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

Research / Araştırma
GIDA (2024) 49 (1) 39-51
doi: 10.15237/gida.GD23094

THE EFFECT OF REDUCING THE SUGAR AND FAT CONTENT ON THE PHYSICAL AND SENSORY PROPERTIES OF CUPCAKES

Mehmet Murat Karaoğlu*, Negin Zabihollahi
Atatürk University, Faculty of Agriculture, Department of Food Engineering, Erzurum, Turkey

Received /Geliş: 16.08.2023; *Accepted* /Kabul: 19.12.2023; *Published online* /Online baskı: 05.01.2024

Karaoğlu, M.M., Zabihollahi, N. (2024). The effect of reducing the sugar and fat content on the physical and sensory properties of cupcakes. GIDA (2024) 49 (1) 39-51 doi: 10.15237/ gida.GD23094

Karaoğlu, M.M., Zabihollahi, N. (2024). Şeker ve yağ içeriğini azaltmanın top keklerin fiziksel ve duyusal özelliklerine etkisi. GIDA (2024) 49 (1) 39-51 doi: 10.15237/ gida.GD23094

ABSTRACT
In this study, the effect of reducing the sugar (50%, 100%) and fat (50%, 75%) content on the physical and sensory properties of cupcakes was investigated by using stevia and polydextrose as sugar and fat replacers, respectively. While reducing the fat content increased the density of the cake batter, it caused a decrease in the consistency values such as firmness, consistency, cohesiveness and viscosity index. Reducing the sugar content had the opposite effect, decreasing the batter density and significantly increasing the batter consistency. Reducing only sugar and only fat content showed better results than control, while reducing both sugar and fat content together negatively affected the textural properties of cakes. In general, reducing only sugar content decreased sensory satisfaction compared to reducing only fat content. The samples with only 50% reduced fat content were most liked in terms of all sensory parameters. It was concluded that only sugar or only fat contents can be reduced by 50% in cake production, especially considering the specific volume, textural and sensory properties.
Keywords: Cake, sugar reduction, fat reduction, physical properties, sensory evaluation

ŞEKER VE YAĞ İÇERİĞİNİ AZALTMANIN TOP KEKLERİN FİZİKSEL VE DUYUSAL ÖZELLİKLERİNE ETKİSİ

ÖZ
Bu çalışmada, şeker ve yağ ikame maddesi (sırasıyla, stevia ve polidekstroz) kullanılarak şeker (%50, %100) ve yağ (%50, %75) içeriğinin azaltılmasının top keklerin fiziksel ve duyusal özellikleri üzerindeki etkisi incelenmiştir. Yağ oranının düşürülmesi kek hamurunun yoğunluğunu arttırırken, sertlik, konsistens, kohesivlik ve viskozite indeksi gibi kıvam değerlerinde azalmaya neden olmuştur. Bununla birlikte, şeker içeriğinin azaltılması, hamur yoğunluğunu azaltarak ve hamur kıvamını önemli derecede artırarak ters yönde bir etkiye sahip olmuştur. Sadece şeker ve sadece yağ miktarının azaltılması kontrole göre daha iyi sonuçlar verirken, hem şeker hem de yağ miktarının birlikte azaltılması keklerin tekstürel özelliklerini olumsuz yönde etkilemiştir. Genel olarak, sadece şeker içeriğinin azaltılması, sadece yağ içeriğinin azaltılmasına göre duyusal beğeniyi azaltmıştır. Tüm duyusal parametreler bakımından incelendiğinde, yağ içeriği %50 azaltılmış kek örneklerinin en çok beğenildiği görülmüştür. Kek üretiminde, özellikle özgül hacim, tekstürel ve duyusal özellikler dikkate alındığında sadece şeker veya sadece yağ içeriklerinin %50 oranında azaltılabileceği sonucuna varılmıştır.
Anahtar kelimeler: Kek, şeker azaltılması, yağ azaltılması, fiziksel özellikler, duyusal değerlendirme

* *Corresponding author* / Yazışmalardan sorumlu yazar:
✉: mmurat@atauni.edu.tr ☎: (+90) 442 231 2492 🖷: (+90) 442 231 5878

M. Murat Karaoğlu; ORCID no: 0000-0002-9919-8824
Negin Zabihollahi; ORCID no: 0009-0004-0762-282X

INTRODUCTION

Cake is a food with a high calorie value and a variety that can appeal to people's taste in addition to being easy to prepare, delicious and satisfying. Since cake contains both satisfying and basic nutrients, it is the most produced and consumed product in the bakery industry after bread and biscuits (Gerçekaslan and Boz, 2018). Basic components in cake production; flour, milk, sugar, fat, egg and baking powder. Each component has a very important function in the formation of the volume, texture and sensory properties that make up the consumption quality of the cake. In the cake, the components that have the most important effect on the structure are flour, sugar, fat and egg. The flour creates the basic texture in the cake, while the egg has an important effect on the formation of the desired pore structure in the final product since it increases the stabilization of the gas cells in the cake batter (Hesso et al., 2015). In addition to being a sweetener, the sugar contributes greatly to the formation of the desired volume by incorporating air into the structure during mixing the batter. It also plays a role in the color formation (Sun et al., 2023). As in all bakery products, the fat is the most important component that creates the textural properties of the product. The fat shows this function by surrounding the air cells and increasing the interaction between starch and protein. It also increases the consumption quality of the final product with the formation of a soft and moist structure (Zhang et al., 2021).

In a standard cake formulation, whose basic component is wheat flour, the energy value of the product obtained is quite high due to the presence of significant amounts of sugar and fat. The fact that both its textural and sensory properties are preferred by consumers significantly increases the amount of consumption of cake, which is a food with a high energy value (Tuna, 2015). This situation causes important health problems especially in consumer groups such as obesity and diabetes patients (Yazar and Rosell, 2023).

In recent years, the understanding that most of the basic nutritional problems are closely related to the consumption of foods containing high amounts of fat and sugar has led to the development of awareness of healthy nutrition in consumers and their cautious approach to foods containing high sugar and fat (Dündar et al., 2023). High fat and sugar intake in the diet leads to various health problems such as obesity, cancer, high blood cholesterol and coronary heart disease. Therefore, in recent years, the food industry and scientists have made great efforts to reduce sugar and fat content in processed products to meet conscious consumer demands (İnanç and Çınar, 2009). There are many fat and sugar replacers on the market. Stevia, obtained from the leaf of Stevia rebaudiana plant, is an important sugar replacer in food products that satisfies the requirements for low-calorie and high-intensity sweeteners in these products (Azevedo et al., 2015). Polydextrose is a complex carbohydrate formed of glucose, sorbitol and citric acid, which has been used in food as a low-caloric (1 kcal/g) bulking agent. It is used as a both fat and sugar replacer in baked goods (Kothalawala. Et al., 2018). In recent years, many studies have been conducted using stevia extract (Abdel-Salam et al., 2009; Karp et al., 2016; Giritlioğlu, 2017) and stevia leaves (Barakat and Abdulla, 2014; Kulthe et al., 2014; Buarnia et al., 2017; Özcan and Babaoğlu, 2017) to reduce the sugar content in cakes. In addition, in many studies, it has been investigated that the possibility of reducing the fat content by using various fat replacers in cakes and similar products (Doğan et al., 2012; Ang et al., 2017; Dadkhah et al., 2017; Mageed and Al-Abdullah, 2020). However, the number of studies on reducing both sugar and fat content by using stevia instead of sugar and polydextrose instead of fat is limited.

Increasing consumer awareness of healthy food consumption has led to an increased demand for low-calorie foods with reduced sugar and fat content. In this study, it was aimed to reduce sugar and fat content of the cake, which is a widely consumed bakery product in our country, by using different replacers (stevia and polydextrose) and to determine the most suitable formulation that preserves product quality.

MATERIALS and METHODS

Materials

Commercial cake flour (Birlik Un, Erzurum, Turkey) containing 11.75% moisture, 9.5% protein, 0.55% ash, and 30.0 mL zeleny-sedimentation, fine white table sugar (sucrose), soft margarine (Becel), egg, fresh milk, baking powder (Dr. Oetker, İzmir) were purchased from a local market. Stevia (Wisdom Natural Brands) and polydexrose (Litesse, Danisco) were used as sugar and fat substitutes, respectively.

Cake Production

In the research, cupcake production was carried out by preparing cake formulations with reduced sugar (0, 50%, 100%) and fat (0, 50%, 75%) content at different levels. In the formulations with 50% and 100% reduced sugar content, 0.25% and 0.5% stevia extract was used as sweetener on flour basis, respectively. In formulations with 75% reduced fat content, 25% polydextrose was used as fat replacer on flour basis. The cake sample without reduced sugar and fat content was evaluated as control sample. The reduction levels of fat and sugar used in the research were determined as a result of preliminary tests. Additionally, polydextrose was used only in formulations with 75% reduced fat, as there were not many negative changes in cake mixes with 50% reduced fat. The cake production was carried out according to Karaoğlu et al., (2001) with some modifications. The order specified in the production flow chart in the Table 1 was followed for cake production. The cake batter was obtained by mixing the components in Table 1 with the help of a mixer (Arçelik, ARK 99 RS, Turkey) at medium speed. 60 grams of the obtained cake batter was poured into teflon cake molds and baked in an electric oven (Bosch, HBG635BS1/05, Munich, Germany). The baked cakes were cooled for 1 hour at room temperature, then, they were packaged in double-layered polyethylene bags and kept in laboratory conditions during the analyses.

Table 1. Formulation and production flow chart used in the cake production.

Cake formulation		Cake production flow chart	
Ingredients	%	Ingredients	Process
Flour	26.44	Egg white	Mixing (3 m)
Sugar	23.79	Sugar	Mixing (1 m)
Milk	19.83	Milk	Mixing (2 m)
Fat	13.22	Fat	Mixing (2 m)
Egg white	15.87	Flour+Baking powder + Stevia +Polydextrose	Mixing (4 m)
Baking powder	0.45		⇩
Stevia*			60 g batter (in greased pans)
Polydextrose**			⇩
			Cooking (175°C, 35m)

*Stevia extract was used as a sugar replacer at a rate of 0.25% on flour basis in the formulations with 50% sugar reduction and 0.5% in the formulations with 100% sugar reduction.

**Polydextrose was used as a fat replacer at a rate of 25% on a flour basis in the formulations with 75% reduced fat content.

Analysis of the cake batter samples

Back extrusion test of batter

Back extrusion test in cake batter was performed using TA.XTplus Texture Analyzer (Stable Micro Systems Ltd., Godalming, Surrey, U.K). Batter samples (60 ml) were poured into the extrusion cell with internal diameter of 50 mm. The back extrusion test was performed at constant speed of 3 mm/s, 30 mm distance and 5 g trigger force using a cylindrical probe (40 mm diameter). The textural parameters such as firmness, consistency, cohesiveness, and index of the viscosity were calculated from the resulting force-time curves using Texture Pro Software.

Batter density

Batter density was determined at ambient temperature (25°C) by dividing the weight of a standard container filled with batter by the weight

of an equal volume of water (g/cm3) (Majzoobi et al., 2012)

Analysis of the cake samples

Specific volume

The volumes of the cake samples produced were determined according to the AACC Method 10.05.01 (AACC, 2010) using the principle of substitution with rapeseed. The specific volumes of the samples were calculated by dividing the volume values by the weight of the cake samples after they were taken out of the oven and rested for 1 hour.

Color measurement

The inner and crust color of the cake samples were determined by a colorimeter (CR-200, Minolta, Osaka, Japan). The total color change (ΔE*) relative to the control cake sample was calculated using the L*, a* and b* color values read and the equation below.

$$\Delta E = [(L_0-L_1)^2 + (a_0-a_1)^2 + (b_0-b_1)^2]^{1/2}$$

In the given equation, L_0, a_0, and b0 represent the color values of the control cake sample and L_1, a_1, and b_1 represent the color values of the cake samples with reduced sugar and fat content.

Texture profile analysis (TPA)

Cake samples were evaluated using a texture analyser (TA.XTplus, Stable Micro Systems Ltd, Godalming, Surrey, U.K.) equipped with a 50 mm diameter cylindrical probe using a 5 kg load cell. Samples of 30 mm diameter and 20 mm height were prepared from the inner middle part of the cake. TPA test was carried out under conditions 40% compression rate, 30 g trigger force, 30 seconds waiting after first compression, 1 mm/s test speed. The data obtained were processed by Texture Expert Software (Stable Micro System, London, United Kingdom) and expressed as hardness, adhesiveness, cohesiveness, elasticity and chewiness.

Sensory Analysis

The control sample and the cake samples with reduced fat and sugar content at different levels were evaluated by 10 trained panelists (5 male and 5 female, aged 22-30 years) for sensory attributes such as appearance, color, aroma, taste, texture and overall acceptability. The 9-point hedonic scale was used for sensory evaluation. The sample with the highest acceptability was given 9 points and the least acceptable sample was given 1 point. Then, the average value of the scores given by the panelists was calculated.

Statistical Analysis

Cake production was carried out in duplicate by preparing formulations with reduced sugar (0, 50%, 100%) and fat (0, 50%, 75%) contents at three different levels. Analysis of variance (ANOVA) was applied to the data obtained as a result of the three parallel analyzes, using the SPSS 22.0 package program (SPSS, version 18.0 for Windows, SPSS Inc., Chicago, USA). The values found to be significant were subjected to the Duncan Multiple Comparison test.

RESULTS and DISCUSSIONS

Features of cake batter samples

Table 2 shows the density of the cake batter and the firmness, consistency, cohesiveness and viscosity index values obtained from the back extrusion test**.** Cake batter density is an indicator of the volume of air added to the dough and it is significantly affected by the cake formulation (Belorio et al., 2019). At all sugar levels, the reduction of fat content in cake formulation was effective in increasing the density of the cake batter. However, as the sugar content was reduced, the degree of increase in density seen with reducing the fat content decreased. The main function of the fat in the cake batter is to increase the stability of the air bubbles by surrounding them and to keep more air in the mixture with the formation of evenly distributed air bubbles (Psimouli and Oreopoulou, 2013). The increase in the density of the cake batter with the decrease in fat content is due to the fact that as the amount of fat decreases, the mentioned effect decreases and less air is kept in the batter. When the general effect of the amount of sugar on the cake batter density is examined, it is seen that the decrease in the sugar content has a decreasing effect on the batter density. The cake batter must be viscous enough to hold air bubbles and gases during mixing. Low viscosity batters do not have enough

structure to retain the air contained during mixing or the gas released by the baking powder (Rahmati and Tehrani, 2014). The decrease in the density of cake batter, caused by decrease in the amount of sugar can be explained by the effect of the amount of sugar on the viscosity of the dough and the decrease in the total solid content of the dough.

Table 2. Density, firmness, consistency, cohesiveness and viscosity index values of cake batter samples with reduced sugar and fat content at different levels[a].

Sugar Reduction (%)	Fat Reduction (%)	n	Density (g/cm³)	Firmness (g)	Consistency (g.s)	Cohesiveness (g)	Viscosity İndex (g.s)
0	0(C)	2	118.31±0.50ef	74.14±1.60d	693.31±13.89d	45.01±1.10d	376.01±7.19d
	50	2	121.90±0.60c	57.10±3.01e	528.46±29.08e	33.07±1.78e	276.77±14.80e
	75	2	125.45±0.04a	38.54±2.47f	355.71±21.96f	21.37±1.14f	145.64±12.59f
	GA:	6	121.89±1.31A	56.60±6.59C	525.83±62.45C	33.15±4.36C	266.14±42.53C
50	0	2	120.14±0.10d	103.15±4.07c	956.76±34.68c	72.80±2.27c	587.20±18.73c
	50	2	121.50±0.49c	69.18±1.68d	648.49±17.50d	44.35±0.57d	368.08±6.05d
	75	2	123.63±0.23b	56.45±1.23e	522.81±11.28e	32.46±0.49e	268.48±4.81e
	GA:	6	121.76±0.65A	76.26±8.89B	709.35±82.19B	49.87±7.59B	407.92±59.76B
100	0	2	117.74±0.26f	168.96±1.97a	1536.41±16.80a	124.13±0.19a	972.40±4.42a
	50	2	119.31±0.48de	120.30±3.19b	1103.01±32.41b	84.10±2.79b	667.07±19.76b
	75	2	119.57±0.42de	67.28±1.56d	627.51±17.27d	42.86±0.02d	350.52±2.05d
	GA:	6	118.87±0.40B	118.60±18.60A	1088.98±166.32A	83.69±14.85A	663.33±113.66A
	P		**	**	**	**	**

[a]Means showed by the same letter are not statistically different from each other (p≥0.05),
**P<0.01, C: Control, GA: General Average.

The textural properties of the cake batter such as firmness, consistency, cohesiveness and viscosity index significantly affect the quality of the final product (Agrahar-Murugkar et al., 2018). These parameters obtained from the graph drawn by the back extrusion test are closely related to each other and the increase in the values of these parameters means that the semi-solid material is more viscous and more resistant to flow (Murugkar et al., 2021). While consistency includes all the rheological properties of a substance such as viscosity, surface tension, cohesion, etc., cohesiveness refers to the strength between the internal bonds of a food (Rosenthal and Thompson, 2021). On the other hand, the viscosity index can be defined as an indicator of resistance to flow (Mohammadi-Moghaddama et al., 2020). Fat and sugar replacers cannot mimic all the of techno-functional properties of sugar and fat and hence they may have some undesirable effects on batter and final product properties (Majzoobi et al., 2020). At all sugar levels, the reduction of fat content was effective in reducing the firmness, consistency, cohesiveness and viscosity index values of the cake batter. Since the decrease in the amount of fat in the formulation negatively affects the stability of the air bubbles in the cake batter (Kim et al., 2001), the density of the batter increased and the back-extrusion test parameters decreased depending on the increasing batter density. In other words, the fluidity of the cake batter increased and the resistance to flow decreased. When the general effect of the amount of sugar in the formulation on the mentioned textural properties of the cake batter is examined, it is seen that the decrease in the amount of sugar has an increasing effect on these properties. It is thought that sugar is mainly added to obtain the desired sweetness in the product, in addition, it is known that it significantly affects the rheological properties of the cake batter and accordingly the quality of the final product in bakery products such as cakes (Mousavivand et al., 2020). Sugar, which has hygroscopic properties (Milner et al., 2020), also functions as a softener. Therefore, the flowability of cake batter with reduced sugar

content decreased and an increase was observed in back extrusion test parameters.

Features of cake samples

The specific volume values of the cake samples produced by reducing the sugar and fat content at different levels are shown in Fig. 1(A). The specific volume values of all cake samples with reduced sugar and fat content were higher than the control cake sample. As the fat content decreased, the specific volume values regularly decreased in the cake samples with 50% reduced sugar content, while a regular increase occurred in both the samples without reduced sugar content and sugar-free samples. In addition to textural properties, specific volume is an important quality criterion that affects consumer preferences in bakery products such as cakes (Kim et al., 2017). When the specific volume values are examined, it is seen that the decrease in the amount of sugar and fat did not have a negative effect, as expected. It is thought that the formulation used in the research and other processing conditions may be effective in the formation of this situation. In the research, 25% polydextose was used as a fat replacer in the cake samples with 75% reduced fat content. Contrary to the cake samples with 50% reduced sugar content, it is seen that the use of fat replacer is positively effective in terms of specific volume values if the fat content is reduced by 75% in the cake samples with no reduced sugar content and sugar-free.

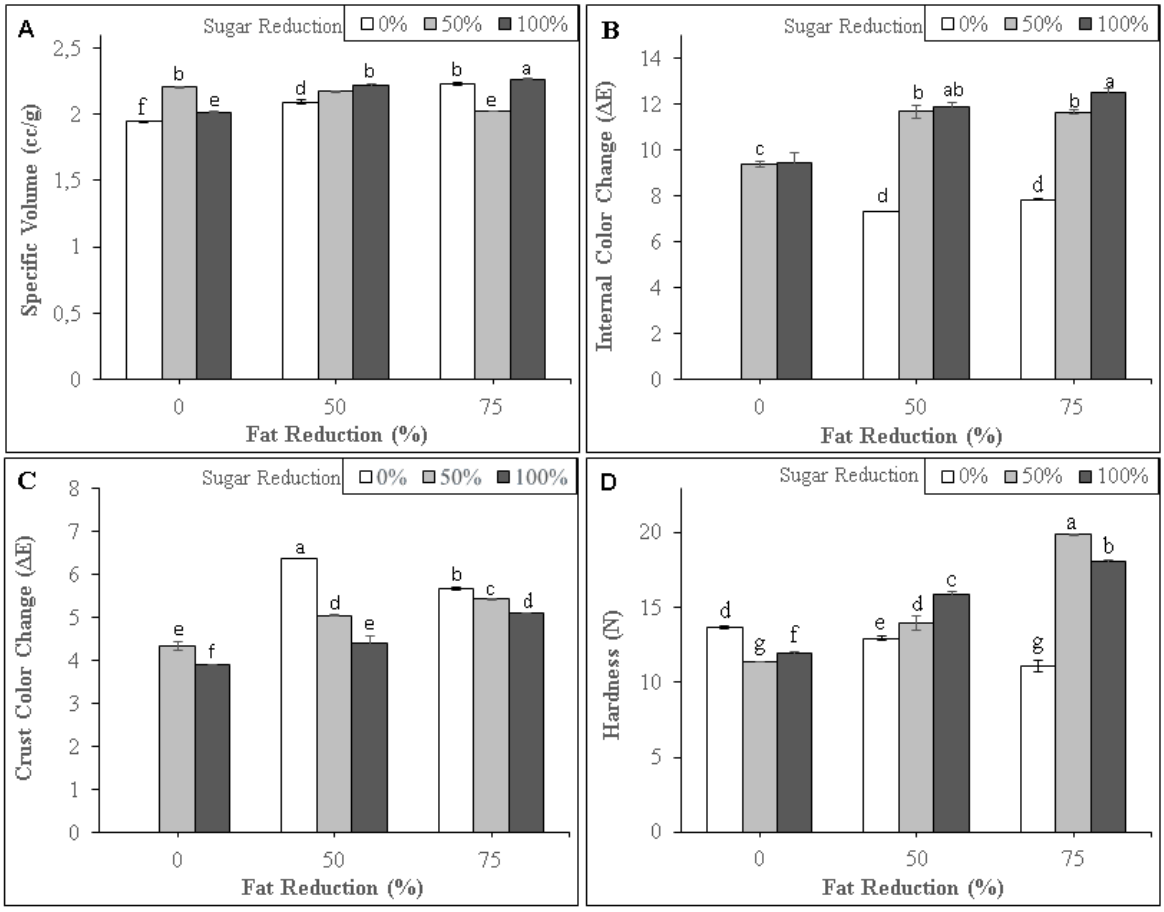

Figure 1. Specific volume (A), internal color change (B), crust color change (C) and hardness (D) values of cake samples with reduced sugar and fat content at different levels.

In chemically leavened cakes, starch gelatinization and protein denaturation, which occur simultaneously with the formation of carbon dioxide during baking, make the inside of the product porous (Agrahar-Murugkar et al., 2018). In bakery products such as cakes, in addition to the high volume, the fact that the internal structure of the product is porous and pores are generally small and homogeneously distributed are of great importance in terms of quality (Shobeiri et al., 2023). The increase in the number of pores in the product also causes an increase in volume. When the cake images produced in the study are examined (Fig. 2), it is seen that reducing only sugar content negatively affects the pore structure compared to the control sample. However, it is also determined reducing only fat content did not cause much change in the size and homogeneity of the pore structure of the cakes. While the pore structure was negatively affected in the samples with reduced both sugar and fat content, it was generally better in the samples with 75% reduced fat content since polydextrose was used as a 25% fat replacer. Sugar adds sweetness to a product while fat improves its chewing properties. In addition, it is known that these two components perform the function of keeping air bubbles in the batter and ensuring their stability in the cake production. Therefore, reducing the sugar and fat content negatively affected the pore structure in general and the fat replacer was effective in eliminating this negative effect.

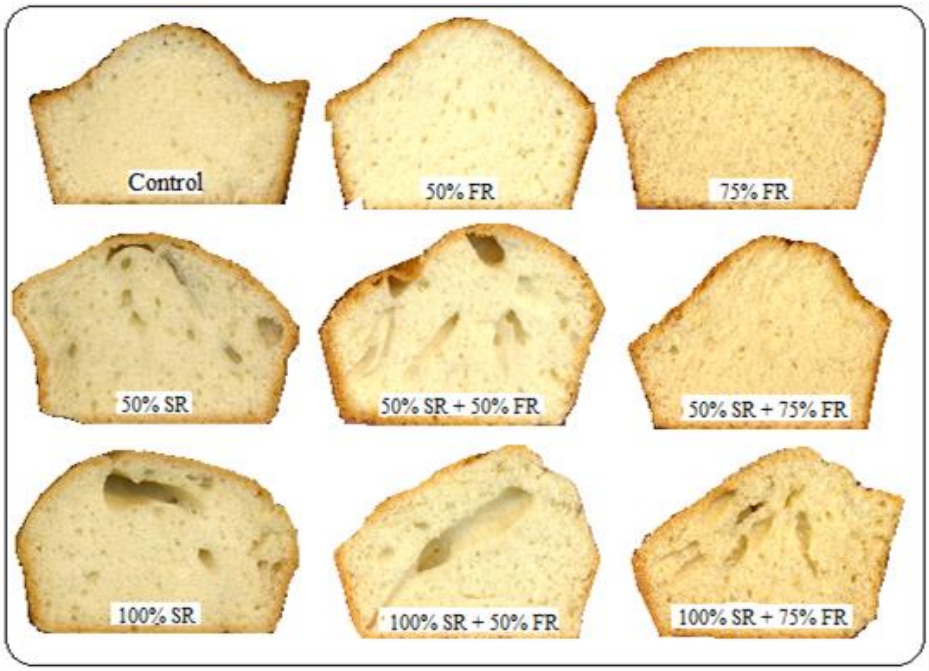

Figure 2. Cake samples produced by reducing the sugar and fat content at different levels (FR: Fat reduction, SR: Sugar reduction).

Color is an important quality criterion in bakery products as it directly affects the appearance of the product. While the inner color of the cake forms by affecting by the color of the ingredients used in the formulation, the crust color is formed by the Maillard reactions between amino acids and reducing sugars and the caramelization of sugars (Majzoobi et al., 2012). Total color change (ΔE) is the degree of overall color change of a sample compared to the color values of the control sample. Compared to the control sample, the internal ΔE values in the cake samples reduced sugar and fat content at different levels ranged from 7.31 to 12.51 (Fig. 1(B)) and the crust ΔE values ranged from 3.89 to 8.36 (Fig. 1(C)). There was more change in the inner color of the cake compared to the crust color. It was determined that the inner color change of samples

with reduced both sugar and fat content, which did not differ statistically between themselves, was higher than the other samples. Since the internal temperature does not exceed 100°C during baking, Maillard and caramelization reactions, which are effective in the color formation, do not occur and therefore the inner color of cakes is primarily affected by the color of the ingredients in the composition (Majzoobi et al., 2012). In this study, since the amount of sugar (23.79%) and fat (13.22%) was high in the cake formulation produced, changing the amounts of these components caused significant changes in the inner and crust color of the final product. In the cake samples, the crust ΔE values generally increased as the fat content decreased, while these values decreased with the decrease in sugar content at each fat level. In addition, lower of crust ΔE values were detected in the cake samples with reduced only sugar content compared to samples with reduced both sugar and fat content. During the baking process, heat and mass transfer occur at high temperature, Maillard and caramelization reactions occur on the dehydrated cake surface, and surface color is formed (Agrahar-Murugkar et al., 2018). Changing the amount of sugar and oil in the composition caused significant color changes in naturally produced cakes.

Hardness can be characterized by the force required to deform (compress) a product at a certain rate (Karaoğlu and Kotancılar, 2009). The softness or hardness of the inside of the cake is one of the most important textural features in terms of the consumption quality of the product, as it is closely related to the perception of freshness in consumers (Chompoorat et al., 2020). In the samples where the amount of sugar alone was reduced, the hardness first decreased and then increased slightly, while in the samples where the amount of fat alone was reduced, the hardness values decreased steadily as the fat decreased (Fig. 1(D)). However, reducing the sugar and fat content together generally caused an increase in the hardness value of cake samples. In the study conducted by Milner et al. (2020), it was stated that reducing the sugar content by 30% did not have a significant effect on the hardness of cakes. The hardness values increased regularly as the fat content was decreased in cake samples with 50% and 100% reduced sugar content. It is expected that reducing the amount of fat, which has a softening effect in bakery products (Psimouli and Oreopoulou, 2013) and the amount of sugar, which reduces moisture transfer from the interior to the crust due to its moisture retention feature (Milner et al., 2020), will cause an increase in hardness. In this study, the opposite effect was observed in the samples with reduced only sugar and only fat content while this effect was observed in the samples with reduced both sugar and fat content. The effect of fat in the samples where only the sugar content is reduced and the effect of sugar in the samples where only the fat content is reduced may have increased the softness. The increase in hardness of the samples, in which both components were reduced, supports this interpretation.

The effect of reducing the sugar and fat content on the textural properties of cake samples is given in Table 3. The adhesiveness value obtained as a result of the texture profile analysis of the inside of the cake was not affected in any way by the reduction of sugar and fat content, while the reduction of the sugar content was effective in reducing the cohesiveness value in general. On the other hand, the reduction of fat content in cakes containing sugar completely (sugar reduction 0%) did not have a statistically significant effect on the cohesiveness value, while the reduction of sugar content caused a significant decrease in cakes in which fat content was not reduced (full fat, fat reduction 0%). In the cake samples in which both sugar and fat content were reduced together, lower cohesiveness values were obtained compared to the other samples, being higher in sugar-free cakes. Cohesiveness is a critical textural peroperty of cake. It is described as an indicator of the internal resistance of a food and is desired to be relatively high in order to better resist structural deformations in both cake batter and final product cake (Karaoğlu and Kotancılar, 2009). Fat acts as a softener in bakery products such as cakes. On the other hand, due to water-binding property, sugar plays a more active role in the formation of structure (Milner et al.,

2020). For this reason, a decrease was observed in the cohesiveness values, especially in the cake samples in which the sugar content was reduced. Elasticity in foods is an indicator of the ability to return to its original shape after mechanical stress has been applied and removed and chewiness is an indicator of the energy required to get ready to swallow a semi-solid food by chewing (Karaoğlu and Kotancılar, 2009). Reducing the sugar and fat content of the cake samples did not cause significant changes on elasticity values. There was a significant decrease in the chewiness values of the cake samples with the reduction of sugar alone and the fat content alone. In addition, in the samples in which the sugar content was reduced by 50% and 100%, the chewiness value also decreased regularly as the fat content decreased. Since chewiness is a secondary parameter calculated by using the hardness, cohesiveness and elasticity values, it is significantly affected by the changes in these values. It is possible to say that the effect of hardness is great in this change. Therefore, the chewiness values showed a similar change to the hardness values.

Table 3. Textural properties of cake samples with reduced sugar and fat content at different levels[a].

Sugar Reducion (%)	Fat Reduction (%)	n	Adhesiveness	Cohesiveness	Elasticity	Chewiness
0	0(C)	2	0.02±0.01a	0.71±0.01a	0.90±0.01a	9.19±0.27bc
	50	2	0.50±0.41a	0.71±0.00a	0.90±0.00a	8.32±0.22cd
	75	2	0.09±0.00a	0.72±0.01a	0.89±0.00a	6.18±0.21ef
	GA:	6	*0.20±0.14A*	*0.72±0.00A*	*0.90±0.00A*	*7.89±0.57B*
50	0	2	0.07±0.00a	0.66±0.00b	0.90±0.01a	6.97±0.49ef
	50	2	0.05±0.00a	0.64±0.00bc	0.90±0.01a	7.26±0.24de
	75	2	0.19±0.01a	0.64±0.01bc	0.89±0.00a	11.58±0.75a
	GA:	6	*0.11±0.02A*	*0.65±0.00B*	*0.90±0.00A*	*8.60±0.97A*
100	0	2	0.01±0.00a	0.60±0.01d	0.90±0.00a	5.86±0.33f
	50	2	0.01±0.00a	0.62±0.01cd	0.90±0.00a	9.07±0.08bc
	75	2	0.04±0.00a	0.62±0.01cd	0.89±0.00a	10.20±0.06b
	GA:	6	*0.02±0.01A*	*0.61±0.01C*	*0.90±0.00A*	*8.38±0.82AB*
	P		--	**	*	**

[a]Means showed by the same letter are not statistically different from each other (p≥0.05),
*P<0.05, **P<0.01, C: Control, GA: General Average.

The effect of reducing the sugar and fat content at different levels on sensory properties such as appearance, aroma, taste, texture and overall acceptability of cake samples is shown in Fig. 3. In general, compared to the control sample, sugar-free cakes had lower sensory scores, while the cake samples with sugar reduction 0%, fat reduction 50% and 75% showed sensory characteristics close to the control group. In terms of taste, aroma and texture, the samples with no sugar and 75% reduced fat content received the lowest score, while the cake samples with only 50% reduced fat content were more appreciated than the control. In terms of general acceptability, samples with no sugar and 50% reduced fat content received the lowest score, while all samples with 50% reduced sugar content scored close to the control group. On the other hand, the samples without reduced sugar content and only reduced fat content had higher values than the control group. Sugar and fat are two important components that affect product quality in cake production. In general, reducing the sugar content alone had more adverse effects on sensory properties than reducing the fat content alone. In the samples with reduced both sugar and fat content together, the samples in which the sugar content was reduced by 50%, were found to be superior in terms of sensory. Changes in sensory properties due to modifications in sugar and fat content are generally consistent with other studies (Milner at al., 2020). When all sensory parameters

are taken into account, it is seen that the cake samples with full of sugar content and 50% reduced fat content received the highest score.

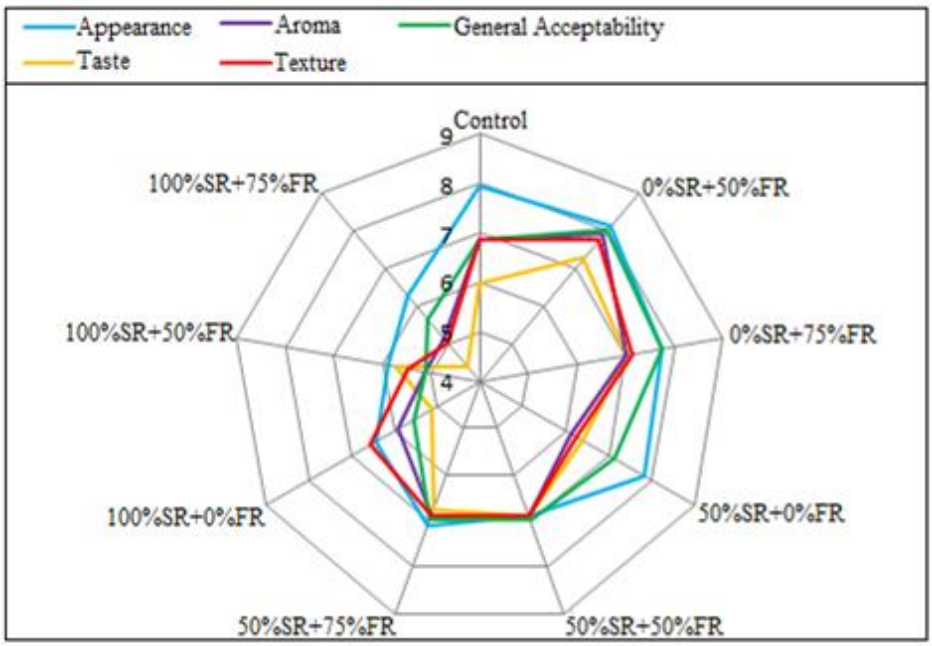

Figure 3. Sensory evaluation of cake samples with reduced sugar and fat content at different levels (SR: Sugar reduction, FR: Fat reduction).

CONCLUSIONS

In this study, the effect of reducing the sugar and fat content at different levels on the quality of cakes was investigated in order to reduce its caloric value. Since sugar and fat are two important components in the cake production in terms of both quantity and function, changing their amounts in the formulation caused significant changes in the properties of both the cake batter and the final product. At all sugar levels, decreasing the amount of fat caused an increase in the density of the cake batter and a decrease in the hardness, consistency, cohesiveness and viscosity index values. Reducing the amount of sugar was effective in decreasing the density of the cake batter and increasing the hardness, consistency, cohesiveness and viscosity index values. Reducing the sugar and fat content had a positive effect on the specific volume. In the cake samples with 50% reduced sugar content, the specific volume values decreased as the fat content decreased, while an increase occurred in the specific volume with the decrease in fat content in both samples with no reduced sugar content and sugar-free. Reducing the sugar and fat content caused a significant color change, more in the interior compared to the crust. Compared to the control sample, the hardness values of the cake samples with only sugar and only fat reduction had lower hardness values while the cake samples with reduced both sugar and fat content had higher hardness values. When all sensory parameters were taken into account, it was observed that the samples with only 50% reduction fat content were most appreciated.

CONFLICT OF INTEREST

The article authors declare that there is no conflict of interest between them.

AUTHOR CONTRIBUTIONS

The authors declare that they have contributed equally to the article.

ETHICAL APPROVAL

Ethical approval is not required for this research.

REFERENCES

AACC (2010). Approved Methods of the American Association of Cereal Chemists. Approved Methods of Analysis 11th Edition, Cereals & Grains Association: St. Paul, MN, U.S.A.

Abdel-Salam, A.M., Ammar, A.S., Galal, W.K. (2009). Evaluation and properties of formulated low calories functional yoghurt cake. *Journal of Food, Agriculture and Environment 7*(2): 218-221.

Agrahar-Murugkar, D., Zaidi, A., Dwivedi, S. (2018). Development of gluten free eggless cake using gluten free composite flours made from sprouted and malted ingredients and its physical, nutritional, textural, rheological and sensory properties evaluation. *Journal of Food Science and Technology 55:* 2621-2630. https://doi.org/10.1007/s13197-018-3183-1

Ang, E.M., Abdullah, N., Muhammad, N., Lizardo, R.C.M. (2017). Effect of formulation with papaya sauce as fat replacer on butter cake texture. *Journal of Science Technology 9*(4): 56-63. https://publisher.uthm.edu.my/ojs/index.php/JST/article/view/2088

Azevedo, B.M., Schmidt, F.L. & Bolini, H.M.A. (2015). High-intensity sweeteners in spresso coffee: ideal and equivalent sweetness and time–intensity analysis. *International Journal of Food Science & Technology 50:* 1374-1381. DOI10.1111/ijfs.12774

Barakat, A., Abdulla, G. (2014). Use of sucralose and stevia leaves extract in producing low calorie bakery products. *Zagazig Journal of Agriculture Research 41*(3):575-586.

Belorio, M., Sahagún, M., Gómez, M. (2019). Psyllium as a fat replacer in layer cakes: batter characteristics and cake quality. *Food Bioprocess Technology 12:* 2085-2092. https://doi.org/10.1007/s11947-019-02362-3

Buarnia, P., Goyal, M., Dunkwal, V., Rathore, R. (2017). Development and quality evaluation of stevia based cake and biscuits. *Food Science Research Journal 8*(1): 64-69. https://doi.org/10.15740/HAS/FSRJ/8.1/64-69

Chompoorat, P., Kantanet, N., Hernández Estrada, ZJ., Rayas-Duarte, P. (2020). Physical and dynamic oscillatory shear properties of gluten-free red kidney bean batter and cupcakes affected by rice flour addition. *Foods 9(5):* 616. https://doi.org/10.3390/foods9050616

Dadkhah, A., Elhami Rad, A.H.E., Azizinezhad, R. (2017). Effect of pumpkin powder as a fat replacer on rheological properties, specific volume and moisture content of cake. *Banat's Journal of Biotechnology 8*(16): 116-126. https://doi.org/10.7904/2068–4738

Doğan, İ., Akbaş, Ö., Tunçtürk, Y. (2012). Use of exopolysaccharide in fat reduced cake production. *Food/Gıda 37*(3): 41-148. https://dergipark.org.tr/en/pub/gida/issue/6929/92519

Dündar, A.N. , Şahin, O.I., Sarıcaoğlu, F.T. (2023). Low-fat cookies with chlorella vulgaris: effects on dough rheology, phsical, textural and sensory properties of cookies. *Food/Gıda 48:* 526-544.

Gerçekaslan, K.E., Boz, H. (2018). Effect of addition of carob flour on physical, sensory and textural properties of cocoa cake. *Iğdır University Journal of The. Institute Science and Technology 8*(1): 95-101. https://doi.org/10.21597/jist.407844

Giritlioğlu, E. (2017). A Research on the Development of New Biscuit and Cake Formulas Using Quinoa (*Chenopodium quinoa Willd.*) and Sugar Grass (*Stevia rebaudiana Bertoni*). Osmaniye Korkutata University, Institute of Natural and Applied Sciences, MSc Thesis, Osmaniye/Turkey, 111 p.

Hesso, N., Loisel, C., Chevallier, S., Marti, A., Le-Bail, P., Le-Bail, A., Seetharaman, K. (2015). The role of ingredients on thermal and rheological properties of cake batters and the impact on microcake texture. *LWT-Food Science and Technology 53*(2): 1171-1178. https://doi.org/10.1016/j.lwt.2015.04.041

İnanç, A., Çınar, İ. (2009). Alternative natural sweetener: Stevia. *Journal of Food 34*(6): 411-415. https://dergipark.org.tr/en/pub/gida/issue/6864/91972

Karp, S., Wyrwisz, J., Kurek, M., Wierzbicka, A. (2016). Physical properties of muffins sweetened with steviol glycosides as the sucrose replacement. *Food Science Biotechnolgy 25*(6): 1591-1596. https://doi.org/10.1007/s10068-016-0245-x

Kim, J.R., Ahn, E.Y., Das, H., Jeong, Y.H., Hong, S.T., Miles, M., Lee, K.J. (2017). Effect of tool geometry and process parameters on mechanical properties of friction stir spot welded dissimilar aluminum alloys. *International Journal of Precision Engineering and Manufacturing 18*: 445-452. https://doi.org/10.1007/s12541-017-0053-0

Karaoğlu, M.M., Kotancilar, H.G., Çelik, İ. (2001). Effects of utilization of modified starches on the cake quality. *Starch/Staerke* 53 (3–4):162-169. https://doi.org/10.1002/1521-379X(200104)53:3/4<162::AID-STAR162>3.0.CO;2–6

Karaoğlu, M.M., Kotancılar, H.G. (2009). Quality and textural behaviour of par-baked and rebaked cake during prolonged storage. *International Journal of Food Science and Technology 44*: 93-99. https://doi.org/10.1111/j.1365-2621.2007.01650.x

Kothalawala S.G., Marasinghe S.P. (2018). review on effects of baking with fat, fat polymorphism and commonly used fat replacers. *International Journal of Research. 5*(15): 2775-2779. https://edupediapublications.org/journals

Kulthe, A.A., Pawar, V.D., Kotecha, P.M., Chavan, U.D., Bansode, V.V. (2014). Development of high protein and low calorie cookies. *Journal of Food Science and Technolgy 51*(1): 153-157. https://doi.org/10.1007/s13197-011-0465-2

Mageed, N.K., Al-Abdullah, B.Y. (2020). Manufacturing of low fat and calorie cake and study its qualitative and storing characteristics. *Tikrit Journal of Agriculture Scence. 20*(2): 57-67.

Majzoobi, M., Darabzadeh, N., Farahnaky, A. (2012). Effects of percentage and particle size of wheat germ on some properties of batter and cake. *Journal of Agriculture. Science and Technology 14*: 827-836

Majzoobi, M., Mohammadi, M., Farahnaky, A. 2020. Simultaneous reduction of fat and sugar in cake production; effects of changing sucrose, oil, water, inulin, and Rebaudioside A on cake batter properties. *Journal of Food Processing and Preservation 44*(10):e14733 https://doi.org/10.1111/jfpp.14733

Milner, L., Kerry, J. P., O'Sullivan, M. G., Gallagher, E. (2020). Physical, textural and sensory characteristics of reduced sucrose cakes, incorporated with clean-label sugar-replacing alternative ingredients. *Innovative Food Science Emerging Technology 59*, 102235. https://doi.org/10.1016/j.ifset.2019.102235

Mohammadi-Moghaddam, T., Firoozzare, A., Shamspour, N. (2020). Black plum peel torshak: physicochemical properties, sensory attributes, and antioxidant capacity. *International Journal of Food Properties 23*(1): 1792-1803.https://doi.org/10.1080/10942912.2020.1833031

Mousavivand, H., Hojati, M., Jooyandeh, H., Barzgar, H., Zaki, H. (2020). Effect of replacement of sugar with grape syrup powder on characteristics of cupcake. *Journal of Food Research 30*(2): 175-188. Https://Sid.İr/Paper/963577/En

Murugkar, D.A., Zanwar, A.A., Shrivastava, A., 2021. Effect of nano-encapsulation of flaxseed oil on the stability, characterization and ıncorporation on the quality of eggless cake. *Applied Food Research 1*(2): 100025. https://doi.org/10.1016/j.afres.2021.100025

Özcan, M.M., Babaoğlu, H.Ç. (2017). The effect of replacing sucrose with stevia (*Stevia rebaudiana*) leaf powder and extract on some physicochemical properties of cakes. *Journal of Agroalimentary Processes and Technology 23*(3): 181- 187.

Psimouli, V., Oreopoulou, V. (2013). The effect of fat replacers on batter and cake properties. *Journal of Food Science 78*: 1495-1502. https://doi.org/10.1111/1750-3841.12235

Rahmati, N.F., Tehrani, M.M. (2014). replacement of egg in cake: effect of soy milk on quality and sensory characteristics. *Journal of Food*

Processing and Preservation 39(6): 574-582. https://doi.org/10.1111/jfpp.12263

Rosenthal, A.J., Thompson, P. (2021). What is cohesiveness? A linguistic exploration of the food texture testing literature. *Journal of Texture Studies 52*(3): 294-302. https://doi.org/10.1111/jtxs.12586

Shobeiri, M., Elhami Rad, A. H., Sheikholeslami, Z., Zenozian, M.S., Saeedi Asl, M.R. (2023). The effects of quinoa and okra incorporation on the quality of diet cake. *Food Science and Technology International* 10820132221140615. https://doi.org/10.1177/10820132221140615

Sun, B., Qian, X., Cui, G., Ma, S., Wang, X. (2023). Synergistic effect of combined sucrose substitutes and partially gelatinized oat flour on gluten-free steamed oat cakes produced only by oat flour. *Journal of Cereal Scence. 110*: 103648, https://doi.org/10.1016/j.jcs.2023.103648

Tuna, H.E. (2015). Evaluation of Cherry, Pomegranate, Pumpkin and Apricot Seeds, Which are Food Wastes, in Cake Production. İstanbul Technical University, Institute of Natural and Applied Sciences, MSc Thesis, İstanbul/Turkey, 74 p.

Yazar, G., Rosell, C.M. (2023). Fat replacers in baked products: their impact on rheological properties and final product quality. *Critical Reviews in Food Science and Nutrition 63(*25): 7653-7676. https://doi.org/10.1080/10408398.2022.2048353

Zhang, Z., Zhou, H., Bai, Y. (2021). Use of glycosylated wheat protein in emulsions and its application as a fat replacer in microwave cakes. *Journal of Cereal Science 100*: 103256. https://doi.org/10.1016/j.jcs.2021.103256