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Influence of using scarlet runner bean flour on the production and physicochemical, textural, and sensorial properties of vegan cakes: WASPAS-SWARA techniques

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A R T I C L E I N F O

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A B S T R A C T

The present study aims to assess the use of scarlet runner bean (*Phaseolus coccineus* L.) flour having high protein content in the production of vegan cake, determine the product properties, and analyze the preferences of consumers. For this purpose, 5 different vegan cakes were produced by adding various concentrations (0, 25%, 50%, 75%, and 100%) of scarlet runner bean flour into wheat flour containing no animal product. Baking properties, physiochemical, biochemical, textural, and sensorial analyses were performed for vegan cakes. Moreover, in sensorial analyses, WASPAS-SWARA method that is one of the multi-criteria decision-making techniques was used and the most preferred cake sample was determined. In the formulation of vegan cakes, increasing concentration of scarlet runner bean flour increased the levels of protein, total phenolic, and antioxidant matter in cakes and they were found to range between 4.29 and 8.70%, 14.19–43.92 (mg/mL gallic acid), and 7.645–34.39%, respectively. On the other hand, with the addition of bean flour, the colors of cake samples got darker and redness values increased. Baking properties did not change but changes were observed in textural properties. Using WASPAS-SWARA analysis, the most preferred cake sample from the aspect of textural properties was found to be C100 that was made of scarlet runner bean flour.

1. Introduction

Dietary preferences gradually change in Turkey, as in the rest of the world. Together with their gradually increasing importance in nutrition in recent years, the products such as bread, cake, and biscuit became the products that are widely preferred by individuals from different age groups (Kaur and Kaur, 2018). Cake is a product that is prepared using various formulations containing soft wheat flour, sugar, egg, and oil and has a high nutrient value (Köten, 2021). Besides its nutrient support, the egg used in the production of cakes and being one of the main ingredients is of significant importance from the textural aspect because it contributes to the emulsification and elasticity (Lin et al., 2017; Yazici and Ozer, 2021). On the other hand, in recent years, the vegan lifestyle gained popularity in the world and the demand for vegan bakery products also increased since it has important effects on the environment and health (Giraje and Hedaoo, 2019). The decrease in demand for animal products because of the vegan-vegetarian dietary preferences throughout the world led to the studies aiming to develop products containing no animal product such as egg and milk and to provide the product with nutritional and structural support to replace these products with substituting protein sources (Movahhed et al., 2020; MacInnis and Hodson, 2021). Moreover, individuals having dietary preferences incorporating no animal products have health problems arising from the protein-deficient nutrition (Torres-Tiji et al., 2020; Pimental et al., 2021). For this reason, the number of those requesting new types of food having high nutritional and functional values also increases (Bryant, 2019). Moreover, many consumers demand plant-based alternatives for the reasons such as sustainability, lifestyle, and nutrition. Thus, consumption of various functional foods such as hazelnut and bean increases (Tangyu et al., 2019; Ploll et al., 2020).

Scarlet runner bean (SRB) (*Phaseolus coccineus* L.) is one of the five species in the Phaseolus family and incorporates 18–24% protein in its

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structure (Corzo-Ríosa et al., 2020; Guerra-García et al., 2021). Furthermore, the oil, dietary fiber, ash, and carbohydrate contents of SRB are 3%, 17%, 4%, and 47%, respectively. Thanks to its nutritional components and high protein content, SRB can be sued as an alternative plant based protein source (Corzo-Ríosa et al., 2020; Sánchez-Villaa et al., 2020).

In the present study, because of the limited food options, it was aimed to develop a protein-rich product for vegan consumers. Within this scope, nutrient-enriched vegan cake samples were produced using SRB flour, which has rich protein content, at different ratios in different formulations. Using the resultant vegan cake samples, the effects of SRB on physicochemical, biochemical, textural, and sensorial properties were investigated. While examining the sensorial properties of vegan cake samples, the preference order of products was determined using WASPAS-SWARA, one of the multi-criteria decision-making techniques.

2. Material and method

2.1. Material

Wheat flour, sunflower oil, sugar, baking powder, and vanilla used in the production of vegan cake samples were purchased from local companies. Obtained from a producer located in Trabzon, Scarlet runner beans (*Phaseolus coccineus* L.) were kept in water at room temperature for 12 h and then dried at room temperature. In the production of bean flour, soaking the beans in water before the milling process is done for two different reasons. The first is to remove the oligosaccharides in the beans that cause undesirable gas problems, and the other is to increase the moisture content of the beans to achieve effective grinding (Siddiq et al., 2010). Then, they were ground (Cvs DN 1912; Turkey) in a mill. The chemical materials used in this study were obtained at the analytical purity level.

2.2. Vegan cake production

After several modifications, the cakes were prepared using the standard cake production procedure. For this purpose, sugar (260 g), oil (120 ml), and water (150 ml) were mixed using a blender (Braun HM 3100 WH, Germany) at maximum speed for 5 min. Then, the wheat flour (270 g), baking powder (5 g), vanilla (5 g), and scarlet runner beans flour (SRB) (25%, 50%, or 75% of wheat flour in formula) were added and mixed at minimum speed for 5 min. The cake dough was divided into 30–35g portions, poured into non-stick muffin molds, and baked at 175 °C for 30 min. The samples were coded according to the amount of SRB they contained (C0, C25, C50, C75 and C100). After the baking process, the cake samples were cooled to room temperature and kept in a cool and dry place until analyzed (Fig. 1).

2.3. Physicochemical properties of vegan cake samples

Moisture, water activity, and protein contents of vegan cake samples were determined using AOAC (1990) method. Protein content was calculated using Kjeldhal method and conversion factor was 6.25. The water activity value of cake samples was measured using laboratory-type water activity (LabMaster-aw neo, Switzerland) device.

SRB-added cake samples' inner and outer crust L * (lightness/darkness), a * (red/green), b * (yellowness/blueness) color value changes were measured using color device (Konica Minolta CR-3600d, Japan).

Baking efficiency of cake dough samples was calculated by dividing the post-baking weight by the pre-baking weight. Volume index, symmetry index, and uniformity index were calculated using the method of the American Association of Cereal Chemists 10–91 (AACC 2000).

2.4. Textural properties of vegan cake samples

Texture profile analysis of vegan cake samples was performed using a texture measurement device (T.A.HD Plus Stable Micro Systems, UK) incorporating a cylindrical probe (TA4/1000) with 4 cm diameter and 2.5 cm height (Topkaya and Isik, 2018). The analysis was conducted with trigger load of 5g and test speed of 5 mm s^{-1} and the samples were analyzed in terms of hardness (N), adhesiveness (g.sec), springiness (cm), cohesiveness, gumminess, and chewiness parameters.

2.5. Total phenolic contents and antioxidant activity values of vegan cake samples

The phenolic contents, which have changed with SRB flour addition, were extracted by making some modifications in the method introduced by Yalcin et al. (2021). For this purpose, the crumbled cakes were mixed with 80% (v/v) methanol at the ratio of 1:5 (w/v) and the extracts were used in DPPH free radical scavenging activity and total phenolic content analyses. Total phenolic content of samples was determined using a spectrophotometer (Genesys 10S) at 760 nm in accordance with Folin-Ciocalteu (FC) method. Analyzing the antioxidant activities, DPPH antiradical activities of samples were determined using the spectrophotometric method according to the reduction of 1,1-diphenyl-2-picrylhydrazil (DDPH) radical (Brand-Williams et al., 1995).

2.6. Sensorial analysis

Sensorial analyses of cake samples were conducted by 30 trained panelists in terms of crust and crumb color, taste, dispersibility, aroma, and general acceptance. The items were scored between 1 (worst) and 9 (best).

2.7. SWARA-WASPAS method

Sensorial analyses were performed using SWARA-WASPAS method,

Fig. 1. Vegan cake samples.

one of the multi-criteria decision-making techniques. The weights of six sensorial assessment criteria determined for vegan cake samples were calculated using the SWARA (The Stepwise Weight Assessment Ratio Analysis) criterion weighting method. The criteria were assessed by 4 decision-makers (specialists) having sufficient knowledge of criteria. After the assessments, the criteria were weighted using SWARA method and the most preferred sample was chosen using WASPAS (The Weighted Aggregates Sum Product Assessment) method (Zolfani and Saparauskas, 2013).

2.8. SWARA application

While calculating the significance weights of criteria, the personal orders set by decision-makers were used. In this method, the calculation is performed following these steps (Keršuliene et al., 2010).

Step 1. Sorting the criterion by significance: In this step, decision-makers are asked to sort the criteria by ranking the criterion, which they deem most important, first.

Step 2. Determining the significance level of each criterion: In this step, s_j value is calculated for each criterion. Comparing the criterion j to the previous one (j-1), it is shown how significant the criterion is.

Step 3. Calculation of k_j coefficient: In this step, the k_j value is calculated using the equation below.

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases}$$

Step 4. Calculation of q_j significance vector: In this step, p_j significance vector is calculated using the equation below.

$$q_j = \begin{cases} 1 & j = 1 \\ \dfrac{q_j - 1}{k_j} & j > 1 \end{cases}$$

Step 5. Calculation of w_j relative significance weights of criteria: In this step, w_j that is the relative significance weight of criterion j is calculated using the equation below.

$$w_j = \frac{q_j}{\sum_{j=1}^{n} q_j}$$

2.9. WASPAS application

Developed by Zavadskas et al. in year 2012, WASPAS method was developed combining the "*Weighted Sum Mode*" and "*Weighted Product Model*" methods, which are among the main multi-criteria decision-making methods. Combining these two methods, WASPAS method is preferred since it yields more accurate results and offers ease of mathematical calculation. Besides assessing the maximization and minimization criteria together, this method is also suitable for both qualitative and quantitative assessment criteria. WASPAS method consists of 6 steps (Chakraborty and Zavadskas, 2014; Zavadskas et al., 2012).

Step 6. Establishing the decision matrix: Decision matrix for assessment criteria is established as follows, where m refers to the number of candidates, n to the number of criteria, and it consists of values referring to ith alternative's relative value to jth criterion.

$$x = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}$$

Step 7. Establishing the normalized decision matrix: In order to compare the criteria, all the items in decision matrix are normalized for maximization (utility) and minimization (cost) by using the suitable one of two equations.

$$\bar{x}_{ij} = \frac{x_{ij}}{\text{maks}_i \ x_{ij}}; \ i = 1,2,3,.., \ m; = 1,2,3,\dots, \ n; \text{ for maximization criteria,}$$

$$\bar{x}_{ij} = \frac{\min_i \ x_{ij}}{x_{ij}}; \ i = 1,2,3,.., \ m; j = 1,2,3,\dots, \ n; \text{ for minimization criteria,}$$

Step 8. Calculation of total relative significances of alternatives by using "*Weighted Sum Model (WSM)*": After establishing the normalized decision matrix, the relative significances of alternatives are calculated using the formula below.

$$Q_i^{(1)} = \sum_{j=1}^{n} w_j r_{ij}; \ i = 1,2,3,\dots,m$$

Step 9. Calculation of total relative significances of alternatives by using "*Weighted Product Model (WPM)*": After establishing the normalized decision matrix, the relative significances of alternatives are calculated using the formula below.

$$Q_i^{(2)} = \prod_{j=1}^{n} r_{ij}^{w_j}; 1 = 1,2,3,\dots, \ m$$

Step 10. Calculation of weighted common general criteria value by using "*Weighted Sum Model (WSM)*" and "*Weighted Product Model (WPM)*": In this step, the relative significance values calculated using two different methods are weighted and the criterion significance values are calculated.

$$Q_i = \frac{1}{2}\left(Q_i^{(1)} + Q_i^{(2)}\right) = \frac{1}{2}\left(\sum_{j=1}^{n} w_j r_{ij} + \prod_{j=1}^{n} r_{ij}^{w_j}\right); i = 1,2,3,\dots, \ m$$

Step 11. Ranking the calculated relative weights: The relative significance weights obtained in previous step are ranked and the best alternative is determined.

2.10. Statistical analysis

The data obtained from the analyses of vegan cake samples were analyzed using "Minitab 16" statistical software. Statistical significance was set to be $p<0.05$ and the comparison was performed using Turkey's multiple comparison test and ANOVA test. Vegan cake samples with different formulations were produced twice and every analysis was performed in triplicate.

3. Results and discussion

3.1. Physicochemical properties

Vegan cakes' water activity, moisture, and protein values are presented in Table 1. Water activity value, which is an important criterion for the microbial growth control, was found to range between 0.80 and

Table 1
Physical properties of vegan cakes.

Samples	a_w	Moisture Content (%)	Protein Content (%)
C0	$0.86^{a} \pm 0.00$	$6.96^{a} \pm 0.12$	$4.29^{d} \pm 0.04$
C25	$0.85^{b} \pm 0.00$	$7.13^{a} \pm 0.25$	$5.62^{c} \pm 0.12$
C50	$0.82^{d} \pm 0.00$	$6.64^{a} \pm 0.30$	$6.94^{b} \pm 0.06$
C75	$0.83^{c} \pm 0.00$	$6.90^{a} \pm 0.21$	$7.80^{ab} \pm 0.03$
C100	$0.80^{c} \pm 0.00$	$6.65^{a} \pm 0.15$	$8.70^{a} \pm 0.53$

Different letters in the same column mean significantly different ($p < 0.05$).

0.86 in vegan cake samples. The moisture levels of cakes were found to range between 18.16% and 21.25%. In a similar study, egg was replaced with soybean protein isolates and polysaccharides and the effects on cakes were observed. The moisture content of egg-free cakes was found to range between 28.03 and 29.01 (Lin et al., 2017). With the increase in volume of cakes, it was observed that the moisture content decreased and it is explained with the easier vaporization of water from the spongy structure originating from the increase in volume (Arozerana et al., 2001; Movahhed et al., 2016). In parallel with literature, the volume of vegan cakes produced with SRB flour was found to decrease with increasing moisture. The protein content of vegan cakes increased with the increase in SRB flour, which is the plant based protein source of vegan cake formulations and contains 25% protein. Protein content of control sample was found to be 4.29% and it increased to 8.70% in the sample containing SRB flour. Protein content increased with increasing rate of SRB flour addition; this result suggests that SRB protein will provide vegan consumers with an additional protein source.

The vegan cakes' color values, which are important in assessing the foods, were measured in L^*, a^*, and b^* and the results are presented in Table 2. The color values of cake samples were measured in two regions named crumb and crust. It was determined that L^* values ranged between 36.15 and 70.85 and the highest L^* value was found in C0 sample. L^* d-values of samples were found to be statistically significantly different from each other ($p<0.05$) and SRB flour darkened the color of cakes. Expressing the red-yellow color, a^* values ranged between 0.36 and 7.41. SRB flour addition increased the redness of samples but no statistically significant was found between a^* values of C50, C75, and C100 samples. b^* value refers to the yellow-blue color scale. The yellowest sample, C0 cake made only of wheat flour, was found to have the value of 24.22 and the other cakes containing SRB flour were found to have values ranging between 14.58 and 14.88 and no statistically significant difference ($p>0.05$) was found between b^* values. In a study, in which muffin cakes were added with lentil flour instead of egg, no statistically significant difference was found between L^* values of lentil flour-added cakes and those of control cakes but a^* and b^* values decreased (Jarpa-Parra et al., 2017).

Crust color values of vegan cakes were observed to change in parallel with the crumb color values. For the crust sections of cakes, L^* values were found to significantly differ ($p<0.05$). SRB flour addition decreased the L^* values and the darkest sample was found to be the sample C100. As with the crumb a^* values of cakes, SRB flour addition increased the crust a^* values and the lowest value was found to be 0.91 in sample C0. Examining the crust b^* values, the yellowest sample was found to be the sample C0. In many studies varied out on the cakes, the materials used as an ingredient in cake production affected the crumb and crust color values of cakes (Majzoobi et al., 2012; Hedayati and Tehrani, 2018; Hedayati et al., 2021).

Vegan cake samples' baking efficiency, volume index, symmetry index, and uniformity index values are presented in Table 3 and it was found that there was no statistically significant difference between the samples ($p>0.05$). Volume index gives information about the volumes of cakes and there is a linear relationship between volume index and volume (Topkaya and Isik, 2018). On the other hand, many factors such as viscosity of cake dough, mixing speed and time, mixture, and baking speed affect the volume of cake. As the concentration of SRB flour increased, decreases were observed in the volume index values of samples. Volume index values of vegan cake samples C50, C75, and C100 vegan were found to be lower than control and C25 samples. The higher symmetry index values suggest that cakes rise at the center (Borneo et al., 2010). C100 sample's symmetry index value was found to be lower than the others but there was no statistically significant difference between the symmetry index values of other cakes. On the other hand, high-quality cakes have homogeneity index values close to zero (Topkaya and Isik, 2018). In general, cake samples' uniformity index values were found to be close to zero and C0 and C25 samples showed a better uniformity.

3.2. Total phenolic contents and antioxidant activity values

Scarlet runner bean flour addition's effects on vegan cake samples' total phenolic content and antioxidant activity are presented in Fig. 2. With SRB flour addition, total phenolic content and antioxidant activity of cake samples were found to increase. Total phenolic content and antioxidant activity values of cake samples ranged between 27.74 and 43.93 mg gallic acid/mL and between %7.65 and 34.39, respectively. When compared to the control samples, the highest total phenolic content and antioxidant activity values were found in C75 and C100 samples. In a similar study examining the spaghetti pastas containing bean flour at concentrations of 15% and 30%, it was reported that the total phenolic content was at higher level in samples with higher bean flour concentration (Gallegos-Infante et al., 2012). In another study, the chip samples prepared with different combinations of bean and almond flours were examined and it was found that the addition of bean flour had a positive effect on the antioxidant capacity (Ramírez-Jiménez et al., 2018). Plant sources rich in antioxidants and phenolic compounds affect the processing processes in the product groups to which they are added,

Table 3
Physical properties of vegan cakes.

Samples	Cooking Efficiency (%)	Volume Index (mm)	Symmetry Index (mm)	Uniformity Index (mm)
C0	$83.45^{a}\pm0.28$	$76.00^{a}\pm1.41$	$25.50^{a}\pm2.82$	$1.00^{a}\pm0.00$
C25	$84.32^{a}\pm0.88$	$73.00^{a}\pm8.48$	$25.00^{a}\pm0.70$	$1.00^{a}\pm0.00$
C50	$84.45^{a}\pm0.52$	$70.50^{a}\pm2.12$	$24.00^{a}\pm1.41$	$2.50^{a}\pm0.70$
C75	$85.04^{a}\pm1.30$	$70.00^{a}\pm1.41$	$24.00^{a}\pm4.24$	$2.50^{a}\pm0.70$
C100	$84.80^{a}\pm0.08$	$63.50^{a}\pm2.12$	$22.50^{a}\pm2.12$	$1.50^{a}\pm0.70$

Different letters in the same column mean significantly different ($p < 0.05$).

Table 2
Crumb and crust color values of vegan cakes.

Samples	Crumb Color			Crust Color		
	L^*	a^*	b^*	L^*	a^*	b^*
C0	$70.85^{a}\pm0.16$	$0.36^{b}\pm0.24$	$24.22^{a}\pm0.19$	$69.69^{a}\pm0.26$	$0.91^{b}\pm0.12$	$23.22^{a}\pm0.24$
C25	$49.82^{b}\pm0.13$	$3.05^{b}\pm0.16$	$14.66^{b}\pm0.02$	$58.66^{ab}\pm0.33$	$3.53^{b}\pm0.25$	$17.94^{b} \pm a0.17$
C50	$42.39^{bc}\pm0.16$	$6.99^{a}\pm0.08$	$14.71^{b}\pm0.15$	$43.97^{bc}\pm0.26$	$6.81^{a}\pm0.12$	$17.68^{b}\pm0.25$
C75	$38.38^{c}\pm0.65$	$7.41^{a}\pm0.17$	$14.88^{b}\pm0.47$	$36.16^{bc}\pm0.21$	$7.20^{a}\pm0.40$	$17.48^{b}\pm0.20$
C100	$36.15^{c}\pm0.36$	$7.41^{a}\pm0.24$	$14.58^{b}\pm0.36$	$32.56^{c}\pm0.31$	$8.60^{a}\pm0.06$	$17.83^{b}\pm0.17$

Different letters in the same column mean significantly different ($p < 0.05$).

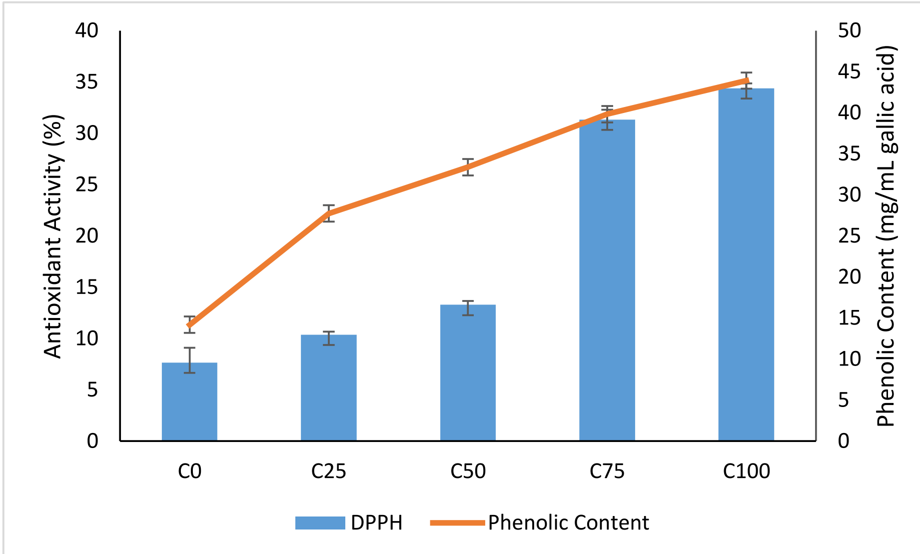

Fig. 2. Antioxidant and phenolic values of cake samples.

as well as change the antioxidant activity and phenolic content of the final product (Singh et al., 2015; Tolga and Işık, 2018; Sung et al., 2020; Yalcin et al., 2021). The antioxidant activity and phenolic content of scarlet bean flour, which is used as a raw material in vegan cake production, were determined as 125,714 mg gallic acid/mL and 68.43%, respectively. It is thought that the low antioxidant activity and phenolic values detected in vegan cakes are due to the heat treatment applied due to cooking. Aguilera et al. (2011) reported that thermal process such as soaking and cooking caused significant decreases in antioxidant activity and phenolic contents of two different varieties of beans. In additional, there were increases in total phenolic content and antioxidant activity values with increasing amount of added scarlet runner bean flour into the cakes. In Ramirez-Jimènez et al. (2018) were determined that phenolic content and antioxidant activity of snack bar elaborated with common bean and oat flour trend to increase when compared against control and had a positive impact on the antioxidant capacity in the additional bean flour. In Sung et al. (2020), it was found that a gluten-free rice layer cakes with 10%, 20% and 30% chia seed flour instead of wheat flour had higher an antioxidant activity value and total phenolic content of that of the control. Similarly, researchers investigating the effect of pomegranate peel on the chemical properties of muffin cakes reported that the antioxidant activity and total phenolic substance content increased with the enhance in the addition rate. (Topkaya and Isik, 2018).

3.3. Textural properties

Texture is an important criterion for the consumer preferences. The vegan cake samples' hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness values are presented in Table 4. It is known that the textural properties of cakes change with the interaction of cake volume, moisture content, and other ingredients used (Majzoobi et al., 2016). The technological properties of ingredients such as water and oil binding affect the structure of final product. The hardness values of vegan cakes range between 71.63 and 124.33 N. The softest product was C0 sample made of wheat flour and the addition of SRB flour yielded harder products. The second hardest product was the sample C100, which was made only of SRB flour. When combining the wheat and SRB flours, the cakes with 25% and 50% of wheat flour concentrations were found to be harder. However, the cakes tend to be softer with 75% SRB addition. The possible explanation is that it creates synergy and yielded harder structures. Water and oil holding capacity of dietary fibers from cereal derivatives has a greater affinity (Elleuch et al., 2011). For this reason, it was thought that the hardness of vegan cakes increased with the increase in the addition of scarlet runner bean flour because of its dietary fiber content. Adhesiveness values of samples exhibited a trend that was similar to the hardness values. The stickiest product was the product coded with C0, whereas the least sticky product was the sample C100 made completely of SRB flour. Among the other textural properties, springiness and cohesiveness values ranged between 0.64 and 0.86 cm and between 0.22 and 0.27. Lower cohesiveness value is related to the high dispersibility and lower product hardness (Shevkani et al., 2015; Hessoa et al., 2015). In general, high results of texture parameters in combinations of wheat and SRB flours indicate that there is an interaction between gluten and SRB flour. However, further studies are needed on this subject. In another similar study, in production of gluten-free cakes, the addition of sweet potato increased the firmness, cohesiveness, and chewiness values (Shih et al., 2006).

3.4. Sensorial properties

Sensorial analysis results of vegan cakes are presented in Fig. 3. Unlike the production of classical cake production, the ingredients added into the cake formulation affect many properties of cake such as

Table 4
Texture properties of vegan cakes prepared with different scarlet runner bean ratio.

Samples	Hardness (N)	Adhesiveness (g.sec)	Springiness (cm)	Cohesiveness	Gumminess	Chewiness
C0	$71.63^{c}\pm4.95$	$-763.23^{d}\pm17.52$	$0.79^{ab}\pm0.11$	$0.27^{a}\pm0.04$	$1985.50^{b}\pm19.53$	$1577.74^{b}\pm43.18$
C25	$107.63^{ab}\pm19.30$	$-598.78^{c}\pm19.23$	$0.74^{ab}\pm0.11$	$0.25^{ab}\pm0.01$	$2791.86^{a}\pm19.12$	$2104.31^{ab}\pm62.88$
C50	$124.33^{a}\pm14.63$	$-755.43^{d}\pm29.58$	$0.81^{a}\pm0.09$	$0.23^{b}\pm0.02$	$2847.46^{a}\pm15.57$	$2323.54^{a}\pm70.91$
C75	$120.27^{ab}\pm18.06$	$-423.84^{b}\pm30.00$	$0.86^{a}\pm0.07$	$0.23^{b}\pm0.03$	$2749.57^{a}\pm20.06$	$2387.68^{a}\pm78.84$
C100	$100.66^{b}\pm10.69$	$-260.17^{a}\pm23.22$	$0.64^{b}\pm0.08$	$0.22^{b}\pm0.02$	$2289.22^{ab}\pm24.87$	$1457.68^{b}\pm98.12$

Different letters in the same column mean significantly different ($p < 0.05$).

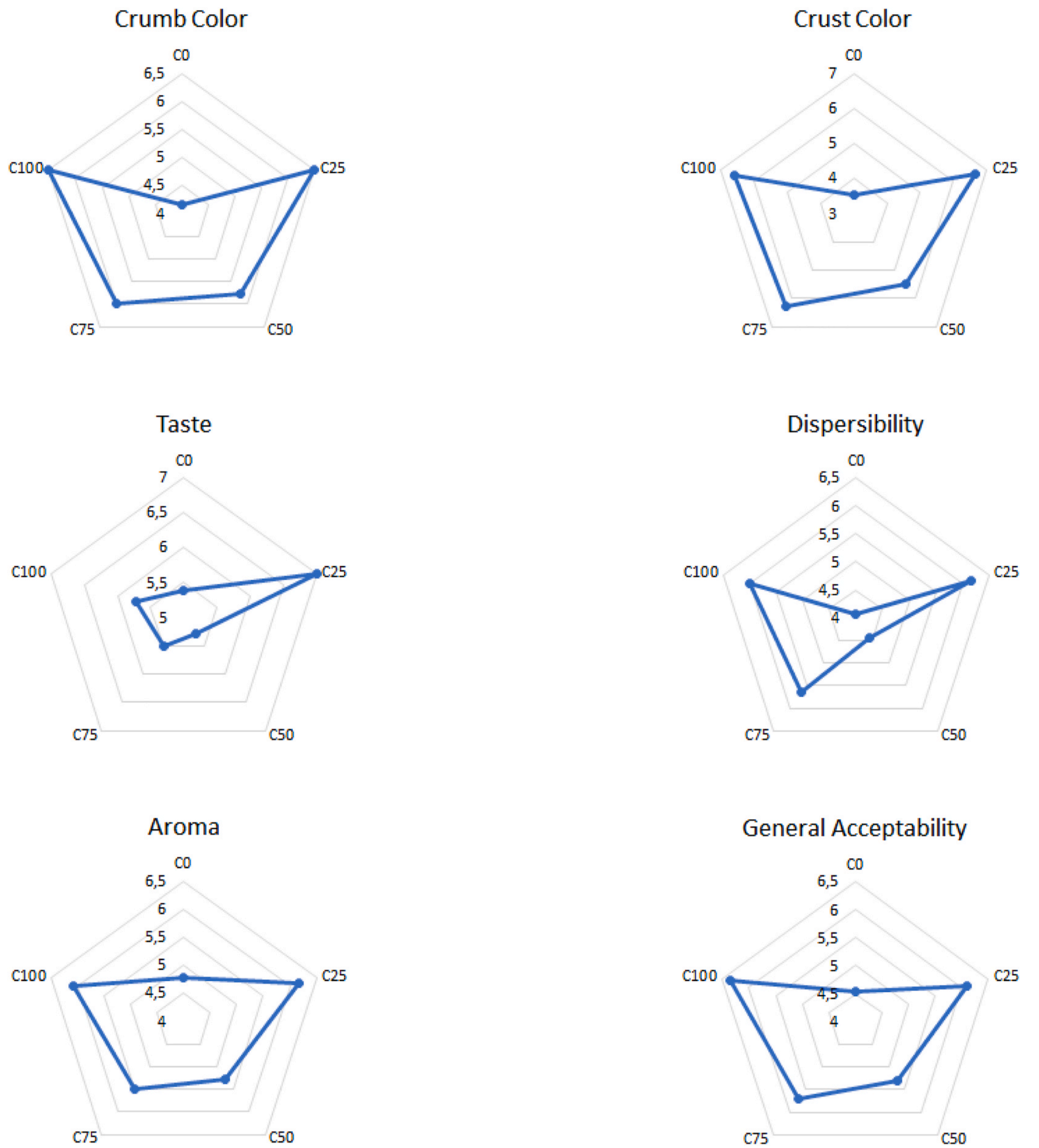

Fig. 3. Sensory properties of vegan cakes.

color and appearance and, thus, they are less preferred by the consumers (Gomes et al., 2015). However, in the present study, crumb and crust color values were found to be similar and, for both parameters, the most appreciated sample was found to be C100 and the least appreciated sample was C0 sample. Referring to the chewiness and cohesiveness parameters, similar results were obtained in dispersibility criterion. Regarding the taste consideration, the most preferred sample was found to be C25, followed by C100, C75, C50, and C0. Assessing the aroma criterion, it was determined by the panelists that scarlet runner bean flour addition resulted in a higher level of acceptability by panelists and it was appreciated more than the sample made of wheat flour. In "General Acceptance", it was found that the addition of scarlet bean runner flour positively contributed to preferences and the most preferred sample was found to be C100. Similarly, in a previous study, it was determined that the addition of carrot pomace powder increased the general acceptability of cakes (Majzoobi et al., 2016). Given the analysis results, it can be seen that tastier products with high protein content for vegan-vegetarian individuals were obtained.

3.5. SWARA-WASPAS method

In order to select the most appreciated product, six parameters (inner color, crust color, taste, dispersibility, aroma, and general acceptance) were determined. SWARA method was used in weighting the criteria. First, the decision-makers were asked to sort them by the level of significance and to determine the relative significance level by performing paired comparisons. The ranking made by decision-makers and the significance levels are presented in Table 5.

In parallel with the data presented in Table 5, for each decision-maker (KV_1), coefficient value k_j, significance vector q_j, and criterion significance weights w_j were calculated. The results of calculations are presented in Table 6.

The calculations made for (KV_1) in Table 6 were repeated for the other decision-makers and the significance weights were calculated for each decision-maker. The calculated criterion weights are presented in Table 7. In Table 7, the calculated criterion weights should be combined in order to determine the final weight of criterion. At this step, the geometrical average of the criterion weights for every decision is calculated and the final criterion weights are presented in Table 7.

Table 5
The ranking made by decision-makers and the significance levels.

Decisions	KV_1		KV_2		KV_3		KV_4	
	Order	s_j	Order	s_j	Order	s_j	Order	s_j
General Acceptability	1		1		1		4	0,122
Taste	3	0,201	2	0,227	3	0,192	1	
Aroma	2	0,219	4	0,094	4	0,172	2	0,168
Crumb Color	6	0,029	6	0,023	2	0,226	6	0,028
Dispersibility	4	0,060	5	0,036	6	0,052	3	0,144
Crust Color	5	0,037	3	0,127	5	0,127	5	0,037

Table 6
Criterion weights of Decision Maker-1.

Decision Maker-1					
Decisions	Significance Order	sj	kj	qj	wj
General Acceptability	1		1,000	1,000	0,229
Aroma	2	0,219	1,219	0,820	0,188
Taste	3	0,201	1,201	0,683	0,156
Dispersibility	4	0,060	1,060	0,644	0,147
Crust Color	5	0,037	1,037	0,621	0,142
Crumb Color	6	0,029	1,029	0,604	0,138

Table 7
Calculated weights of criteria on the basis of decision makers.

Decisions	Final Weights				Final Criterion Weights
	KV-w_1	KV-w_2	KV-w_3	KV-w_4	
General Acceptability	0,229	0,229	0,229	0,153	0,207
Taste	0,156	0,186	0,156	0,229	0,179
Aroma	0,188	0,151	0,134	0,196	0,165
Crumb Color	0,138	0,143	0,187	0,143	0,152
Dispersibility	0,147	0,146	0,113	0,171	0,143
Crust Color	0,142	0,165	0,119	0,147	0,142

After obtaining the final criterion weights, the alternatives were ranked using WASPAS method and considering the criterion weights. At this point, the decision matrix is established first. Sensorial analyses were performed in order to determine the acceptability of vegan cakes produced with different formulas. Given the sensorial analyses performed by 14 tasting specialists, each of alternatives was scored between 1 (worst) and 9 (best) considering the criteria identified before. After the analyses, the decision matrix is seen in Table 8.

After establishing the matrix, the normalization procedure was conducted by using the utility criterion formula for each utility criterion. After the calculations, the decision matrix was normalized and the normalized decision matrix is presented in Table 8.

After establishing the normalized decision matrix, considering the criterion weights (see Table 9) calculated using SWARA method on the decision matrix, the relative significance values were calculated using "Weighted Sum Model (WSM)" and "Weighted Product Model (WPM)". The relative significance values obtained are presented in Table 9.

Then, using the general criterion weighting formula, the significance weights of criteria were calculated and the results are presented in Table 10.

Examining the table, the alternatives were ranked considering the weighted relative significance values shown in the table. The most appreciated product was found to be the sample C100.

4. Conclusion

In the present study, vegan cake formulations were developed using scarlet runner bean flour and no animal source and the final product properties were determined. Vegan-vegetarian individuals suffer protein deficiency. Besides that, the structural problems are observed in cakes produced without animal products (egg and milk group). Compared to the control samples, the cakes produced using scarlet runner bean yielded superior results from the biochemical, physicochemical, textural, and sensorial aspects. The present study is important in terms of examining the alternative plant based sources in the frequently consumed food groups. With the addition of SRB flour, a decrease in L^* value was observed and darker cakes were obtained. There was no difference in the cooking efficiency, volume, symmetry and uniformity index values, which occurred with the change in the cake formulation. On the other hand, the addition of SRB flour caused the formation of harder cakes. Moreover, since the most appreciated product from a sensorial aspect was the sample C100, a product that is suitable for celiac patients was obtained. The results suggested that manufacturers may offer the individuals, who have different dietary preferences, the product diversity by modifying the product formulations. In future studies, other plant based protein sources, especially the scarlet runner bean, can be investigated in different food groups and the product properties can be determined.

Table 8
The decision matrix and normalized decision matrix for vegan cake.

Decision Matrix						
Alternatives	Crumb Color	Crust Color	Taste	Dispersibility	Aroma	General Acceptability
C0	3,47	2,76	4,98	3,08	4,27	4,16
C25	6,06	6,36	6,27	4,60	5,51	5,07
C50	5,62	5,25	4,83	3,56	4,80	4,79
C75	5,72	6,01	5,16	5,15	5,15	5,05
C100	6,29	6,40	5,26	5,40	5,51	5,90
Normalized Decision Matrix						
Alternatives	Crumb Color	Crust Color	Taste	Dispersibility	Aroma	General Acceptability
C0	0,55	0,43	0,79	0,57	0,77	0,71
C25	0,96	0,99	1,00	0,85	1,00	0,86
C50	0,89	0,82	0,77	0,66	0,87	0,81
C75	0,91	0,94	0,82	0,95	0,93	0,86
C100	1,00	1,00	0,84	1,00	1,00	1,00

Table 9
"Weighted sum model (WSM)" and "weighted product model (WPM)" relative significance values.

Normalized Matrix -WSM						
Alternatives	Crumb Color	Crust Color	Taste	Dispersibility	Aroma	General Acceptability
C0	0,08	0,06	0,14	0,08	0,13	0,15
C25	0,15	0,14	0,18	0,12	0,17	0,18
C50	0,14	0,12	0,14	0,09	0,14	0,17
C75	0,14	0,13	0,15	0,14	0,15	0,18
C100	0,15	0,14	0,15	0,14	0,17	0,21
Normalized Matrix -WPM						
Alternatives	Crumb Color	Crust Color	Taste	Dispersibility	Aroma	General Acceptability
C0	0,91	0,89	0,96	0,92	0,96	0,93
C25	0,99	1,00	1,00	0,98	1,00	0,97
C50	0,98	0,97	0,95	0,94	0,98	0,96
C75	0,99	0,99	0,97	0,99	0,99	0,97
C100	1,00	1,00	0,97	1,00	1,00	1,00

Table 10
Weighted relative significance values.

Alternatives	P-WSM	P-WPM	P-WSPM	Order of WSPM
C0	0,64	0,64	0,64	5
C25	0,93	0,94	0,94	2
C50	0,80	0,80	0,80	4
C75	0,89	0,90	0,89	3
C100	0,96	0,97	0,96	1

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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