardness are very important quality parameters that describe the textural characteristics of the final product. The influence of the incorporated components on the breaking strength and hardness of cookies is given in Figure 3 and Table 7, respectively. Breaking strength varied between 13.94 – 19.33 N with insignificant changes among the samples developed using the selected proportions of lentil flours, banana fruit, and banana peel powders ($p<0.05$). Nonetheless, there is a noticeable decrease in breaking strength as the wheat flour was partially replaced with GLF, YLF, BP, and BPP (Figure 3). Breaking cookies can become easier as the proportion of wheat flour decreases (Duta and Culetu, 2015). Regarding the hardness measurement, BC sample prepared with only BP (5%) and BPP (5%) incorporation showed the lowest hardness value than other formulations (Table 7). This could be due to the higher moisture content of BC sample. Addition of lentil flours, on the other hand, resulted in hardness values similar to those of wheat flour cookie (WC). Kaur et al. (2019) also reported hardness values of 12.01 – 13.55 N for raw and roasted flaxseed flour incorporated in cookies up to 30%, indicating a decrease in hardness as the amount of flaxseed flour increased in cookie formulation. On the contrary, Ganorkar and Jain (2014) reported harder cookies with incorporation of flaxseed flour up to 15% due to the water absorbing components such as fiber and proteins. In study of Hajas et al. (2022), the authors demonstrated significant increases in hardness of cookies as the rice flour was replaced with brown, green, red, and yellow lentil flours. The changes in hardness of cookies are attributed to the differences in protein and starch contents as well as the water binding capacity of flours used in the cookie formulation (Hajas et al., 2022).

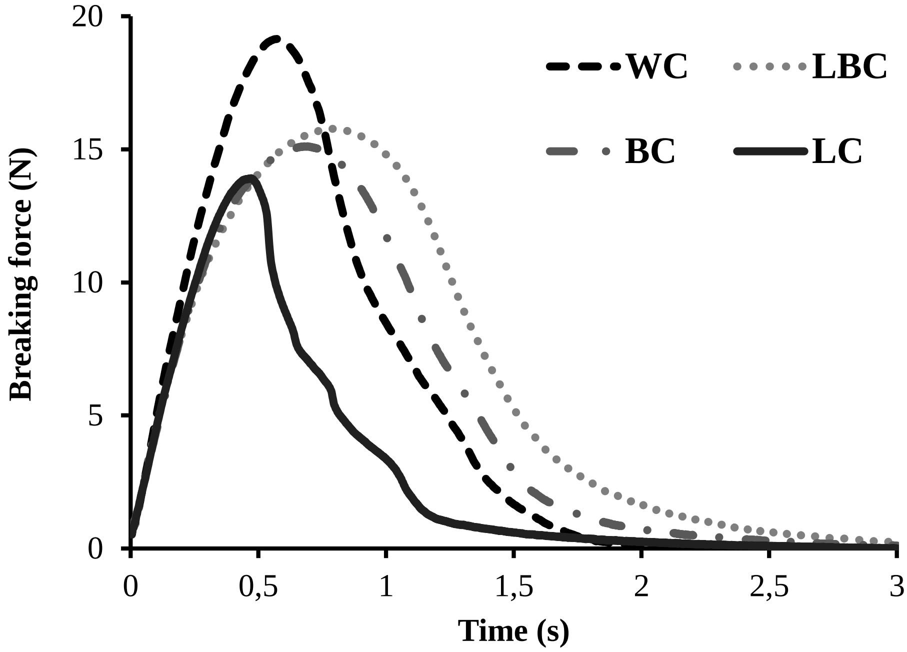


Figure 3. Change in applied force during measurement of breaking strength of cookies
WC refers to Wheat only Cookies as control. LBC: Lentil flour, Banana fruit and banana peel powder incorporated Cookies, BC: Banana fruit and banana peel powder incorporated Cookies, LC: Lentil flour incorporated Cookies.

Sensory attributes

Sensory attributes of cookies are given as a radar plot in Figure 4. Lentil flour-incorporated cookies (LC) without the addition of banana products were superior to WC, BC, and LBC in terms of appearance, color, hardness, fracturability, taste, mouthfeel, after-taste, and overall acceptability. Color is one of the primary quality criteria since consumer attitudes are first influenced by the color of the final product. There were no significant differences in the degree of liking for the surface color and appearance of cookies at the selected proportions of flours and powders. In accordance with the instrumental texture measurements, panelists ranked the hardness and fracturability in favor of lentil flour incorporated cookies (LC). BP and BPP additions resulted in lower fracturability and hardness rankings for the LBC and BC samples. Similarly, banana-based cookies received significantly lower rankings than wheat-only and lentil-based cookies in terms of odor, taste, mouthfeel, after-taste, and overall acceptability. In fact, the lentil-based cookies were more preferred than other samples, indicating the relevance of using lentil flour in cookie formulations that can make the final product more appealing to consumers. Hajas et al. (2022) also reported higher liking degree in overall acceptance for red and brown lentil cookies than rice-based cookies. Both sensory analysis and instrumental texture analysis reveal that the cookies with less breaking strength are more preferable.

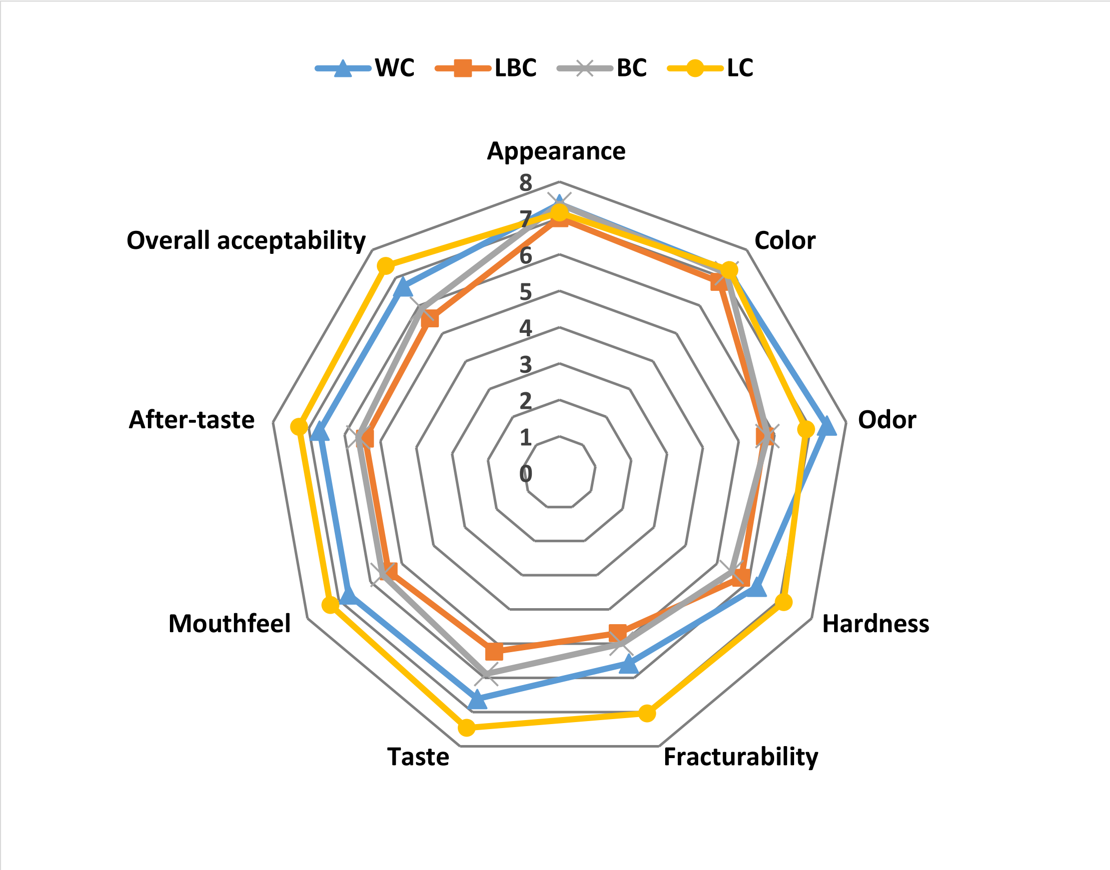


Figure 4. Sensory analysis of cookies supplemented with lentil flour, banana fruit powder, and banana peel powder

CONCLUSION

In the present study, cookies were enriched with dietary fiber by partially replacing the wheat flour with green and -yellow lentil flours, banana fruit powder, and banana peel powder. The mixture design approach allowed optimization of the proportions of the lentil and wheat flours. Physicochemical, textural, and sensory characteristics were examined while developing fiber-enriched cookies using alternative sources. The use of banana fruit and banana peel powders enhanced the dietary fiber content; however, no more than 5% is suggested for each powder in order to avoid the likely undesired changes in taste and color attributes of banana powder and banana peel powder incorporated cookies. Enzymatic and non-enzymatic browning reactions should be further studied while incorporating agricultural and industrial by-products into cookie formulations. Lentil flours can be suggested as an alternative ingredient to partially replace wheat flour in new food formulations and to develop new food products with desired physicochemical, textural, and sensory attributes.

ACKNOWLEDGMENT

We would like to thank Prof. Dr. Zehra Ayhan for providing us the opportunity to use the texture analyser equipment in her laboratory.

CONFLICT OF INTEREST

No conflict of interest.

AUTHOR CONTRIBUTIONS

Semanur Yildiz: Conceptualization, Methodology, Investigation, Writing original draft, Formal analysis, Supervision, Visualization, Review and editing. Eylem Karakuş: Investigation and Methodology. Serpil Öztürk: Methodology, Investigation, Review and editing.

REFERENCES

AACC (2000). American Association of Cereal Chemists Approved methods of the AACC (10th ed.). St. paul, MN, USA.

Ajila, C.M., Leelavathi, K.U.J.S., Rao, U.P. (2008). Improvement of dietary fiber content and antioxidant properties in soft dough biscuits with the incorporation of mango peel powder. *Journal of Cereal Science*, 48(2), 319-326.

Anhwange, B.A., Ugye, T.J., Nyiaatagher, T.D. (2009). Chemical composition of Musa sapientum (banana) peels. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, 8(6), 437-442.

AOAC (2000). Official Methods of Analysis. 15th edn. Association of official analytical chemists, Washington, DC, USA.

Bravo-Núñez, Á., Gómez, M. (2021). Enrichment of cakes and cookies with pulse flours. A review. *Food Reviews International*, 1-19.

Colantuono, A., Ferracane, R., Vitaglione, P. (2016). In vitro bioaccessibility and functional properties of polyphenols from pomegranate peels and pomegranate peels-enriched cookies. *Food & Function*, 7(10), 4247-4258.

Duta, D.E., Culetu, A. (2015). Evaluation of rheological, physicochemical, thermal, mechanical and sensory properties of oat-based gluten free cookies. *Journal of Food Engineering*, 162, 1-8.

Ellouze-Ghorbel, R., Kamoun, A., Neifar, M., Belguith, S., Ayadi, M. A., Kamoun, A., Ellouze-Chaabouni, S. (2010). Development of fiber-enriched biscuits formula by a mixture design. *Journal of Texture Studies*, 41(4), 472-491.

Falguera, V., Aliguer, N., Falguera, M. (2012). An integrated approach to current trends in food consumption: moving toward functional and organic products? *Food Control* 26:274–281.

Ganorkar, P.M., Jain, R.K. (2014). Effect of flaxseed incorporation on physical, sensorial, textural and chemical attributes of cookies. *International Food Research Journal*, 21(4).

Hajas, L., Sipos, L., Csobod, É. C., Bálint, M. V., Juhász, R., Benedek, C. (2022). Lentil (Lens culinaris Medik.) Flour Varieties as Promising New Ingredients for Gluten-Free Cookies. *Foods*, 11(14), 2028.

Hall, C., Hillen, C., Garden Robinson, J. (2017). Composition, nutritional value, and health benefits of pulses. *Cereal Chemistry*, 94(1), 11-31.

He, Y., Wang, B., Wen, L., Wang, F., Yu, H., Chen, D., Su, X., Zhang, C. (2022). Effects of dietary fiber on human health. *Food Science and Human Wellness*, 11(1), 1-10.

Kaur, P., Sharma, P., Kumar, V., Panghal, A., Kaur, J., Gat, Y. (2019). Effect of addition of flaxseed flour on phytochemical, physicochemical, nutritional, and textural properties of cookies. *Journal of the Saudi Society of Agricultural Sciences*, 18(4), 372-377.

Montgomery, D.C. (2001). *Design and Analysis of Experiments*, fifth ed. John Wiley & Sons, New York.

Narayanan, C.M., Das, S., Pandey, A. (2017). Food waste utilization: green technologies for manufacture of valuable products from food wastes and agricultural wastes. In: *Food Bioconversion*, Grumezescu, A.M. and Holban, A.M. (Eds), Volume 2, Academic Press, pp. 1-54.

Portman, D., Maharjan, P., McDonald, L., Laskovska, S., Walker, C., Irvin, H., Blanchard, C., Naiker, M., Panozzo, J.F. (2019). Nutritional and functional properties of cookies made using down-graded lentil–A candidate for novel food production and crop utilization. *Cereal Chemistry*, 97(1), 95-103.

Sen Gupta, D., Thavarajah, D., Knutson, P., Thavarajah, P., McGee, R. J., Coyne, C. J., Kumar, S. (2013). Lentils (Lens culinaris L.), a rich source of folates. *Journal of Agricultural and Food Chemistry*, 61(32), 7794-7799.

Sidhu, J.S., Zafar, T.A. (2018). Bioactive compounds in banana fruits and their health benefits. *Food Quality and Safety,* 2(4): 183-188.

Sudha, M.L., Vetrimani, R., Leelavathi, K. (2007). Influence of fibre from different cereals on the rheological characteristics of wheat flour dough and on biscuit quality. *Food Chemistry*, 100(4), 1365-1370.

Šarić, B., Dapčević-Hadnađev, T., Hadnađev, M., Sakač, M., Mandić, A., Mišan, A., Škrobot, D. (2019). Fiber concentrates from raspberry and blueberry pomace in gluten-free cookie formulation: effect on dough rheology and cookie baking properties. *Journal of Texture Studies*, 50(2), 124-130.

Thipayarat, A. (2007). Quality and physiochemical properties of banana paste under vacuum dehydration. *International Journal of Food Engineering*, 3(4).

Turksoy, S., Özkaya, B. (2011). Pumpkin and carrot pomace powders as a source of dietary fiber and their effects on the mixing properties of wheat flour dough and cookie quality. *Food Science and Technology Research*, 17(6), 545-553.

Tyagi, S. K., Manikantan, M. R., Oberoi, H. S., Kaur, G. (2007). Effect of mustard flour incorporation on nutritional, textural and organoleptic characteristics of biscuits. *Journal of Food Engineering*, 80(4), 1043-1050.

Weickert, M.O., Pfeiffer, A.F. (2008). Metabolic effects of dietary fiber consumption and prevention of diabetes. *The Journal of Nutrition*, 138(3), 439-442.

Zucco, F., Borsuk, Y., Arntfield, S.D. (2011). Physical and nutritional evaluation of wheat cookies supplemented with pulse flours of different particle sizes. *LWT-Food Science and Technology*, 44(10), 2070-2076.