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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Development of vegan cookies using composite flour and determination of their principal quality characteristics

Kompozit un kullanılarak vegan bisküvilerin geliştirilmesi ve bunların temel kalite özelliklerinin belirlenmesi

Emir Ayşe ÖZER[1], Neslihan ÖZBULDU[1], Nasra ÇOBAN[1]

[1]*Hatay Mustafa Kemal University, Faculty of Agriculture, Department of Food Engineering, Hatay, Türkiye.*

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Corresponding author/Sorumlu yazar:
Emir Ayşe ÖZER
ayseozer@mku.edu.tr

ABSTRACT

The aim of this study was to investigate and optimise the quality characteristics of cookies that can be consumed by vegans and individuals of all age groups. The study was designed by using the Response Surface Method, in which oil mixture (A) and bean flour (B) were selected as independent variables. The maximum and minimum ranges of these variables were determined as 10.0-25.0% for A and 0.0-100.0% for B. Variable A was a 1:1 mixture of olive oil and sunflower oil. Oat flakes and whole wheat flour in a 1.0:1.5 ratio were used in formulations with a variable B of less than 100 g. The effects of oil mixture and composite flour of beans, oat flakes and whole wheat on physical and sensory properties of cookies were investigated. As a result of the experimental design, the optimum production conditions were determined as 25.0 g oil mixture and 24.0 g bean flour. In these production conditions, water activity value was 0.50, diameter value was 4.50, thickness value was 0.65, L* value was 52.00, overall acceptability value was 4.00 and affordability value was 4.00. The desirability value of the optimised cookie was determined as 80%. With this study, a cookie formulation completely free of animal products was developed for individuals of all age groups who have both vegan diet preference and healthy eating awareness.

ÖZET

Bu çalışmanın amacı, vegan ve her yaş grubundan bireylerin tüketebileceği bisküvilerin kalite özelliklerini incelemek ve optimize etmektir. Çalışma, Tepki Yüzey Yöntemi kullanılarak tasarlanmış ve bağımsız değişken olarak yağ karışımı (A) ve beyaz fasulye unu (B) seçilmiştir. Bu değişkenlerin maksimum ve minimum aralıkları A için %10.0-25.0 ve B için %0.0-100.0 olarak belirlenmiştir. A değişkeni 1:1 oranında zeytinyağı ve ayçiçek yağı karışımıdır. B değişkeninin 100 gramdan az olan formülasyonlarında 1.0:1.5 oranında yulaf gevreği ve tam buğday unu karışımı kullanılmıştır. Yağ karışımı ve fasulye, yulaf gevreği ve tam buğdaydan oluşan kompozit ununun bisküvilerin fiziksel ve duyusal özellikler üzerindeki etkileri araştırılmıştır. Deneysel tasarım sonucunda, en uygun üretim koşulları 25.0 g yağ karışımı ve 24.0 g fasulye unu olarak belirlenmiştir. Bu üretim koşullarında su aktivitesi değeri 0.50, çap değeri 4.50, kalınlık değeri 0.65, L* değeri 52.00, genel kabul edilebilirlik değeri 4.00 ve satın alınabilirlik değeri 4.00 olarak belirlenmiştir. Optimize edilen bisküvinin arzu edilebilirlik değeri ise %80 olarak belirlenmiştir. Bu çalışma ile, hem vegan beslenme tercihine sahip hem de sağlıklı beslenme bilinci taşıyan her yaş grubundan bireyler için tamamen hayvansal ürünlerden arındırılmış bir bisküvi formülasyonu geliştirilmiştir.

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INTRODUCTION

Veganism is defined as a lifestyle aimed at preventing the exploitation and harming of animals for food, clothing or other areas (Akbulut & Yeşilkaya, 2021; Hule et al., 2021; Durlu Özkaya et al., 2022). In recent years, the number of individuals adopting a vegan diet is increasing in many countries and this trend is rapidly spreading worldwide (Sakkas et al., 2020; Jakše, 2021; Koeder & Perez-Cueto, 2024). According to surveys, vegan individuals constitute 13% of the population in Asia, 6% of the population in the USA and 4% of the population in Europe (The Vegan Society, 2021; Selinger et al., 2022). In Türkiye, the number of vegan individuals is reported to be below 5% of the population (Güler & Çağlayan, 2021).

The common trait of vegans is that they avoid all foods derived from animals, such as dairy products, meat (including fish, shellfish and insects), eggs and honey (Tunçay, 2018; Koeder & Perez-Cueto, 2024). Therefore, having an adequate and balanced diet in vegan individuals is a very important factor in terms of a healthy diet (Durlu Özkaya et al., 2022; Koeder & Perez-Cueto, 2024). Vegans typically consume legumes and cereals as their primary sources of protein. In addition, oilseeds, vegetables, and fruits play a significant role in their diet. These foods, which constitute the basic elements of a healthy diet, are very important in the prevention of chronic diseases. It has been reported that high consumption of these foods can reduce the risk of diseases such as obesity, diabetes, hypertension, and cancer (Yegen & Aydın, 2018; Akbulut & Yeşilkaya, 2021; Craig et al., 2021). However, when vegans are unable to maintain an adequate and balanced diet, the risk of vitamin B_{12} and protein deficiency may be unavoidable. In addition to vitamin B_{12}, deficiencies in vitamin D, calcium, zinc, iron, and omega-3 fatty acids may also be observed in these individuals. It has been reported that these deficiencies can be overcome by regular use of supplements (Tunçay, 2018; Akbulut & Yeşilkaya, 2021; Balcı & Göktaş, 2023; Koeder & Perez-Cueto, 2024).

In recent years, snack consumption has also increased due to lifestyle changes such as increased awareness of healthy eating and education levels, more women entering the business life, an increase in the number of vegans and the importance of time (Ahmed et al., 2018; Craig et al., 2021; Hule et al., 2021; Durlu Özkaya et al., 2022; Özer et al., 2022). Cookies, as one of these snack products, provide convenience to individuals because they are affordable, readily available, have a long shelf life and are ready to eat. Because of these characteristics, cookies are consumed by people of almost every age group (Nogueira & Steel, 2018; da Silva et al., 2021; Hule et al., 2021; Özer, 2022; Gebremariam et al., 2024).

In recent years, different cookie formulations have been developed to overcome potential deficiencies in the diets of vegan individuals and to contribute to a balanced diet (Budsabun et al., 2019; da Silva et al., 2021; Aksu, 2023; Alexandrino et al., 2023; Pyanikova et al., 2024). In these formulations, vegetable margarines (Breschi et al., 2024), sunflower oil (Hule et al., 2021), palm and soybean oils (Cantele et al., 2022), olive oil (Durlu Özkaya et al., 2022) were used as oil sources. The 2-3% of phenolic compounds present in olive oil have a significant effect on the prevention of cardiovascular diseases (Ganesan et al., 2018; Gorzynik-Debicka et al., 2018). In addition, oleic acid, one of the main components of olive oil, has the potential to reduce LDL cholesterol and triglyceride levels (Akçay & Öngün Yilmaz, 2019). For this reason, it is recommended that olive oil should be included in the daily diet of people of all ages.

As a nutritious and economical food, beans are an important food source in vegan diets. Due to their high protein and fibre content, they support body functions, regulate the digestive system and help balance cholesterol levels. Since it is rich in iron, it contributes to the elimination of iron deficiency in vegans (Suárez-Martínez ve ark., 2015; Marrone ve ark., 2021; Terzi ve ark., 2020; Koeder & Perez-Cueto, 2024, Sánchez-Quezada ve ark., 2024).

Regarding the grains, oats provide energy, lowers cholesterol, supports digestive health and contributes to the immune system thanks to its high carbohydrate and dietary fibre content. Due to its low glycaemic index, it balances blood sugar and provides a feeling of satiety for a long time. As an economical and easily accessible option, oats are

very important in the balanced nutrition plans of vegan individuals (Hule et al., 2021; Thakur ve ark., 2023; Henden ve ark., 2024; Seyhan ve ark., 2024).

Increasing individual demands for healthy eating and popular nutrition trends have also increased the sensitivity in dietary preferences. In this context, the aim of this research was to produce sensory acceptable cookies using a composite flour and vegetable oil mixture. Vegan dietary requirements and easy availability of ingredients were taken into account when formulating the cookies. Consequently, for people of all ages who prefer a vegan diet and are concerned about their health, a cookie recipe was developed and evaluated that is completely free of animal products in this work.

MATERIALS and METHODS

Baked white bean flour (İpek Değirmen, Türkiye), whole wheat flour (Söke, Türkiye), oat flakes (Eti, Türkiye), sunflower oil (Yudum, Türkiye), olive oil (Komili, Türkiye), magnesium, calcium and vitamin D mixture tablets (Altapharma, Germany), sodium and ammonium bicarbonate (Merck, Germany) were used in cookie production. The other ingredients of the cookie formulation (sunflower seeds, turmeric, vanilla, guar gum, salt) were purchased from the local markets located in Hatay province, Türkiye.

Determination of formulations for the production of cookies and experimental design

This study was designed using the Response Surface Method (RSM), which is an experimental design method. Design Expert 7.0 software (Stat-Ease Inc., USA) was used for the response surface methodology. Cookies were designed and optimised using Central Composite Design (CCD) in a response surface method. In this method, the first step was to determine the independent variables that are thought to affect the dependent variables and their levels (Myers et al., 2016). For this purpose, preliminary trials were conducted and a CCD with linear and quadratic models was used to examine the combined effects of two independent variables, oil mixture (A) and bean flour (B). As a result of the preliminary trials, the maximum and minimum amount ranges of the independent variables used in the study were determined to be 10.0-25.0% for the variable A and 0.0-100.0% for the variable B. Variable A was a 1:1 mixture of olive oil and sunflower oil. For formulations with variable B less than 100 g, a 1.0:1.5 mixture of oat flakes and whole wheat flour was used. The dependent variables were selected as water activity, diameter, thickness, spreading rate, colour values (L*, a* and b*) and sensory evaluation (appearance, structural properties, overall acceptability and affordability values).

The production of cookies according to CCD was carried out in 13 productions ($N = 2^k + 2k + n_0$, N is the number of experiments, k is the number of factors and n_o is the number of replicates) in different combinations of two variables and the production ranges are shown in Table 1.

Table 1. Experimental design used in the production of cookies
Çizelge 1. Kurabiye üretiminde uygulanan deneysel tasarım

Independent variables	**Code**	**-1**	**0**	**+1**
Oil mixture (g/100 g)	A	10.0	17.5	25.0
Bean flour (g/100 g)	B	0.0	50.0	100.0

Run	**A**	**B**
1	10.0	0.0
2	17.5	50.0
3	17.5	50.0
4	25.0	50.0
5	10.0	50.0
6	10.0	100.0
7	25.0	0.0
8	17.5	100.0
9	17.5	0.0
10	17.5	50.0
11	17.5	50.0
12	25.0	100.0
13	17.5	50.0

Production of cookies

The cookies were produced according to the American Association of Cereal Chemists (AACC) Method No: 10-54.01 with some modifications (AACC, 2000). First, the amount of bean flour specified in the formulation was mixed with hot water and left to stand for 20 min. Then turmeric (3 g), guar gum (5 g), vanilla (1.5 g), sunflower seeds (15 g), salt (1 g), ammonium bicarbonate (0.5 g), sodium bicarbonate (1 g) and mineral mixture (2 tablets) were added to the bean flour and homogenised by mixing in a blender (Kitchenaid, USA) for 2 min. Oil was added in the amounts determined in the experimental design and mixed for 3 min, scraping every 30 sec. Finally, different amounts of water (30-50%) were added according to the ratios of oil mixture and bean flour. The mixture was again mixed for 2 min by scraping every 30 sec and the kneading process was completed. After resting for 20 minutes at room temperature, the doughs were shaped into discs with a diameter of about 50 mm and a thickness of 5 mm. The cookies were baked at 180°C for 20 min, then turned and baked again for a further 2 min in a household oven (M4256, Simfer, Kayseri, Türkiye) (Figure 1). After the cookies reached room temperature (after approximately 30 min), some of them were used for analysis and some of them were ground in a grinder (Premier PRG 259, Istanbul, Türkiye) and stored in polyethylene containers.

Figure 1. The appearance of functional vegan cookies produced in the study
Şekil 1. Çalışmada üretilen fonksiyonel vegan kurabiyelerin görünümü

Physical analyses of cookies

Water activity analysis

The water activity values of the cookies were determined by using the Novasina LabStart-AW (Switzerland) water activity meter. The ground cookies were transferred to the water activity meter containers and placed in the chamber of the instrument and then measurements were carried out in three parallels at room temperature (Li et al., 2017).

Determination of diameter, thickness and spread ratio

The diameter and thickness of the cookies were measured using callipers (W 2320, Wert, China) according to the AACC Method No: 10-50.05. To determine the diameter and thickness values, measurements were taken at different points of five cookies from each production and the data were recorded. The spread ratio of the cookies was obtained by dividing the diameter value by the thickness value for each cookie (AACC, 2000).

Colour analysis

The CIE L* (lightness), a* (redness/greenness), and b* (yellowness/blueness) colour values of the cookies were determined using a Minolta CM 3600d model colour measuring meter (Cansev et al., 2024).

Sensory analysis of cookies

The sensory evaluation of the cookies was carried out by 10 trained panellists aged between 25 and 45 years, consisting of faculty members and graduate students from the Faculty of Agriculture at Hatay Mustafa Kemal University, Antakya, Hatay, Türkiye. Prior to the study, the panellists were provided with detailed information about the purpose, processes and expected contributions of the research and their participation was entirely voluntary. The evaluation process was conducted in accordance with ethical principles.

The cookies were evaluated in terms of four sensory attributes (appearance, structural characteristics, overall acceptability and affordability) using a 1-5 hedonic scale. For the parameters of appearance, structural characteristics and overall acceptability, the scale was rated as '1 = did not like at all', '3 = liked moderately' and '5 = liked very much'. For the affordability parameter, the expressions '1 = definitely would not buy', '3 = undecided' and '5 = definitely would buy' were used (Özer et al., 2022).

The optimisation of cookies and statistical evaluation

Design Expert 7.0 software was used for regression analysis, analysis of variance and optimisation of the experimental design. Numerical optimisation was used to determine the dependent and independent variables of the cookies and the optimum values of these variables. The method was based on the desirability function (Myers et al., 2016). While performing the optimisation, the maximum and minimum value ranges of the independent variables specified in the experimental design were selected. The dependent variables were the minimum and maximum ranges of water activity, diameter and thickness values, the maximum values of L*, overall acceptability and affordability.

RESULTS and DISCUSSIONS

Physical analysis results of cookies

Water activity values

Cookies can be easily stored for a long time due to their low moisture content and water activity compared to other bakery products (Dizlek, 2020). The water activity values of the cookies were found to be between 0.35 and 0.75 (Figure 2). The water activity values of the cookies were similar to those reported in the literature (Cantele et al., 2022; Alexandrino et al., 2023). The water activity of the cookies decreased as the amount of oil mixture increased (Figure 2) and this decrease was found to be significant (0.001<p). It was found that the cookie with the highest water activity value was the one with the lowest oil content and without bean flour. It was determined that the water activity values of the cookies were higher than those reported in the study of Engi (2024). This is thought to be related to the significant amount of dietary fibre content and water absorption capacity of oats in the cookie composition (Yang ve ark., 2023). This is supported by the fact that the cookie with the lowest water activity was consisted of 100.0% bean flour.

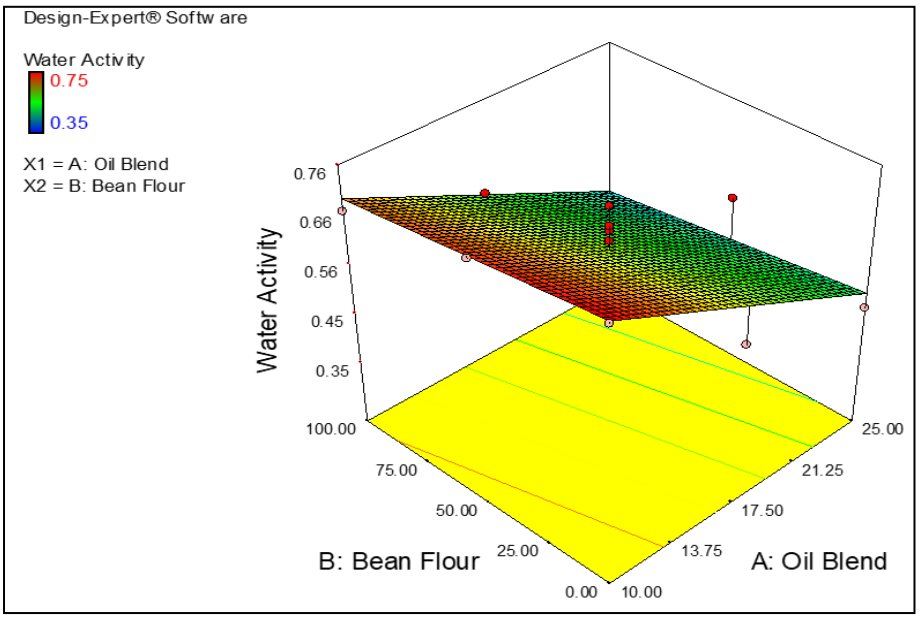

Figure 2. 3D Response Surface Method model plots of the water activity values of cookies

Şekil 2. Bisküvilerin su aktivitesi değerlerinin 3D Tepki Yüzey Yöntemi model grafikleri

Diameter, thickness and spread ratios

Diameter, thickness and spread ratio are important factors in determining the technological quality of cookies. In general, cookies with a large diameter, high spread ratio and low thickness are preferred (Demirel & Demir, 2018; Aydos & Ertaş, 2023; Demirbüker Kavak & Akdeniz, 2023).

The diameter values of the cookies ranged from 4.38 to 4.68 cm (Figure 3). The diameter value of the cookies increased in parallel to the increase in the ratio of bean flour and oil mixture and these increases were found to be insignificant ($p>0.05$). However, the interaction of the bean flour and oil mixture was found to be significant ($p<0.05$). It was found that the ranges of diameter values of the cookies were similar to those reported in the literature (Özer, 2022; Özer et al., 2022).

The thickness values of the cookies were found to be between 0.50 and 0.74 mm (Figure 3). As the bean flour content increased up to 50.0%, the thickness value tended to decrease non-linearly and then showed a slight increase ($p<0.05$). A slight increase in the thickness values was observed with the increase in oil mixture, but this increase was found to be insignificant ($p>0.05$). The range of cookie thickness values was found to be similar to those reported in the literature (Özer et al., 2022; Aydos & Ertaş, 2023; Dada et al., 2023).

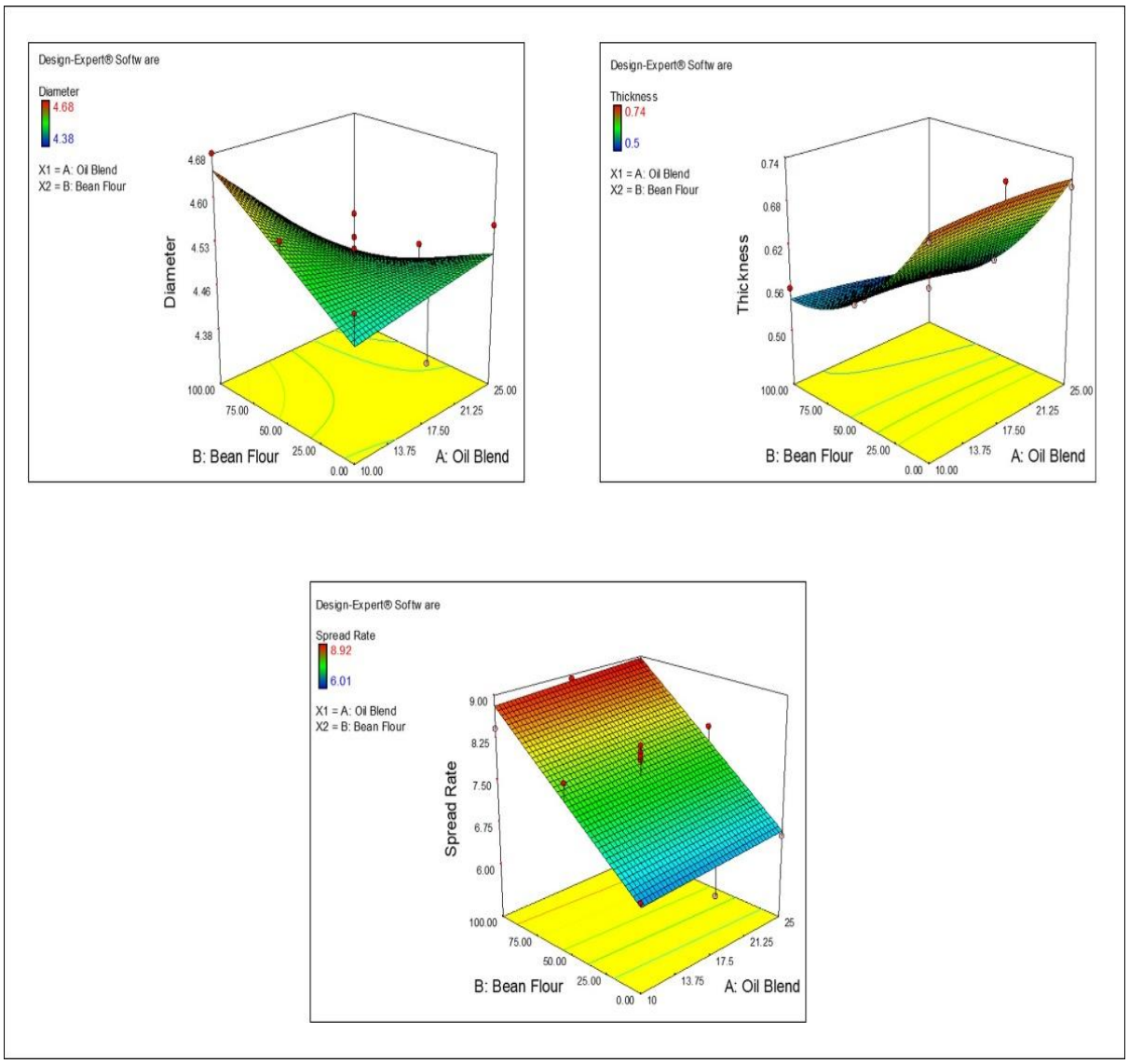

Figure 3. 3D Response Surface Method model plots of diameter, thickness and spread ratio values of cookies

Şekil 3. Bisküvilerin çap, kalınlık ve yayılma oranı değerlerinin 3D Tepki Yüzey Yöntemi model grafikleri

The spread ratio values of the cookies ranged from 6.01 to 8.92 (Figure 3) which increased linearly as the bean flour ratio increased and this increase was found to be significant ($p<0.0001$). The spread ratio increased with increasing oil mixture (Figure 3); however, this increase was not significant ($p>0.05$). The spread ratio is related to the viscosity of the cookie dough (Aydos & Ertaş, 2023) and it has been reported that the higher this value is, the higher the acceptance of the cookie (Dada et al., 2023). It was observed that the range of spread ratio values of cookies were similar to those reported in the literature (Özer et al., 2022; Aydos and Ertaş, 2023; Demirbüker Kavak and Akdeniz, 2023).

Colour values

Colour is an important parameter for the overall acceptability of cookies (Dada et al., 2023). The L* (lightness) values of the cookies ranged from 45.89 to 52.22 (Figure 4). In the analysis, the effect of the bean flour on the L* value was found to be insignificant ($p>0.05$), while the effect of the oil mixture was found to be significant ($p<0.01$). The L* value decreased as the bean flour ratio increased, but the slope of this reduction decreased when the bean flour ratio was 50.0% and the oil mixture ratio was 10.0%. The L* value increased as the oil mixture increased, but this increase became less significant after 17.5% oil content (Figure 4). The L* values of the cookies were found to be consistent with the data reported in other studies on vegan cookies (Cantele et al., 2022; Alexandrino et al., 2023).

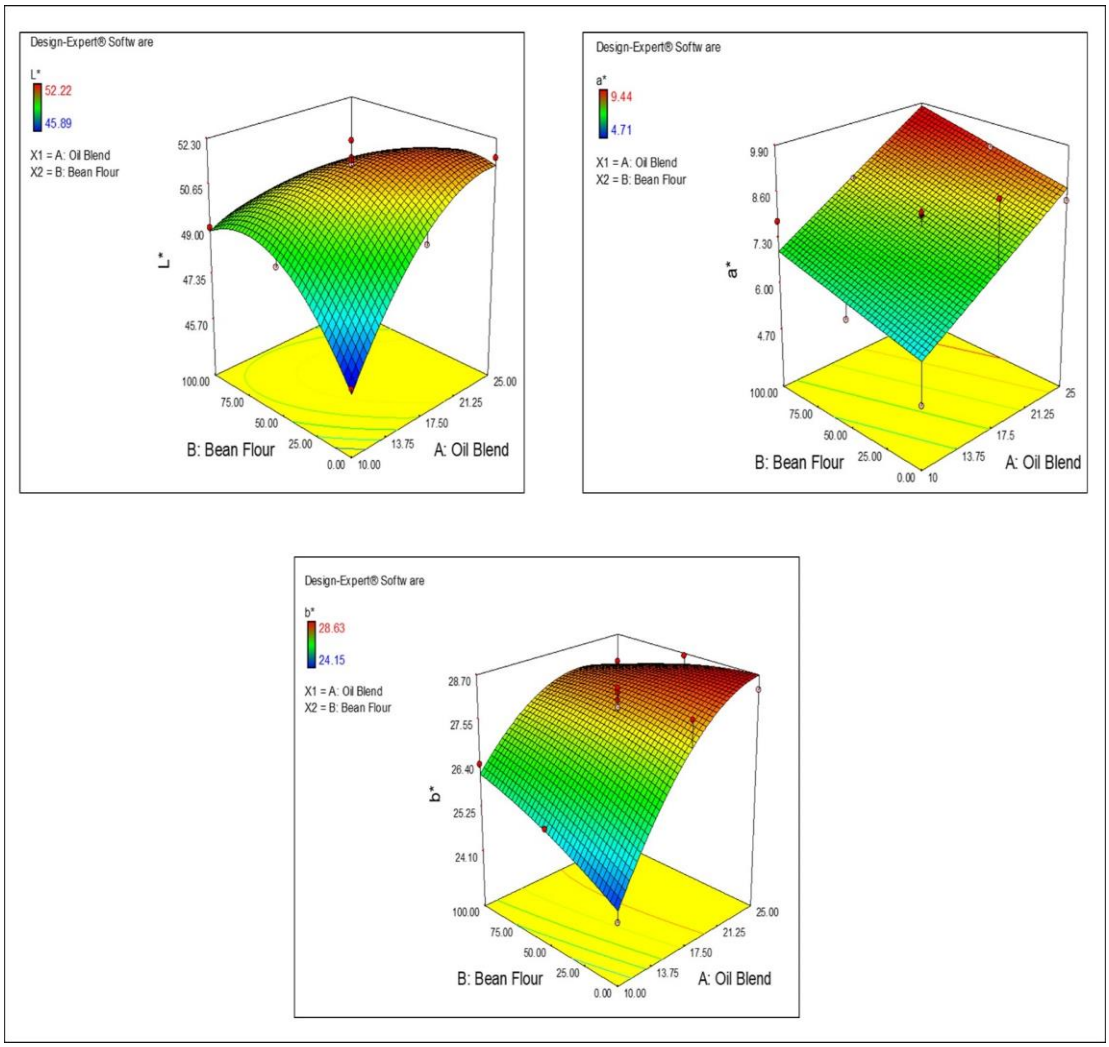

Figure 4. 3D Response Surface Method model plots of L*, a* and b* values of cookies

Şekil 4. Bisküvilerin L, a* ve b* değerlerinin 3D Tepki Yüzey Yöntemi model grafikleri*

The a* colour values of the cookies were found to be between 4.71 and 9.44 (Figure 4). While the effect of bean flour on the a* value was not significant ($p>0.05$), the effect of the oil mixture was significant ($p<0.0001$). A slight increase in the a* values of the cookies was observed as the bean flour ratio increased, while a linear increase in the a* values was observed as the oil blend increased (Figure 4). The a* values of the cookies were found to be compatible with the study on vegan cookies (Breschi et al., 2024).

The b* values of cookies ranged from 24.15 to 28.63 (Figure 4). While the effect of bean flour on b* values was found to be insignificant ($p>0.05$), the effect of oil mixture was found to be significant ($p<0.001$). A slight increase in the b* values of the cookies was observed as the bean flour ratio increased. While a rapid increase in b* values was observed as the oil mixture increased from 10.0% to 17.5%, a slight increase in b* values continued as the oil mixture increased from 17.5% to 25.0% (Figure 4). The b* values of the cookies were found to be compatible with other studies on vegan cookies (Alexandrino et al., 2023).

Sensory evaluation of cookies

In the product development process, sensory acceptability values play an important role in determining how a product is perceived and accepted by the consumers and target market (Loong & Wong, 2018; Byrne, 2020). Consumer acceptance is analysed based on various factors such as product attributes, functionality and pricing strategies (Byrne, 2020; Rai et al., 2023). Therefore, market research and consumer feedback are essential elements of an effective product development processes.

The scores for the appearance of the cookies ranged from 3.78 to 4.78 (Figure 5). In the analysis, the effect of the amount of bean flour on the appearance was found to be significant ($p<0.05$), but the effect of the amount of oil mixture was found to be insignificant ($p>0.05$). It was observed that the scores given for the appearance of the cookies increased as the amount of bean flour and oil mixture increased (Figure 5).

It was observed that the scores for the structural characteristics of the cookies ranged from 3.22 to 4.44 (Figure 5). In the analysis of the structural characteristics, the effect of the amount of bean flour was found to be insignificant ($p>0.05$), while the effect of the amount of oil mixture was found to be significant ($p<0.01$). It was observed that as the amount of oil mixture in the composition of the cookies increased, the scores given to the structural characteristics of the cookies also increased (Figure 5).

The overall acceptability scores of the cookies were found to be between 3.33 and 4.44 (Figure 5). The overall acceptability scores increased with increasing oil mixture ($p<0.01$). The overall acceptability scores decreased as the amount of bean flour increased, but this decrease was not significant ($p>0.05$).

The cookie affordability scores ranged from 3.00 to 4.22 (Figure 5) and these scores increased with increasing oil mixture and this increase was found to be significant ($p<0.01$). Affordability scores decreased as the amount of bean flour increased, but this decrease was not significant ($p>0.05$).

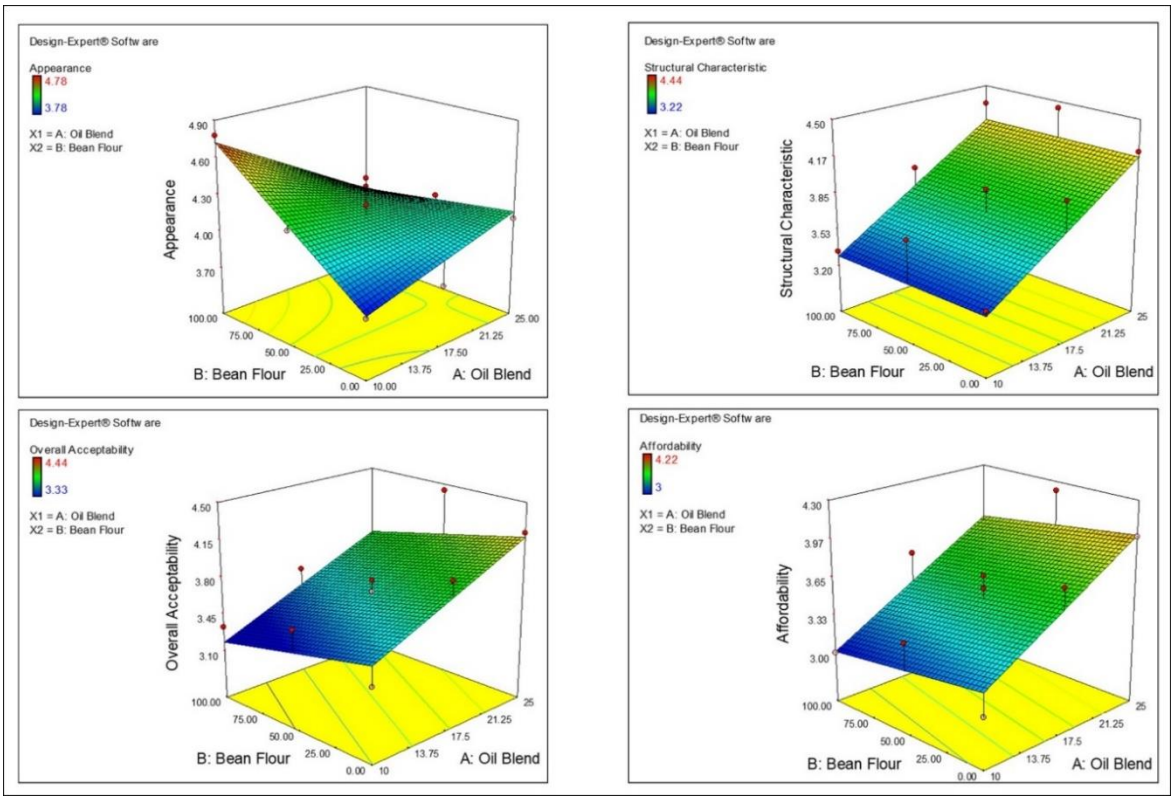

Figure 5. 3D Response Surface Method model plots of sensory evaluation of cookies

Şekil 5. Bisküvilerin duyusal değerlendrimelerinin 3D Tepki Yüzey Yöntemi model grafikleri

Statistical evaluation of cookie analyses

In the context of the physical and sensory analyses of the cookies, the results of the statistical analysis of the independent variables obtained by the Response Surface Method and the equations derived from the coded factors are presented in Table 2. Lack of fit was found to be insignificant ($p>0.05$) in all models for 11 responses.

The factor A, one of the independent variables, was found to have a significant effect on water activity, L*, a*, b* colour parameters, structural characteristics, overall acceptability, and affordability values (Table 2) ($p<0.01$). The effect of the factor B was found to be significant on thickness, spread ratio and appearance values ($p<0.001$). The effect of variables A and B on the diameter values was found to be statistically insignificant and therefore this model was also considered insignificant ($p>0.05$).

When the equations derived from the coded factors explaining the relationships between the independent variables were analysed, it was found that the variables A and B had a negative linear effect on water activity (Table 2). This showed that as both variables increased, the water activity value decreased.

In the analysis performed on the diameter values, it was observed that variable A had a negative linear effect while variable B had a positive linear effect (Table 2). In addition, the model also included a negative two-way interaction term (oil mixture-bean flour). When the model was evaluated, it was seen that the diameter value decreased as variable A increased, and it increased as variable B increased and both variables had a negative interaction.

In the model explaining the effect of the independent variables on the thickness value, it was determined that variables A and B had negative linear effects (Table 2). In addition, the model includes a negative two-way interaction term (oil mixture-bean flour) and it was found that oil mixture had a negative and bean flour had a positive quadratic effect. This showed that the variables had both a linear and a quadratic effect on the thickness value.

It was also observed that the variables A and B were found to have positive linear effects in the spread ratio analysis (Table 2). Moreover, this model was found to be significant. This shows that an increase in both variables had a positive effect on the spread ratio and the model strongly reflected this effect.

In the model explaining the effect of the independent variables on the L* value, it was determined that variable A had positive linear effects as variable B had negative linear effects (Table 2). In addition, it was found that there was a negative two-way interaction term (oil mixture-bean flour) in the model and both oil mixture and bean flour had negative quadratic effects ($p<0.001$). These results showed that the variables had both a linear and a quadratic effect on the L* value.

In the analysis of the a* value, variables A and B were found to have positive linear effects and the model was significant (Table 2) ($p<0.01$). This showed that an increase in both variables had a positive effect on the a* value.

Table 2. Model summaries and analyses of variance (ANOVA) of dependent variables of vegan cookies

Çizelge 2. Vegan kurabiyelerin bağımlı değişkenlerinin model özetleri ve varyans analizleri (ANOVA)

Response	Model	LF	R^2	Adj. R^2	SD	Final equation in terms of coded factors
Water activity	Linear ***	ns	0.75	0.70	0.06	$Water\ Activity = 0.60 - 0.13A - 0.03B$
Diameter	2FI Model ns	ns	0.51	0.34	0.07	$Diameter = 4.51 - 0.05A + 0.02B - 0.08A * B$
Thickness	Quadratic***	ns	0.93	0.88	0.03	$Thickness = 0.58 - 0.01A - 0.09B - 0.01A * B - 0.01A^2 + 0.05B^2$
Spread ratio	Linear ***	ns	0.87	0.84	0.36	$Spread\ Rate = 7.71 + 0.08A + 1.18B$
L*	Quadratic***	ns	0.96	0.94	0.48	$L^* = 51.40 + 0.87A - 0.31B - 1.95A * B - 1.46A^2 - 1.72B^2$
a*	Linear **	ns	0.67	0.61	0.82	$a^* = 7.85 + 1.42A + 0.54B$
b*	Quadratic**	ns	0.88	0.79	0.61	$b^* = 27.91 + 1.46A + 0.19B - 0.66A * B - 0.96A^2 - 0.18B^2$
Appearance	2FI Model *	ns	0.63	0.51	0.19	$Appearance = 4.17 - 0.09A + 0.18B - 0.28A * B$
Structural Characteristic	Linear *	ns	0.55	0.46	0.31	$Structural\ Characteristic = 3.73 + 0.44A + 0.01B$
Overall acceptability	Linear *	ns	0.58	0.50	0.24	$Overall\ Acceptability = 3.68 + 0.33A - 0.16B$
Affordability	Linear **	ns	0.65	0.58	0.24	$Affordability = 3.51 + 0.41A - 0.09B$

***p<0.001, **p<0.01, *p<0.05; LF, Lack of fit; ns–not significant; SD, standart deviation; 2FI Model, Two-Factor Interaction Model.

In the analysis of the b* value, the variables A and B were found to have positive linear effects (Table 2). In addition, a negative two-way interaction term (oil mixture - bean flour) and a negative quadratic effect of both variables were found in the model ($p<0.01$). These results suggested that the variables had both a linear and a quadratic effect on the b* values.

In the analysis of the appearance, it was found that the variable A had a negative linear effect while the variable B had a positive linear effect (Table 2). In addition, the model also included a negative two-way interaction term (oil mixture-bean meal). This finding showed that the appearance value decreased as variable A increased, and it increased as variable B increased and both variables together resulted in a negative interaction.

In the structural characteristics analysis, variables A and B were found to have positive linear effects and the model was significant (Table 2) ($p<0.05$). This showed that increasing both variables had a positive effect on the structural properties of the cookies.

A similar trends were observed in the analysis of overall acceptability and affordability values (Table 2). It was found that variable A had a positive linear effect and variable B had a negative linear effect ($p<0.01$). This showed that the

overall acceptability and affordability values increased as variable A increased and it decreased as variable B increased.

Optimisation of cookies

When optimising the cookies, the optimum production conditions were found to be 25.0 g of oil mixture and 24.0 g of bean flour in the range of values in which the independent variables specified in the experimental design were produced (Figure 6). Under these production conditions, the water activity value was 0.50, the diameter value was 4.50, the thickness value was 0.65, the L* value was 52.00, the overall acceptability value was 4.00 and the affordability value was 4.00. It was found that the desirability value of the optimised cookie under these conditions was 80%.

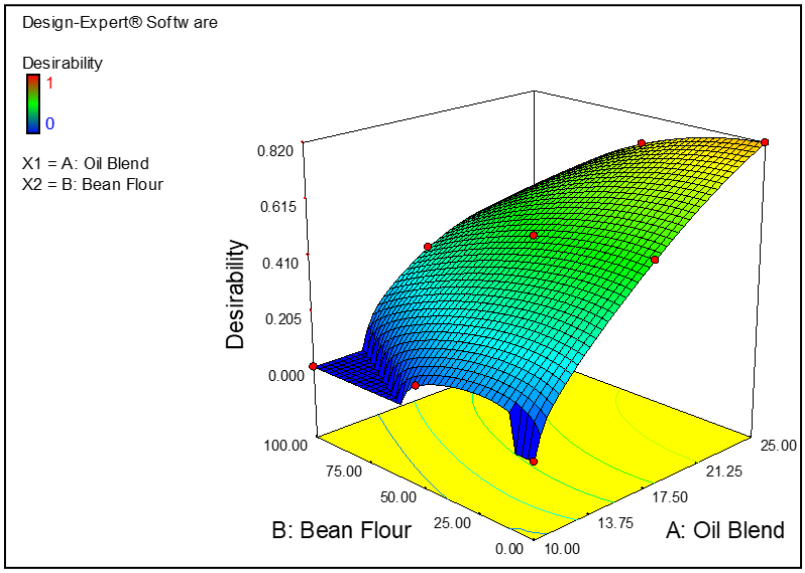

Figure 6. 3D Response Surface Method graph of the effect of independent variables on the desirability value

Şekil 6. Bağımsız değişkenlerin kabul edilebilirlik değerine etkisinin 3D Tepki Yüzey Yöntemi grafiği

In conclusion, this study was conducted considering the healthy eating needs of vegan individuals and the growing vegan population. In the study, vegetable oil mixture and composite flour consisting of bean flour, whole wheat flour and oat flakes were used. Using experimental design, both sugar-free cookie formulations were developed and optimisation of the cookies was carried out. The optimum production conditions were found to be 25.0 g oil mixture and 24.0 g bean flour. Under these production conditions, the water activity value was 0.50, the diameter value was 4.50 cm, the thickness value was 0.65 mm, the L* value was 52.00, the overall acceptability value was 4.00 and the affordability value was 4.00. It was found that the desirability of the optimised cookie was 80%. This formulation has enabled the development of cookie that is completely free of animal products for individuals of all age groups who have both vegan dietary preferences and healthy eating awareness. The sensory evaluation criteria of these cookie formulations were used to determine consumer feedback and demand for cookies made without the use of animal products. Therefore, it is envisaged that this optimised formulation may be used in future studies for fortification applications with health-promoting bioactive components.

STATEMENT OF CONFLICT OF INTEREST

The authors declare no conflict of interest for this study.

AUTHOR'S CONTRIBUTIONS

The contribution of the authors is equal.

STATEMENT OF ETHICS CONSENT

Ethical approval is not applicable, because this article does not contain any studies with human or animal subjects.

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