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THE USE OF CAROB FLOUR AND STEVIA AS SUGAR SUBSTITUTES FOR CAKE PRODUCTION AND ENRICHMENT WITH WHEAT GERM

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CÜNEYT GÖKÇE
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in

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Gaziantep University

Supervisor

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by

Cüneyt GÖKÇE

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This is to certify that we have read this thesis and that in our consensus opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Cüneyt GÖKÇE

ABSTRACT

THE USE OF CAROB FLOUR AND STEVIA AS SUGAR SUBSTITUTES FOR CAKE PRODUCTION AND ENRICHMENT WITH WHEAT GERM

GÖKÇE, Cüneyt

M.Sc. in Food Engineering

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In this study, carob flour and stevia were used instead of sugar which is one of the main ingredients in the production of cakes. Also, wheat germ was used to enrich nutritional value of cake. Process variables were sugar (0-25 %), stevia concentration (0-2 %) and carob flour concentrations (0-30 %) in constant amount of wheat flour. From these variables, 20 different cakes were produced. The best cake formulation was decided from optimization and it was PC12 among these cakes. In optimization process, UI was set as zero. SSV, TSV, hardness, cohesiveness, gumminess, chewiness and resilience were minimum; springiness and volume were set as maximum. Also, maximum taste and general evaluation values were set parameters of sensory analysis. In order to increase nutritional values of the best cake decided, the wheat germ was replaced with wheat flour in different amounts (0-10 %) and 8 different cakes were produced. Among these cakes, the best cake formulation was decided from optimization of the parameters mentioned above. Enrichment with wheat germ led to increase some properties of cakes such as UI value got zero. TSV, cohesiveness and resilience were decreased. It led to increase springiness of cakes. Moreover, it affected the sensorial properties that both taste and general evaluation were increased. On the other hand, addition of wheat germ had negative effect on cakes such as increasing hardness, gumminess and chewiness. It decreased the volume of cakes. Besides all of them, the addition of wheat germ had no effect on SSV.

Keywords: Cake, Sugar, Carob Flour, Stevia, Wheat Germ

ÖZET

ŞEKER İKAMESİ OLARAK KEÇİBOYNUZU UNU VE STEVYA KULLANARAK KEK ÜRETİMİ VE BUĞDAY RÜŞEYMİ İLE ZENGİNLEŞTİRİLMESİ

GÖKÇE, Cüneyt

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Bu çalışmada, keçiboynuzu unu ve stevya kek üretiminin ana malzemelerinden biri olan şeker yerine kullanıldı. Ayrıca, buğday rüşeymi kekin besin değerini zenginleştirmek için kullanıldı. Proses değişkenleri şeker (% 0-25), stevya konsantrasyonu (% 0-2) ve keçiboynuzu unu konsantrasyonları (% 0-30) sabit miktar buğday ununa göreydi. Bu değişkenlerden 20 farklı kek üretildi. En iyi kek formülasyonu, optimizasyon sonucuna göre belirlenen PC12 olmasına karar verildi. Optimizasyon sürecinde, tekdüzelik indeksi sıfır olarak ayarlandı. Alt büzülme değeri, üst büzülme değeri, sertlik, iç yapışkanlık, sakızımsılık, çiğnenebilirlik ve elastikiyet minimum; esneklik ve hacim maksimum olarak ayarlandı. Ayrıca, maksimum lezzet ve genel değerlendirme değerleri duyusal analizin parametreleri olarak belirlendi. En iyi keke karar verildikten sonra besin değerini artırmak için buğday rüşeymi farklı miktarlarda (% 0-10) buğday unu ile değiştirildi ve 8 farklı kek üretildi. Bu kekler arasından en iyi kek formülasyonuna yukarıda belirtilen optimizasyon parametrelerine göre karar verildi. Buğday rüşeymi ile zenginleştirme, tekdüzelik indeksi değerinin sıfır olması gibi kekin bazı özelliklerinin artmasına neden oldu. Üst büzülme değeri, iç yapışkanlık ve elastikiyet azaldı. Keklerin esnekliğinin artmasına neden oldu. Ayrıca, duyusal özellikler bakımından hem lezzetin hem de genel değerlendirmenin arttığı görüldü. Diğer taraftan, buğday rüşeyminin eklenmesi keklerde sertlik, sakızımsılık ve çiğnenebilirlik özelliklerinin artması gibi olumsuz etkilere neden oldu. Kek hacmini düşürdü. Bunların yanı sıra, buğday rüşeyminin eklenmesinin alt büzülme değerine etkisi olmadı.

Anahtar Kelimeler: Kek, Şeker, Keçiboynuzu Unu, Stevya, Buğday Rüşeymi

To My Family

E. C. E. A.

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LIST OF SYMBOLS

A	Sugar
A	Elongation (mm) in Resistance and Elasticity Analysis
a*	Redness-greenness value
B	Carob flour
b*	Yellowness-blueness value
C	Stevia
°C	Celsius degree
d	Tare of case (g) in Moisture Content Analysis
F	Nitrogen protein conversion factor in Protein Analysis
f	Factor of 0.1 M HCl solution in Protein Analysis
H	Moisture content of sample (%)
K	Ash content in dry mass (%)
L*	Lightness-darkness value
P	Protein in dry mass (%)
$\mathbf{R^2}$	Correlation coefficient

LIST OF ABBREVIATIONS

AACC	American Association for Clinical Chemistry
ANOVA	Analysis of variance
BC	Before Christ
BD	Shrinkage value
CC	Cake Code
CIE	Commission internationale de l'éclairage
Co.	Company
CO_2	Carbon dioxide
cm	Centimeter
EC	European Commission
EN	Europeane Norm
Eq.	Equation
Ex	Extensibility in Resistance and Elasticity Analysis
Fb	Baking strength in Resistance and Elasticity Analysis
Fehling A	Copper sulfate solution
Fehling B	Alkaline tartrate solution
FDA	The American Food and Drug Administration
g	Gram
GRAS	Generally Recognized as Safe
HCI	Hydrogen chloride
HI	Volume index
HYD2200	Water absorption capasity in 15% humidity
ICC	International Association for Cereal Science and Technology
Iec	Elasticity index (%)
Inc.	Incorporated
ISO	International Organization for standardization
kg	Kilogram

km	Kilometer
m	Meter
µm	Micrometer
mg	Milligram
min	Minutes
ml	Milliliter
mm	Millimeter
NaOH	Sodium hydroxide
PC	Product Code
rev	Revolution
RSM	Response surface methodology
sec	Second
SI	Symmetry index (mm)
SSV	Sub shrinkage value (mm)
T	Resistance in Resistance and Elasticity Analysis
T/A	Configuration ratio
TA	Texture Analyzer
THI	Total volume index
TI	Uniformity index
TS	Turkish Standard
TSI	Turkish Standards Institute
TSV	Top shrinkage value (mm)
TPA	Texture Profile Analysis
TVI	Total volume index (mm)
UI	Uniformity index (mm)
UK	United Kingdom
USA	United States of America
w/w	Weight per weight
VI	Volume index (mm)

CHAPTER I
INTRODUCTION

In societies with prosperous and economically advanced, the physical activity of people and consumption of bread and other cereals have decreased significantly. Individuals have started to provide most of the daily energy from foods with high content of meat, fat and sugar. This situation has led to increase and spread of some diseases such as obesity, cardiovascular diseases, diabetes and intestinal diseases (Dizlek et al., 2008). As a prevention against these diseases, careful selection of diets, consumption of more nutritious foods, and patient groups need to carefully select the foods they consume.

Cake is a nutritive food containing protein, fat and high amounts of carbohydrates. However, it contains small amount of vitamins, minerals and dietary fibers required for body metabolism. For this reason, studies on cakes have focused on increasing nutritional values. The addition of dietary fibers from various sources, use of flour obtained from whole grains in making of cakes is one of solutions for this problem. This situation in the cake formulation naturally change the parameters that affect the quality of the cake. Increasing the nutritional values of the cake is not enough exclusively. Various measures are required to ensure that the quality of cake is not adversely affected by the changes (Yavaş, 2012).

1.1. Cake

Date of cake is back to ancient times and it is known from the beginning of civilization. The cake is a word in German language and it is derived from the word called as "kaka" (Ayto, 2002).

Having a lot of diversity makes it difficult to definition of cakes. However, Turkish Standard Institute defines the standard (TSI, 13375, "Cakes", Anonymous, 2008) as "wheat flour or cereal flours and/or mixtures, white sugar, edible vegetable oil, eggs, salt, swelling agents, flavoring agents, fillings and other additives are prepared by mixing and adding water and then processed in accordance with the technique and prepared by baking served as a packaged product for consumption".

Another definition of the cake is "flour, sugar, fat and eggs are mixed to prepare soft dough then cooked at appropriate temperature and time is called prepared food" that it can be consumed (Elgün and Ertugay, 2002).

The classification of cakes is usually made according to the ingredients in the composition of the cakes and their proportions. Cakes with different varieties and formulas according to their industrial shapes are divided into 6 classes. They are top, slice, baton, mold, sponge and bar (Mercan and Boyacıoğlu, 1999a). Cakes are generally divided into three categories according to their formulations and mixing methods as Batter type, Foam type and Chiffon type. Foamy cake consists of large cells inside after baking by holding air bubbles in the tissue. The chiffon cake is a combination of batter and foam types, including oil and egg yolk as the liquid component. Since the eggs are present in foamy cakes but shortening is not. Foamy cakes are more resistant than shortening cakes. In Europe, this type is used much more, it is cut into thin layers and filled with various rich fillings (cream and fruits). These cakes are usually moistened with flavored sugar syrup (Hui, 2005).

Cakes, biscuits, crackers, waffles and bars are the oldest known snack foods. These types of foods have high carbohydrate and fat contents because they are mainly produced with wheat flour, sugar, fat and chocolate, which are consumed by hot or cold drinks or consumed alone, which can cause to skip meals. Due to the length of their shelf life and their easy transportability, they are increasingly preferred by both producers and consumers (Karaoğlu et al., 2006). Bakery products are one of the most important areas of the industry and can be produced in a wide variety of ways. Unlike crackers, wafers and biscuits, cakes are a foodstuff that can be easily prepared in a short time and in a wide variety of houses. It is possible to find a large variety of cakes and formulas produced in the industry (Pyler, 1988).

Several studies are available in the literature focused on improving physical, chemical, textural and sensorial properties of cakes. Koçak (2018) studied some emulsifiers' effects on quality of gluten free cake. He used different flours (buckwheat, corn and rice) to produce cakes for celiac patients. The effects of diacetyl tartaric ester of monoglycerides, lecithin, distilled monoglycerides, sodium stearoyl lactylate and commercial emulsifier mixtures were investigated in his study on the quality parameters (volume, symmetry, textural properties and color) of cake and they were compared with control cake (wheat flour). He found that cakes which were produced with buckwheat flour (1 % sodium stearoyl lactylate form), corn flour (0,5 % lecithin form) and corn flour (6 % commercial emulsifier mixture) were closest to the control cake produced with wheat flour.

Özuğur and Hayta (2011) carried out a study about adding xanthan gum, guar gum, locust bean, carob gum, κ-karragenan and their mixtures in gluten-free rice cakes for increasing emulsion stability of the cake dough. They found that addition of xanthan gum and emulsifier mixture significantly increased the cake volume and porosity. Also they observed that the cake viscosity significantly increased and prevented collapse during the baking by xanthan gum.

Yücel (2009) studied use of xanthan gum, guar gum and hydroxypropyl methyl cellulose to produce gluten free cakes at levels of 0.5 %, 1.0 % and 1.5 % respectively. She found that volume, total volume and symmetry index of cakes increased. At the end of her study it was reported that the use of both xanthan gum, guar gum and hydroxypropyl methyl cellulose had positive effects on the quality of cake.

Arozarena et al. (2001) studied the effect of combinations of xanthan gum and monoglyceride on production of cake. They found that hardness, volume and shrinkage values of the cake were effected by these combinations. At the end of their study it was reported that the use of xanthan gum decreased the shrinkages and monoglyceride had a positive effect on volume.

Bennion and Bamford (1997) studied gluten-free bakery products for people suffering from celiac disease due to sensitivity to gluten. The effect of partial substitution of rice flour at 20 %, 30 % and 40 % with sorghum and germinated chickpea flours on physical, rheological, sensory properties and staling rate of prepared gluten-free cake were investigated. They reported that the quality and nutritional properties of gluten-free rice cakes could be improved when using 20 %, 30 % of sorghum flour and 20 % of germinated chickpea flour as substitution levels of rice flour.

1.2. Sugar

There are approximately 99.8 % sucrose, no more than 0.05 % moisture, 0.05 % invert sugar and other carbohydrates and very little amounts of ash present in the commercial sugar structure used in cake production (Matz, 1992).

Sugar is one of the important components affecting the structure of the cake and increases the gelatinization temperature of the starch. Due to delay of gelatinization, the cake dough is fully expanded and symmetrical volume of cakes are obtained because of the air bubbles in the dough with the help of carbon dioxide and water vapor (Kim and Walker, 1992b).

Sugar increases the time required for the pore walls to stretch in the inner structure by slowing gluten development during mixing and increasing the denaturation temperature of proteins during cooking (Frye and Setser, 1991). Sugar not only affects taste properties, but also affects the texture and appearance of cakes. It plays an important role on the control of dough viscosity, the degree of gelatinization of starch and denaturation of proteins. It increases the coagulation of proteins from egg and milk components resulting in the expansion of the cake dough (Mc Williams, 1989).

The main functions of sugar used as a sweetener in making cakes are; increase the calorific value of the product, extend shelf life and improve texture. When sugar is added as crystal form into dough, it acts as a solidifier; when it is added as liquid sugar or syrup, it acts as a moisturizer (Dizlek et al., 2008).

Sugar which are the basic energy source required to show the vital functions of the body, threaten human health when they are taken in large amounts in the daily life. Industrial biscuit and cake markets are growing day by day using more sugar (especially sucrose and glucose syrups). Today it is observed that many biscuits and cakes offered on the market contain significant amount of sugar. Food industry tries to offer healthier, natural, nutritional and low-calorie sweeteners to consumers (İnanç and Çınar, 2009).

Ronda et al. (2005) studied the use of maltitol, mannitol, xylitol, sorbitol, isomalt, oligofructose and polydextrose as sugar substitute for production of sponge cake. The effects of polyol and oligosaccharides on sponge cake production was determined in their study by texture, color and volume measurements. At the end of their study it was seen that the cake samples prepared with xylitol and maltitol gave results close to the control cakes.

Koçer (1999) carried out a study about using of polydextrose as sugar and fat substitutes for production of cakes which have high ratios of sugar and fat. She studied the use of polydextrose for sugar-replacement on a set of samples containing both them corresponding to the total sugar in the orginal formulation of the cake firstly. She concluded that the polydextrose could be used for sugar (33.87 %) and fat (15.03 %) replacement in the production of a diet cake formulation.

1.3. Carob Flour

The Carob (*Ceratonia siliqua* L.) is one of the most typical examples of the *Caesalpiniaceae* subfamily of the family *Leguminosae*, which is distributed in Mediterranean climate (Karkacıer and Artık, 1995). Carob is grown in the countries which have Mediterranean climate such as Spain, Italy, Morocco, Portugal, Greece, Cyprus and Turkey (Pazır and Alper, 2016). Carob is spreading from the coastline of 1750 km starting from Urla (İzmir) to Samandağ (Hatay) in Turkey. It is the most commonly found within 1-2 km of the coast and in the interior areas up to 600-700 m above sea level (Pekmezci et al., 2008).

Carob is also known as 'Harnup' and 'Boynuz' in Turkey. There are various names in many countries (Tunalıoğlu and Özkaya, 2003). The names of carob in various languages are 'Keçiboynuzu' in Turkish, 'Algarroba and Garrofera' in Spanish, 'Carruba' in Italian, 'Caroubier' in French, 'Johanesbrot' in German, 'Alfarrobeira' in Portuguese, 'Charaoupi' in Greek, 'Kharov' in Hebrew, 'Garrofer or Garrover' in Catalan and 'Carob' in English (Turhan, 2005).

Carob core weights are very close to each other so it was used as a weight measure in ancient times and it was used in jewelery weighing, Carat, the weight unit of jewels (Urbaş, 2008).

General characteristics of carob are at least 5 cm long, dark brown, distinctive shape, taste and odor according to Carob (Harnup) Standard of TSI (TS 2907, Anonymous, 1977). The maximum levels for broken carob weight 25 %, undeveloped fruit ratio 3 %, foreign matter rate 1 %, corrupt fruit rate 10 %, moldy or rotten rate 0.5 % and there should be no insects (TS 2907, Anonymous, 1977). Carob has been used as food since 4000 BC. Due to its high sugar content, it was used for children in emergency situations such as sugar, war and famine throughout history (Owen et al., 2003). Baked carob and juicy carob extracts have been part of the diets of many people with low income levels for hundreds of years (Iıpumbu, L., 2008). Carob is generally used as dried fruit, flour, molasses and animal feed in Turkey (Batu et al., 2007).

When carob is used as an alternative to cocoa, the fleshy portion of the fruit is roasted and then milled. The obtained carob flour can be used in the production of confectionery and pastry like cocoa. It is also emphasized that the use of this product in the chocolate industry has advantages such as not containing caffeine and theobromine (Hillcoat, D. et al., 1980). Caffeine and theobromine are the examples of alkaloids and they are present in coffee and cacao. They have the role of indicator for foods as well as giving the typical bitter taste. They have been used for a long time in order to benefit from its stimulant effect and treatment purposes when consumed like food (Pelletier, 1983).

Berk (2016) studied quality of gluten-free cakes (weight loss, porosity, specific volume, hardness, color and image analysis) which were effected by different flour (rice flour, buckwheat flour and carob bean flour), gum (xanthan gum and guar gum) and protein types (soy protein and whey protein). She reported that higher quality could be achieved when using buckwheat flour rather than carob bean flour in cake formulation.

Also, Seczyk et al. (2016) studied the quality of wheat pasta (antioxidant capacity, phenolic content, sensory analysis and nutritional quality) which was effected by addition of carob bean flour. It was concluded in their study that addition of carob bean flour (according to amount) increased phenolic and antioxidant property of pasta. On the other hand, they observed that glycemic index showed an increasing trend with increasing substitution level, decreasing tendency in digestibility of studied nutrient.

İlhan (2013) carried out a study about addition of carob in bakery products. She explained that carob has high amounts of carbonhydrates, minerals and antioxidant compounds. She reported that it was consumed as carob syrup and the rest of the fruit, pulp, which have high amounts of dietary fibers, was consumed as feed by animals in Turkey. Carob pulp flour was used in pogaca, cake, ice-cream cone at the rates of 5 %, 10 % and 15 % respectively in her study. She concluded that the use of carob pulp flour (15 %) could be used as wheat flour.

Minarro et al. (2012) studied the effect of high protein containing flours (soya, isolated pea, chickpea and carob germ flour) on quality of bread. They reported in their study that dough which included carob germ flour, had thicker structure than others. Bread with chickpea flour had the highest and bread with carob flour had the lowest specific volume. The lowest texture was seen in bread with chickpea flour. Bread with carob germ flour had stiffer structure contrary to chickpea and soya formulations.

Carob flour is an important product in human consumption and it is obtained from carob pulp (Şahin et al., 2009). Carob flour produced from deseeded carob by roasting and grinding (Pazır and Alper, 2018). Its particle size 150 µm (Alsaed and Alghzawi, 2000). The production process of the carob flour is given in Figure 1.1.

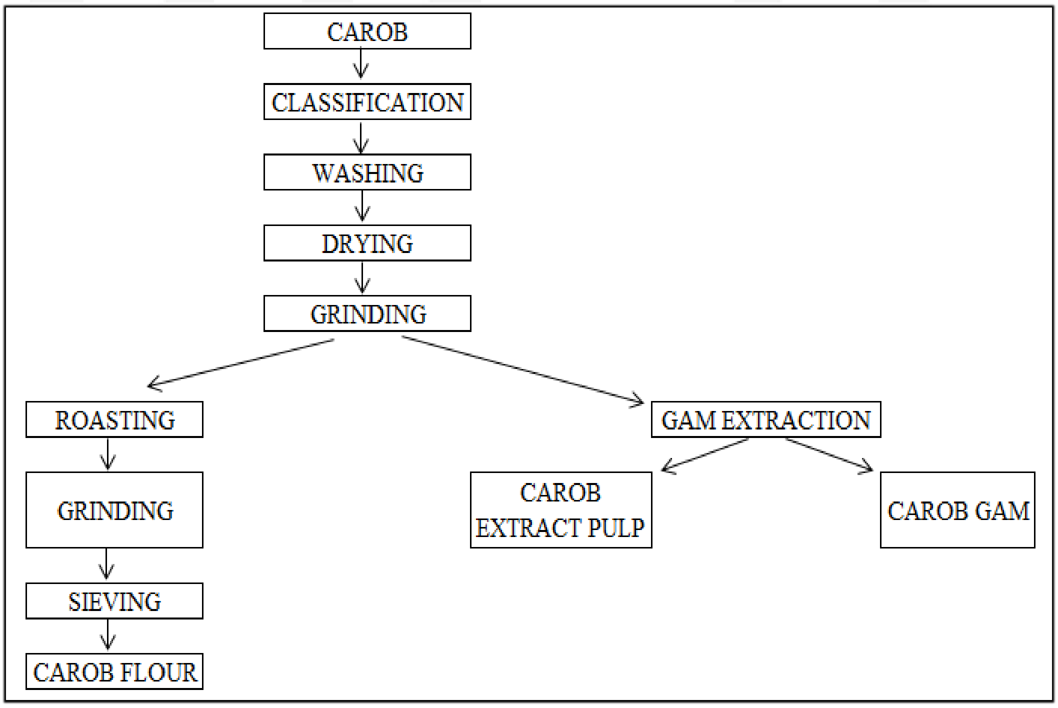

Figure 1.1. Production process of carob flour (Iıpumbu, L., 2008).

1.4. Stevia

Stevia rebaudiana is a small, wild shrub species from the *chrysanthemum* family. It is usually grown in Paraguay and Brazil. It is a kind of plant which likes moist environment, 60-90 cm tall, average 25 °C and some species can grow at 2300-2900 m altitudes (İnanç and Çınar, 2009). Stevia rebaudiana Bertoni has 35-62 % carbohydrate, 15-18.5 % raw fiber, 9.8-20.4 % protein, 6.3-13.1 % mineral substance, 4.7-7.7 % moisture and 1.9-5.6 % lipid (Abou-Arab et al., 2010).

Stevia rebaudiana Bertoni, a non-calorie sweetener, has been used as a natural sweetener in some countries (Zahn et al., 2013). Stevia is 200-300 times sweeter than sucrose (Prakash et al., 2008; Barba et al., 2014). It has high temperature and pH stability, not leave bitter-metallic taste in mouth, and is a natural product with high fiber content (Soliman, 1997). Stevia reduces blood sugar levels without affecting insulin metabolism. For this reason, it is recommended for diabetics (Lisak et al., 2011), obese and chronic patients (İnanç and Çınar, 2009). Steviol glycosides derived from Stevia rebaudiana Bertoni are natural compounds with high sweetness. These glycosides are called as steviosides Rebaudioside A, B and C and they are easily extracted and purified by water, then produced by concentrating and drying (Carakostas et al., 2008; Zahn et al., 2013). Steviol glycosides are good product for individuals with obesity, diabetes, heart disease and tooth decay as well as their sweetness (Ghanta et al., 2007; Manisha et al., 2012). Glycosides have anti-hyperglycemic, anti-hypertensive, anti-inflammatory, anti-tumor, anti-diarrhea and diuretic effects (Chatsudthipong and Muanprasat, 2009).

Terminological distinctions related to Stevia rebaudiana Bertoni; Stevia refers to Stevia rebaudiana Bertoni plant and its dried pieces. Steviol glycosides is sweet ingredients obtained from the Stevia plant by natural extraction method (steviosides and rebaudiosides). Rebaudioside A is the most valuable and quality component among the Steviol glycosides.

The American Food and Drug Administration (FDA) stated that Rebaudiosit A component, which has been purified from stevia, has been accepted as GRAS (safe) since December 2008 (Aidoo et al., 2013). Stevia, which was discussed when it was first discovered and consumed in foods, was allowed to be used as steviol glycoside

(E960) - sweetener in 31 food categories in the European Commission Regulation (EC, 2011) in November 2011.

Stevia can be used nearly in all foods and it is also successful in the formulation of bakery products baked at high temperature in the oven such as pastry, cakes and cookies (Ulusoy, 2011; Zahn et al., 2013). Stevia can be boiled up to 196-198 °C. It is used in hot and cold beverages, jam, compote, custard, pastry, cakes and cookies, seafood, confectionery industry, some vegetables, replace tea sugar, sushi, soy sauce, and yogurt production (İnanç and Çınar, 2009). Although there are several industrial sweeteners in foods, steviol glycosides are used in products such as; soft drinks, fruit juices, acidic beverages (Tadhani and Subhash, 2006), pasteurized milk products, sweet, confectionery, sauce, bread, and biscuits (Lisak et al., 2011; Ulusoy, 2011).

Koç (2018) studied the production of cake by using stevia plant as sugar subtitute. There were 350 participants to determine the sensory properties. Stevia extract was used at the levels of 0.3 g, 0.5 g and 1 g, respectively in her study. After cake production trials, she decided to produce cakes by using 0.3 g of stevia extract. Giritlioğlu (2017) carried out a study on the devolopment of new formulas for cakes and biscuits by using stevia and quinoa. The use of stevia powders (stevia commercial preparation and pure extract powder) were determined properly. After the effects of wheat and quinoa flour, sucrose and stevia commercial preparation on the quality properties of cupcakes and biscuits. It was concluded that stevia commercial preparation (40 %) was suitable for using stevia form in his study.

Zabihollahi (2014) studied the production of low-calorie cake by using toasted wheat flour, stevia and polydextrose. Cakes are produced from toasted wheat flour (0 %, 50 %, 100 %), sugar (0 %, 50 %, 100 %) and oil (50 %, 75 %). The physical, rheological and textural properties of the cakes were measured. Stevia extracts (0.25 %, 0.5 %) were used as sugar substitute and polydextrose (25 %) was used as oil substitute. She reported that toasted whole wheat (50 %), sugar (50 %), stevia (0.25 %) and oil (50 %) can be used to produce low-calorie cakes.

Zahn et al. (2013) carried out a study the production of muffin by using fibres and rebaudioside A. Sucrose (30 %) was used in production of their cake. Rebaudioside A with several fibres were used to decrease amounts of sugar. As a results of analyses (chemical, color, texture and sensory) it was concluded in their study that the combination of rebaudioside A with inulin or polydextrose in products were suitable to get the desired quality of control cake. Moisture, color and hardness values were increased whereas volume was decreased with the use of fibres and rebaudioside A. The cohesiveness and resilience of muffins did not change generally in their study.

There are several methods for production of stevia products (İnanç and Çınar, 2009). The well known production process of the stevia is given in Figure 1.2.

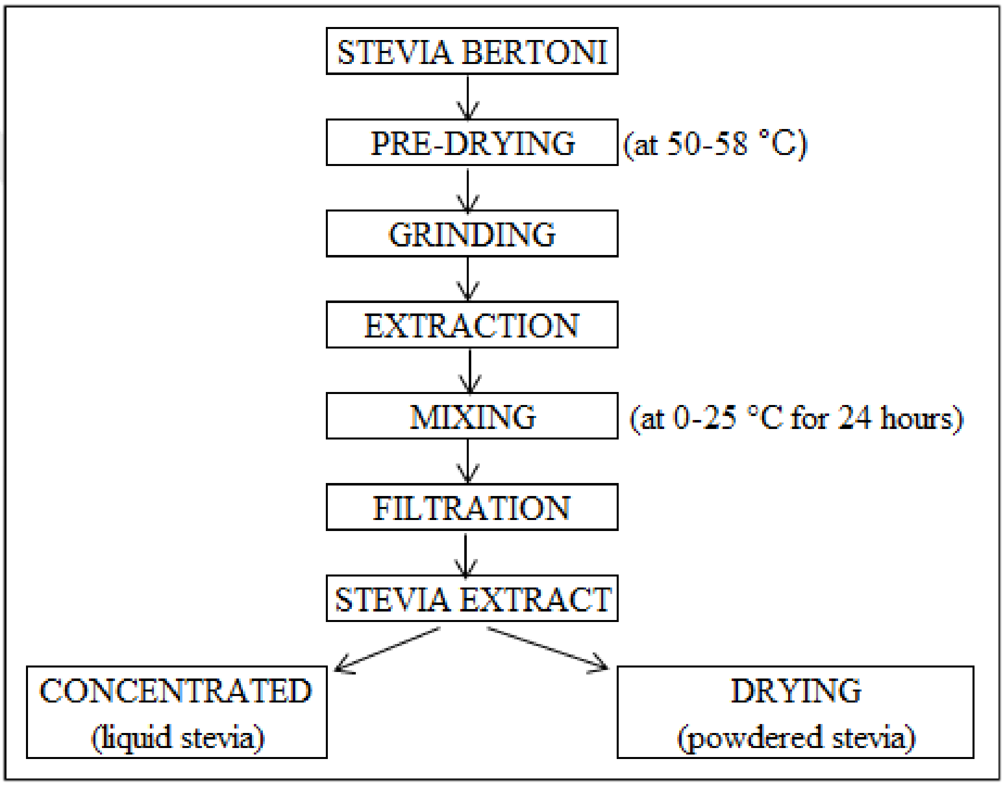

Figure 1.2. Production process of stevia (İnanç and Çınar, 2009).

1.5. Wheat Germ

Wheat germ which is present in wheat as 2.5-3.5 %, locates in the back part of the grain and close to the axis of the spikelets. Germination of the new plant occurs in germ and it is composed of two main parts, namely the scutellum and the embryonic axis (Hoseney, 1998).

The composition of the germ depends on wheat type, grain size, method of production and degree of purity (Shurpalekar and Rao, 1977). The germ contains about 28 % protein, 10 % fat, 42 % carbohydrate, 2 % fiber and 4 % mineral. It has a high fat content, in particular linoleic acid, stearic acid and oleic acid. It also contains essential linolenic acid, which is insufficient in most grains. Lysine, methionine and threonine from essential amino acids are also present in the wheat germ. The germ has high contents of vitamin E and B. Considering the high nutritional value of the germ, it can be used as an additive in many foods to increase the nutritional value of products (Demir and Elgün, 2011).

The high protein content of wheat germ and its excellent amino acid ratio make it attractive for flour (Pomeranz, 1987). The highest nutrient loss occurs in vitamins when wheat is grinding to flour. The amount of Vitamin B6 in the flour at the end of the grinding remains as 13 % of the amount before milling. This amount decreases to 7 % in vitamin E. According to the mineral loss, manganese 82 % and magnesium 84 % are significantly reduced. After grinding, 22 % of the fiber can remain in flour. On the other hand, the wheat germ is rich in antioxidants but significantly lost during grinding (Moore et al., 2009).

Levent and Bilgiçli (2013) studied the quality of cakes prepared with wheat germ and different emulsifiers. The wheat germ (coarse and fine) was replaced for wheat flour at the amounts of 0 %, 10 %, 20 % and 30 %. Emulsifiers, which were used at 0.5 % level, were sodium stearoyl-2 lactylate and diacetyl tartaric acid esters of mono glyceride. The effects of wheat germ particle size, emulsifier type and wheat germ level on batter and cake quality were investigated in their study. They concluded that coarse wheat germ could be incorporated into cake formulation up to 20 % level with the aid of sodium stearoyl-2 lactylate.

Baeva, Panchev and Terzieva (2000) studied textural properties of normal and energy reduced sponge cakes. Microencapsulated aspartame and bulking agents (sorbitol, wheat starch and wheat germ) were used instead of sucrose in two diabetic sponge cakes. The effects on the springiness, porosity, volume and shrinkage of sponge cakes were substantial and depended on the amount of ingredients in their study. The diabetic sponge cakes which were produced from wheat germ showed the least physical and sensory properties. The energy value of the diabetic sponge cakes reduced up to 25 % for the ordinary sponge cake without sucrose and reduced up to 29 % for sponge cake without sucrose containing wheat germ.

1.6. Cake Components and Functions

Flour, sugar, egg, milk, shortening (oil), baking powder, vanilla and salt are commonly used for cake production and emulsions of these substances. These ingredients provide the desired taste, texture and volume in the final products (Lawson, 1995).

1.6.1. Wheat Flour

Flour consists of starch and protein. It is the basic building block of cake. Structural properties of the cake are improved by starch gelatinization and clotting of flour proteins during cooking (Koçer, 1999). Cake flour should form a suitable gluten system in the soft and juicy cake dough. It does not have strong and hard properties such as in bread dough. The most important feature of cake flour is the high-water capacity (Alp, 2006). Flour form unique physical properties and appearance characteristics of cake. It is usually obtained from low protein containing wheat. Flour does not contain only protein but also starch, oil, some minerals and vitamins. When wheat starch is heated with water, the granules begin to absorb water and expand according to the origin. The crystal structure melts, the amylose exits the granules and the structure of the granules deteriorates. Gelatinization occurs over a wide temperature range and is affected by the presence of sucrose and other emulsifying agents (Bennion and Bamford, 1997). There are many important factors for choosing the flour. The first one is the amount of moisture. The moisture content of flour is usually 14 %. Another important factor is the amount of protein. It is changeable according to the final product. The determination of the amount of ash is another important parameter that determines whether the flour is suitable for bakery products. Total alpha amylase and falling number are other important parameters for flour specification. Water absorption and rheological properties are also important for specification. As a result, the properties of the flour should be known in order to achieve an appropriate result (Bennion and Bamford, 1997).

1.6.2. Egg

Egg is one of the basic ingredients of the cake. It improves the structure of the cake, increases the volume, symmetry index, softness and quality (Mercan, 1998). Eggs are also effective in maturing the dough and have binding and emulsifying properties. Also, it contributes to the development of color and flavor characteristics (Kıranlı, 2006). Addition of egg into the dough facilitates the combination of dough components. It ensures the formation of air pores by allowing the dough to swell and these pores to come together. In addition, it gives constant structure for dough. It prevents the gas output from the dough (Pyler, 1988; Lawson, 1995). The egg contributes to the formation of the protein matrix in cakes and is effective on swelling. For this reason, it provides a brittle structure by providing volume increase. Apart from this, it also adds nutrient, color and flavor to the cake produced (Pyler, 1988; Dizlek, 2003).

1.6.3. Milk

The use of milk and dairy products in bakery products increases the nutritional value and taste of the product. When milk is used in liquid form, it contributes as a liquid phase in cake formulation (Köklü, 2007). If it is used in milk powder form, it supports for the internal structure of cakes. Milk contributes to browning or shell color as it contains lactose. Skimmed milk powder and whey powder are the most commonly used dairy products in bakery products. However, fresh milk and skimmed milk powder are generally used in cakes (Ünver, 1987). Water can be used directly in the production of cakes. Also, egg (approximately 74 % of water) and milk are used as water in cakes (Pyler, 1988; Mercan and Boyacıoğlu, 1999b).

1.6.4. Shortening (Oil)

Oil increases volume of the cake, affects the formation of the shell and internal structure, reduces the swelling ratio of the starch, prevents the moisture loss of the product, provides freshness in the product and prolongs the product's shelf life, increases the specific weight of the cake dough when the amount of oil in the formula decreases and large pores are formed in the inner structure of the cake (Mercan, 1998). Oil is used to gain necessary qualitative properties for bread, biscuits, cakes and other bakery products, uniform and stable structure for increasing the quality and calorific value of the products. It is also called shortening in bakery products and it is used to obtain desired aroma. The main effects of oils used in dough formulations are: shortening effect (softness and workability effects to the product), ventilation of dough, edible product, quality correction, brittle and increasing uniformity and stability (Elgün and Ertugay, 2002).

1.6.5. Baking Powder

Turkish Standard Institue defines baking powder in the standard (TSI, 9053, "Baking powder", Anonymous, 2002) as "used in the production of some bakery products as an adjunct because of technology requirements, forming CO_2 in the presence of heat and humidity, a product of one or more of the bicarbonates and one or more of the acidic substances and the edible starch".

The baking powders provide the characteristic internal structure of the cake, and the product is formed by the formation of small carbon dioxide bubbles in the dough due to the chemical action of the baking powders. They reduces density by swelling, porous, more delicious and easier to digest (Çelik and Kotancılar, 1998).

1.6.6. Vanilla

Vanilla is the fermented and dried fruit of the orchid plant and it has an important trading volume in the world market (Divakaran et al., 2008). Vanilla is widely used in the food and beverage industry due to its high aromatic properties. It is used as a minor component in foods (especially beverages, ice cream and pastry products). It has antioxidant, antimicrobial, anticarcinogenic and antimutagenic properties (Karathanos et al., 2007).

Vanillin (4-hydroxy-3-methoxybenzaldehyde) is one of the compounds in vanilla. Vanillin is the basic substance that gives taste and smell. Among other small compounds, piperonal (heliotropin) forms the fat content and influences the natural odor of vanilla. Use of vanilla in the food industry as in cake is due to the smell and taste (İlhan, 2013).

1.6.7. Salt

Salt, together with other ingredients in the making of cakes, balances the flavor formation and improves the odor property. It also affects the foaming property of the egg in a positive way (Mercan, 1998). Salt affects the solubility of proteins. It increases the solubility of gluten especially at low salt concentrations. Sodium chloride affects the mixing conditions, absorption and process conditions of the dough (Roach et al., 1992).

1.7. The Aim of This Thesis

In the production of cake too much sugar is used as sweetener. The increasing consumption of sugar has resulted in several health problems such as obesity due to its high caloric value. Furthermore, there are increasing in the number of diabetic patients. Carob flour and stevia can be used as natural sugar substitutes in the cake production. Stevia is a natural plant, about 200-300 times sweeter than sucrose and has zero calorific value. Also, the nutritional values of cake can be increased by the addition of wheat germ in the formulation of cake dough.

As a result of the literature analysis, the number of diabetic patients and obese people are increasing day by day because of the consumption of sugar, which is one of the main components of the cake production. Nowadays, people want to consume more natural, nutritious and products that will not adversely affect human health. Because of these situations, the production of cake using carob flour and stevia as sugar substitute and enrichment with wheat germ can help people.

The aims of this thesis are 1) to use carob flour and stevia instead of sugar, which is one of the main ingredients in production of cakes, 2) to use wheat germ to enrich nutritional values of cake. Process variables in this study are sugar concentration (0-25 %), stevia concentration (0-2 %) and carob concentration (0-30 %) in constant amount of wheat flour. From these variables, 20 different cakes were produced. The best cake formulation was decided from physical, textural and sensorial properties of these cakes. Finally, in order to increase nutritional values in the best cake decided from optimization process, the wheat germ was replaced with wheat flour in different amounts (0-10 %) and 8 different cakes were produced. Among these cakes, the best cake formulation was decided according to the physical, textural and sensory properties of the cakes. The production of cake using carob flour, stevia and wheat germ can help obese and diabetic people to consume cakes have reduced sugar.

CHAPTER II
MATERIALS AND METHODS

2.1. Materials

In this study, wheat flour, sugar, eggs, milk, shortening, baking powder, vanilla and salt were used for the production of cakes. They were obtained from Gaziantep (Turkey) local markets. Carob flour (Zazel'la, Zazel Ecological Agriculture and Food Products, Turkey), stevia (Zhucheng Haotian Pharm Co. Inc., China) and wheat germ (Işıklar Food Co. Inc., Turkey) were used in the production of cakes.

The instruments used in the analyses were; analytical balance (AY 220 model, SHIMADZU, Japan); oven (RT 500 model, W.C. HERAEUS HANAU, Germany); muffle furnace (MF 120 model, NUVE, Turkey); protein detection device and oil testing device (VELP SCIENTIFICA, Italy); sedimentation shaker (EKİN, Turkey); falling number device (PERTEN, Swedish); TPA/TA, XTplus texture analyzer (Stable Micro Systems, Surrey, UK); HunterLab colorflex (A60-1010-615 model, VESTON, VA, USA).

Chemicals used in the analyses; diethyl ether, 90 % lactic acid, ethanol, 2-propanol, 95-98 % sulfuric acid, 37 % hydrochloric acid, sodium sulphate and methylene blue were taken from Isolab (Germany). Sucrose, methylene red, bromophenol blue and phenolphthalein were taken from Sigma-Aldrich (Germany). Kjeldahl tablet, sodium hydroxide, 0.1 N hydrochloric acid and boric acid were taken from Merck (Germany). Fehling A, Fehling B, Carez-I and Carez-II were taken from Norateks (Turkey).

2.2. Methods

2.2.1. Production of Control Cake

Eggs, milk, sugar, shortening, wheat flour, baking powder, vanilla and salt were used as ingredients for control cake production. The composition of control cake is given in Table 2.1.

Table 2.1. Ingredients, composition (%) and mass (g) of control cake

Ingredients	Composition (%)	Mass (g)
Egg	15.87	60.02
Milk	19.83	75.00
Sugar*	23.79	89.98
Shortening	13.22	50.00
Wheat Flour**	26.44	100.00
Baking Powder	0.40	1.51
Vanilla	0.40	1.51
Salt	0.05	0.19
Total	100.00	378.21

*The use of sugar, carob flour and stevia as sugar substitutes are shown in Table 2.4.

**Using wheat germ instead of wheat flour are shown in Table 2.5.

Control cakes were produced according to AACC Standard Method 10-90. The dough was produced using the mixer (SM-1203N, COOKPLUS, Turkey). Photos of the dough mixer was given in Appendix A (Figure A1). Initially, the eggs were whipped. After that, whole milk was added to eggs and mixed, then sugar was added and mixed again. Shortening was added after the addition of milk and sugar, just before the addition of wheat flour and other dry ingredients and then they were mixed. Whipping of eggs in 2.0 min at 190 rev/min speed. Adding milk, sugar and shortening respectively in 0.5 min at 95 rev/min speed for each one. Also, these were mixed in 0.5 min at 190 rev/min speed respectively.

Then, wheat flour and dry ingredients were added in 1.0 min at 95 rev/min speed. When the dough becomes homogeneous (mixing for 1.0 min at 190 rev/min speed), the mixing was completed. Dough was filled in 50 mm bottom diameter, 70 mm top diameter and 40 mm height sizes of capsules in 2.0 min. The dough was baked in an air circulation convection oven (9622 GI model, ARÇELİK, Turkey) at 180 °C for 45 minutes and after that cakes were allowed to cool for 1 hour. The processing parameters and recipie of control cake are shown in Table 2.2.

Table 2.2. Process name, process time and process speed of control cake

Process Name	Process Time (min)	Process Speed (rev/min)
Whipping Eggs	2.0	190
Adding Milk	0.5	95
Mixing	0.5	190
Adding Sugar	0.5	95
Mixing	0.5	190
Adding Shortening	0.5	95
Mixing	0.5	190
Adding Wheat Flour, Baking Powder, Vanilla and Salt	1.0	95
Mixing	1.0	190
Putting dough into capsules	2.0	---
Baking dough (180 °C)	45.0	---
Cooling cake in capsules	20.0	---
Removing cake from the capsules and cooling to room temperature	40.0	---

2.2.2. Experimental Design

The central composite design for three independent variables was performed. The independent variables were sugar (%) (A), carob flour (%) (B) and stevia (%) (C). The independent variables and variation levels are shown in Table 2.3. Instead of the significant amount of sugar found in the cake formulation, carob flour and stevia were used as a natural sugar source. Process variables were sugar concentration (0-25 %, w/w), carob flour concentration (0-30 %, w/w) and stevia concentration (0-2 %, w/w) in constant amount of wheat flour. The levels of each variable were based on literature data and preliminary trials. The outline of experimental design with coded and actual levels for 20 types of cakes (carob flour and stevia were used as sugar substitutes) are presented in Table 2.4. The values shown as Product Code (PC) in the tables and figures of this study refers to the run number of each cake in 20 types of cake. Dependent variables were volume, total volume, symmetry and uniformity indexes, sub and top shrinkage values, hardness, springiness, cohesiveness, gumminess, chewiness, resilince, inside and surface colors, pore numbers and sizes, volume and sensory as product responses. Response surface methodology (RSM) was applied for experimental data using a commercial statistical package, Design-Expert (version 6.0, Statease Inc., Minneapolis, MN, USA) for the generation of response surface mathematical models and plots. Design-Expert (version 7.0.3, Statease Inc., Minneapolis, MN, USA) was used for statistical analysis of experimental data. The results were compared by one-way analysis of variance (one-way ANOVA) to test for significant differences.

Table 2.3. Process variables used in central composite design for three independent variables

		Independent Variable Levels				
Independent Variables	Code	-1.68	-1	0	1	1.68
Sugar (%)	A	0.00	5.10	12.55	20.00	25.00
Carob Flour (%)	B	0.00	6.25	15.38	24.50	30.00
Stevia (%)	C	0.00	0.40	1.00	1.60	2.00

Table 2.4. Experimental design for 20 types of cake with coded and actual variable levels

	Coded Levels			Actual Levels		
Run*	A	B	C	Sugar (%)	Carob Flour (%)	Stevia (%)
1	-1.00	-1.00	-1.00	5.10	6.25	0.40
2	1.00	-1.00	-1.00	20.00	6.25	0.40
3	-1.00	-1.00	1.00	5.10	6.25	1.60
4	1.00	-1.00	1.00	20.00	6.25	1.60
5	-1.00	1.00	-1.00	5.10	24.50	0.40
6	1.00	1.00	-1.00	20.00	24.50	0.40
7	-1.00	1.00	1.00	5.10	24.50	1.60
8	1.00	1.00	1.00	20.00	24.50	1.60
9	-1.68	0.00	0.00	0.00	15.38	1.00
10	1.68	0.00	0.00	25.00	15.38	1.00
11	0.00	0.00	-1.68	12.55	15.38	0.00
12	0.00	0.00	1.68	12.55	15.38	2.00
13	0.00	-1.68	0.00	12.55	0.00	1.00
14	0.00	1.68	0.00	12.55	30.00	1.00
15	0.00	0.00	0.00	12.55	15.38	1.00
16	0.00	0.00	0.00	12.55	15.38	1.00
17	0.00	0.00	0.00	12.55	15.38	1.00
18	0.00	0.00	0.00	12.55	15.38	1.00
19	0.00	0.00	0.00	12.55	15.38	1.00
20	0.00	0.00	0.00	12.55	15.38	1.00

* The values shown as Product Code (PC) in the tables and figures of this study refers to the run number of each cake in 20 types of cake.

2.2.3. Production of 20 Types of Cake

In production of cakes, sugar composition (%) was decreased and carob flour (%) with stevia (%) were used as sugar substitutes according to actual levels given in Table 2.4. The remaining amount was calculated and it was completed with wheat flour. Twenty types of cake were produced by using the process of control cake (Table 2.2). Carob flour and stevia were added to dough mixture at the same step and time of sugar addition. After producing 20 types of cake, they were analyzed for the parameters of structural, textural, sensory and volume. The best cake formulation from 20 types of cake was decided by using Design-Expert (version 7.0.3, Statease Inc., Minneapolis, MN, USA) software. Photos of the 20 types of cake and the best cake were given in Appendix A (Figure A2 and Figure A3).

2.2.4. Production of 8 Types of Cake (Enrichment with Wheat Germ)

The best cake formulation obtained from 20 types of cake was enriched by using wheat germ. The ingredients were the same but wheat germ was replaced with wheat flour in different amounts (0-10 %). The ratios were obtained from experimental desing and they are given in Table 2.5. The values shown as Cake Code (CC) in the Tables and Figures of this study refers to the run number of each cake in 8 types of cake. The process conditions were the same as the best cake formulation from 20 types of cake. After, wheat germ was added to dough mixture at the same step and time of wheat flour addition. After producing 8 types of cake, they were analyzed for the parameters of structural, textural, sensory and volume. The best cake formulation from 8 types of cake was decided by using Design-Expert (version 7.0.3, Statease Inc., Minneapolis, MN, USA) software. Photos of the 8 types of cake and the best cake were given in Appendix A (Figure A4 and Figure A5).

Table 2.5. The ratios of wheat flour (%) and wheat germ (%) in 8 types of cake

Run*	Wheat Flour (%)	Wheat Germ (%)
1	100.00	0.00
2	100.00	0.00
3	97.50	2.50
4	95.00	5.00
5	95.00	5.00
6	92.50	7.50
7	90.00	10.00
8	90.00	10.00

***** The values shown as Cake Code (CC) in the tables and figures of this study refers to the run number of each cake in 8 types of cake.

2.3. Analysis

All of the analysis for wheat flour, cakes dough, carob flour, wheat germ and cakes were duplicated and their averages were used.

2.3.1. Wheat Flour Analysis

For wheat flour; moisture content, ash, protein, wet gluten, gluten index, dry gluten, sedimentation, delayed sedimentation, falling number, fat and sugar analysis were performed.

2.3.1.1. Moisture Content Analysis

Five g sample was weighed in a case and put in an oven up to constant weight reached. Then, it was cooled in a desiccator and weighed again (TS EN ISO 712, 2012; TS 6318, 1989). The moisture content (%, w/w) was calculated from Eq. 2.1.

$$\text{Moisture Content Ratio } (\%,\ \text{w.b.}) = (1 - \frac{m_1 - d}{m_0}) \times 100 \quad \text{(Eq. 2.1)}$$

m_0 : mass of sample (g)

m_1 : Weight of case and sample after drying (g)

d : Tare of case (g)

2.3.1.2. Ash Analysis

Four g sample was weighed in a capsule and put into a muffle furnace with lid closed up to constant weight reached. Then, it was cooled in a desiccator and weighed again. The capsule was cleaned by immersion in hydrochloric acid for at least one hour before use, then, rinsed with distilled water and dried in the oven. If it is necessary, products were burned with ethanol in the pre-ashing stage (TS EN ISO 2171, 2010). The amount of ash (% K, w/w) was calculated from Eq. 2.2.

$$\mathrm{K}\,(\%, \mathrm{w/w}, \mathrm{d.b.}) = \mathrm{m_1} \times \frac{100}{\mathrm{m_0}} \times \frac{100}{100-\mathrm{H}} \quad \text{(Eq. 2.2)}$$

K : Ash content in dry mass (%)

m_0 : mass of sample (g)

m_1 : Weight of residue after ashing (g)

H : Moisture content of sample (%)

2.3.1.3. Protein Analysis

One g of the sample was weighed into the medium mesh filter paper and the paper was folded and placed in the Kjeldahl balloon. 0.1 g of titanium dioxide, 0.5 g of powdered copper sulfate, 5 g of potassium sulfate and 20 ml of sulfuric acid were added into a Kjeldahl balloon. The Kjeldahl balloon was properly and carefully heated until the foaming was finalized. After the balloon was heated until the solution was clear, then, it was heated for another 30 minutes, cooled, 200 ml of water was added and cooled again. 3-4 pieces of zinc and paraffin granule were added to the kjeldahl balloon to prevent splashing in the distillation process. 50 ml of a 40 % NaOH solution was added without stirring (holding the balloon in a tilted state). The balloon end portion was connected to the 25 ml boric acid distilled distillation apparatus in the collection bottle. The boric acid titration flask was heated until all ammonia (at least 150 ml distillate) passes. The collected distillation product was titrated with hydrochloric acid (or sulfuric acid) using the indicator (prepared by dissolving 0.1 g of methylene red in 100 ml of ethanol and 0.18 g of methylene blue). In addition, 1 g of sucrose was tested and the volume of hydrochloric acid solution (v_0) was recorded (TS 1620, 2016; TS EN ISO 5983-1, 2006). The amount of protein was calculated on the dry substance (% P, w/w) from Eq. 2.3.

$$\mathrm{P\ (\%, w/w, d.b.)} = \frac{(\mathrm{v_1 - v_0}) \times \mathrm{F} \times 0.0014008 \times \mathrm{f} \times 100 \times 100}{\mathrm{m_0} - (100 - \mathrm{H})} \qquad \text{(Eq. 2.3)}$$

P : Protein in dry mass (%)

m_0 : mass of sample (g)

v_1 : Volume of 0.1 M HCl solution used for sample (ml)

v_0 : Volume of 0.1 M HCl solution used for the sucrose (ml)

F : Nitrogen protein conversion factor (Factor = 5.7 for wheat products)

f : Factor of 0.1 M HCl solution

H : Moisture content of sample (%)

0.0014008 : Equivalent weight of nitrogen

2.3.1.4. Wet Gluten Analysis

Ten g of sample was weighed in a chamber. Sodium chloride solution (4.8 ml, 2 %) was added to the side wall of the glutamic washing chamber and washed by the device. During this time, centrifugal cassettes were prepared. When the device was stopped, the gluten was removed and placed in the cassettes and centrifuged. When the process was finished, the cassettes were removed from the centrifuge and the whole gluten was passed through the sieve using a steel spatula. The other gluten remaining on the sieve was added and the total wet gluten was calculated (AACC Method 38-12, 2000). The amount of wet gluten (%, w/w) was calculated from Eq. 2.4.

$$\mathrm{Wet\ Gluten\ (\%, w/w, w.b.)} = \frac{\mathrm{Total\ wet\ gluten\ (g)}}{\mathrm{10\ (g)}} \times 100 \qquad \text{(Eq. 2.4)}$$

2.3.1.5. Gluten Index Analysis

The amount of gluten index (%, w/w) was calculated from Eq. 2.5 (AACC Method 38-12, 2000).

$$\text{Gluten index } (\%, \text{w/w}, \text{d.b.}) = \frac{\text{Remaining of gluten (g)}}{\text{Total wet gluten (g)}} \times 100 \qquad \text{(Eq. 2.5)}$$

2.3.1.6. Dry Gluten Analysis

Wet gluten was put into drying device and dried for 5 minutes. The obtained dry gluten was weighed (TS EN ISO 21415-4, 2008). The amount of dry gluten (%, w/w) was calculated from Eq. 2.6.

$$\text{Dry gluten } (\%, \text{w/w}, \text{d.b.}) = \frac{m_1 - m_0}{m} \times 100 \qquad \text{(Eq. 2.6)}$$

m : The amount of wheat flour taken for wet gluten analysis

m_1 : Weight of container (tare) and dry gluten (g)

m_0 : Weight of container (g)

2.3.1.7. Sedimentation Analysis

Lactic acid solution (235 ml) was completed with 1000 ml of distilled water and heated and cooled. Then 10 ml of this solution was titrated using sodium diphosphate as the phenolphthalein indicator (approximately 28 ml of sodium hydroxide is required in 10 ml of lactic acid solution). In a 1000 ml volumetric flask, 180 ml of lactic acid stock solution and 200 ml of propan-2-ol were mixed and completed until 1000 ml with distilled water. A 3.2 g of sample was weighed and placed in a cylinder. 50 ml of bromophenol blue was added to the test sample. The cylinder was shaken with a shaker device and kept in a horizontal position, shaking 12 seconds in each direction about 18 cm to the left and right for 5 seconds. After replacing the cylinder in a shaker and after 5 minutes it was removed, and 25 ml of the sedimentation test solution was added. The cylinder was put back into shaker device and shaking was continued for 5 minutes. The cylinder was removed from the shaker and placed in a vertical position. It was waited 5 minutes at room conditions (25 °C) without sunlight then the volume of sediment in the cylinder was recorded (TS EN ISO 5529, 2013).

2.3.1.8. Delayed Sedimentation Analysis

Preparation of lactic acid stock solution and preparation of test solution were the same as sedimentation analysis. A 3.2 g of sample was weighed and placed in a cylinder. 50 ml of bromophenol blue was added to the test sample. The cylinder was shaken with a shaker and kept in a horizontal position, shaking 12 seconds in each direction about 18 cm to the left and right for 5 seconds. After replacing the cylinder in a shaker and after 5 minutes it was removed. The cylinder was held in a constant place until 2 hours without sunlight. 25 ml of the sedimentation test solution was added after 2 hours. The cylinder was put back into shaker device and shaking was continued for 5 minutes. The cylinder was removed from the shaker and placed in a vertical position. It was waited 5 minutes at room conditions (25 °C) without sunlight then the volume of sediment in the cylinder was recorded (TS EN ISO 5529, 2013).

2.3.1.9. Falling Number Analysis

The moisture content of the wheat flour sample was measured. The amount of sample required for analysis was weighed depending on 7.00 g of sample corresponding to 14% humidity. Sample was placed in the viscous meter tubes and 25 ml of distilled water was added. The viscous meter tubes were shaken until a homogenous suspension was obtained. Tubes with mixers were placed in the cassettes of device. After the device cover was closed it analyzed and gave the results of falling number (ICC No:107/1, 1995).

2.3.1.10. Fat Analysis

Five g of sample (2-3 g (more if necessary) mixed with anhydrous sodium sulphate) was weighed and placed in an extraction bowl. Extraction bowl was placed into Soxhlet device and it was extracted with diethyl ether for 6 hours. At the end of the analysis, it was taken out of the device and placed into an oven which was set at 75 °C and dried for 1.5 hours. It was weighed after cooling in desiccator (TS 6317, 1989). The percentage of fat (%, w/w) was calculated from Eq. 2.7.

$$\text{Fat}\ (\%, \text{w/w}, \text{d.b.}) = \frac{\text{m}_1 - \text{m}_2}{\text{m}_0 - (100 - H)} \times 100 \qquad \text{(Eq. 2.7)}$$

m_0 : mass of sample (g)

m_1 : Weight of dry diethyl ether extracts and extraction bowl (g)

m_2 : Weight of extraction bowl (g)

H : Moisture content of sample (%)

2.3.1.11. Sugar Analysis

Five g of sample was weighed and blended mechanically with 150 ml water. It was placed in a 250 ml beaker and completed with distilled water then shaken and filtered. 50 ml of filtered solution was placed into a water bath at 70 ºC. It was kept for 5 minutes when the temperature of the solution reached at 67 ºC. Invert sugar of the solution was determined by Lane and Eynon's Method (1. Invert Sugar).

Fifty ml of filtered solution was placed into a 250 ml flask and 5 ml of 37 % HCl was added and placed into a water bath at 70 ºC. It was kept for 5 minutes when the temperature of the solution reached at 67 ºC. The sucrose of the solution was broken by HCl to become invert sugar while waiting. Then it was cooled to 20 ºC under cold water and 1-2 drops of phenolphthalein added. It was neutralized with 6 N NaOH until the color had changed to light pink color. The solution was completed with distilled water until the mark. Invert sugar was determined by Lane and Eynon's Method (2. Invert Sugar).

Lane and Eynon's Method

The non-stochiometric volumetric method of Lane and Eynon is often the most convenient method for determining reducing sugars. The volume of sugar solution required to reduce completely 10 or 25 ml mixed Fehling's solution is determined using methylene blue as theredox indicator for assessing the end point. A minute excess of reducing sugar solution is necessary for the reduction of the indicator itself (Bozkurt and Göğüş, 2004).

Preparation of Standard Invert Sugar Solution

Standard sucrose (9.5 g) was dissolved in 50 ml of distilled water and placed into 100 ml beaker then 5 ml of 37 % HCl was added and kept for 3 days at 24 ºC to inversion. After it was placed into a 1 liter cylinder and completed with distilled water. 50 ml of solution was placed into a 150 ml flask and 1-2 drops of phenolphthalein added then neutralized with 0.1 N NaOH until the color had changed to light pink color. The solution was completed with distilled water until the mark then placed in a burette. There were 3.33 mg sugar in 1 ml of the standard invert solution prepared in this way.

<u>Factor Determination of Fehling Solution</u>

Five ml of Fehling A and Fehling B were placed into a 200 ml flask and shaken then 10 ml of standard invert sugar solution added from the burette. It was heated for 2 minutes without shaken and added 3-5 drops of methylene blue while heating. It was titrated with the standard invert sugar solution from burette until the color had changed from blue to red while heating. Factor of fehling solution was determined by multiplying 3.33 with used standard invert sugar solution.

<u>Determination of Invert Sugar</u>

Fifty ml of solution was placed in a 250 ml beaker and 2 ml of Carez-I and Carez-II were added and completed with distilled water until the mark. It was filtered into a burette.

Five ml of Fehling A and Fehling B were placed into a 200 ml flask and shaken then 10 ml of solution added from the burette. It was heated for 2 minutes without shaken and added 3-5 drops of methylene blue while heating. It was titrated with the solution from burette until the color had changed from blue to red while heating and recorded used volume of the solution in the burette (TS 1466, 2008). Invert sugar (g/kg) and sucrose (%, w/w) were calculated from Eq. 2.8 and Eq. 2.9 respectively.

$$\text{Invert Sugar (g/kg)} = \frac{V_2 \times f}{V \times [m-(100-H)]} \qquad \text{(Eq. 2.8)}$$

$$\text{Sucrose } (\%, w/w, d.b.) = 0.95 \times (2.\text{Invert Sugar} - 1.\text{Invert Sugar}) \qquad \text{(Eq. 2.9)}$$

f : Factor of fehling solution

V : Volume of used in the titration, ml

v_2 : Final volume of sample dilution, ml

m : mass of sample (g)

H : Moisture content of sample (%)

2.3.2. Cake Dough Prepared with Wheat Flour Analysis

2.3.2.1. Bulk Density

Bulk density of dough was calculated by the weight of dough in a known cylinder was divided by the volume of water in the same cylinder (Masoodi et al., 2002).

2.3.2.2. Resistance and Elasticity Analysis

Sample (250 g) poured into the mixer of the alveograph device. 2.5% sodium chloride solution was added according to moisture content of the sample. The analysis was started by pressing the start button of the device. The device calculated the amount of sample and sodium chloride solution required for the formation of alveograph dough. The calculated sample and sodium chloride solution was put into the mixer and the device was restarted. After the kneading process for 8 minutes, the dough was placed in the resting part of alveograph device which was adjusted to 24 ºC temperature for resting (AACC 54-30A, 2010).

2.3.3. Carob Flour Analysis

Moisture content analysis (TS 6318, 1989), protein analysis (TS EN ISO 5983-1, 2006), fat analysis (TS 6317, 1989) and sugar analysis (TS 1466, 2008) were performed by the same methods applied for wheat flour analysis.

2.3.4. Wheat Germ Analysis

Moisture content analysis (TS 6318, 1989), protein analysis (TS EN ISO 5983-1, 2006), fat analysis (TS 6317, 1989) and sugar analysis (TS 1466, 2008) were performed by the same methods applied for wheat flour analysis.

2.3.5. Cake Dough Prepared with Wheat Flour and Wheat Germ Analysis

2.3.5.1. Bulk Density

Bulk density of dough prepared from wheat flour and wheat germ was performed by the same method applied for cake dough prepared from wheat flour analysis (Masoodi et al., 2002).

2.3.5.2. Resistance and Elasticity Analysis

Resistance and elasticity analysis was performed by the same method applied to cake dough prepared from wheat flour analysis (AACC 54-30A, 2010).

2.3.6. Cake Analysis

Structural analysis (measurement template), textural analysis (by texture analyzer), color determination (color measurement by Hunter Lab), pore number and pore sizes (with ruler), volume and sensory analysis (panelist method) were performed.

2.3.6.1. Structural Analysis

In the structural analysis of cake; volume, symmetry and uniformity indices, shrinkage values (AACC Method 10-91.01; AACC, 2000) and total volume index values (Bath et al., 1992) were determined. For this purpose, the cake measurement template (AACC Method 10-91.01; AACC, 2000) was used according to the size of the cake capsule. Measurement template for structural analysis is given in Figure 2.1.

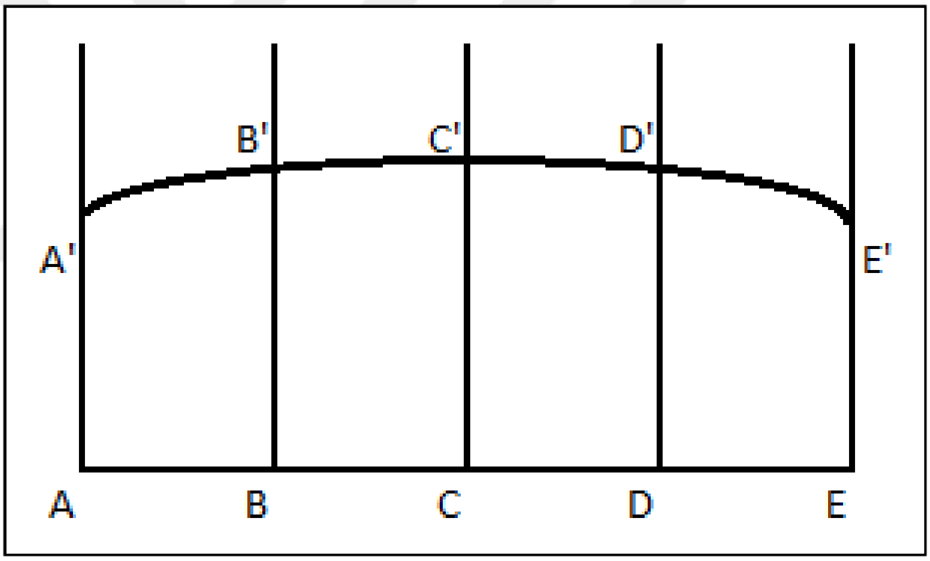

Figure 2.1. Measurement template for structural analysis of the cake samples

Cakes were cut from the centers (Mercan, 1998) to calculate structural analysis. There were seven points and they were shown as AA', BB', CC', DD', EE', AE and A'E'. These points were used to calculate the values of volume index (mm), symmetry index (mm), uniformidy index (mm), sub shrinkage value (mm), top shrinkage value (mm) and total volume index (mm) according to the study of Dizlek et al. (2008). Structural analysis of cakes were calculated from Eqs. 2.10-2.15.

Volume Index (mm) = BB' + CC' + DD' (Eq. 2.10)

Symmtry Index (mm) = 2 x CC' - BB' - DD' (Eq. 2.11)

Uniformity Index (mm) = BB' – DD (Eq. 2.12)

Sub Shrinkage Value (mm) = Lower diameter of cake capsule (50 mm) - Bottom diameter of cake (AE) (Eq. 2.13)

Top Shrinkage Value (mm) = Top Diameter of cake capsule (70 mm) - Top diameter of cake (A'E') (Eq. 2.14)

Total Volume Index (mm) = AA' + BB' + CC' + DD' + EE' + AE + A'E' (Eq. 2.15)

2.3.6.2. Textural Analysis

Cake samples were examined after 24 hours of production by using TPA/TA, XTplus Texture Analyzer (Stable Micro Systems, Surrey, UK) to determine the textural analysis. Top of the cake samples were made flat. They were pressed at 2.00 mm/sec speed and compressed 50 % by using P/36R probe (36 mm Dia Aluminum Radiused AACC, Stable Micro Systems, Surrey, UK). It was waited 5 sec between first and second compression. The parameters were evaluated for hardness, springiness, cohesiveness, gumminess, chewiness and resilience. The hardness is the peak value obtained during the initial compression of the TPA test (for example g force required for 50% compression of the samples). The cohesiveness is calculated as the ratio of the second compression area to the first compression area applied by the probe. The chewiness is obtained by multiplying the value of gumminess and springiness. The resilience refers to the height value associated with the return of the cake after the applied pressure (Ildız, 2015). The working parameters of texture analyzer are given in Table 2.6.

Table 2.6. Working parameters of texture analyzer

Caption	Value	Units
Pre-Test Speed	2.00	mm/sec
Test Speed	2.00	mm/sec
Post-Test Speed	10.00	mm/sec
Target Mode	Strain	
Strain	50.0	%
Time	5.0	sec
Trigger Type		Auto (Force)
Trigger Force	5.0	g
Tare Mode	Auto	

2.3.6.3. Color Determination

Color measurements of the cakes were carried out using a HunterLab ColorFlex (A60-1010-615 Model Colorimeter, Hunter Lab, Reston, VA, USA) according to CIELAB system. Inside and surface color of the cakes were measured as color determination. The color values were expressed as L* (lightness-darkness), a* (redness-greenness) and b* (yellowness-blueness) at any time, respectively. The device was standardized each time with a black and white tile.

2.3.6.4. Pore Number and Pore Sizes Analysis

Cakes were cut into halves and the pores in one part were counted to determine the number of pores. The pore sizes were measured with the ruler from the bottom, middle and top parts of the cake.

2.3.6.5. Volume Analysis

Volume analysis was performed by AACC 10-05 method according to rapeseed displacement principle (AACC, 2000).

2.3.6.6. Sensory Analysis

Sensory evaluation of cakes were performed by 10 semi-trained panelists. Firstly, panelists were informed about the evaluation criterias. Control cake and the manufactured cakes were presented to the panelists in numbered plates. Water was given to the panelists after tasting each cake (to rinse their mouths after tasting each sample) and they record thier scores on a sensory evaluation form (Appendix B). In sensory evaluation, panelists evaluated the color, taste, texture and general evaluation characteristics of the cakes according to control cake. The 7-hedonic scale (1: absolutely disliked, 7: absolutely liked) was used in the evaluation. The sensory analysis points of control cake were evaluated as 7 (absolutely liked) because it was wanted to decide by panelists, which cake had the closest points to the sensory analysis according to the control cake.

2.3.7. Optimization

The process variables were optimized by using Design-Expert (version 7.0.3, Statease Inc., Minneapolis, MN, USA) to obtain best cake from 20 types of cake and 8 types of cake. In optimization process, uniformity index was set as zero. Sub and top shrinkage values, hardness, cohesiveness, gumminess, chewiness and resilience were minimum; springiness and volume were maximum parameters. Also, maximum taste and general evaluation values were parameters for sensory analysis. The optimization parameters were chosen according to literature.

CHAPTER III

RESULTS AND DISCUSSIONS

Carob flour and stevia were used as sugar substitute to produce 20 types of cake. The effect of independent variables on physical, textural and sensory properties of cakes were investigated. The results were given in Appendix C. In first part, multiple regression analyses were performed using response surface analysis to 1) fit mathematical models to the experimental data, 2) define the relationship between three independent variables and the response variable (Horuz, 2011). The results obtained and then analyzed by ANOVA. They were given in Appendix D. The best cake formulation was optimized from its physical, textural and sensory properties by using Design-Expert (version 7.0.3, Statease Inc., Minneapolis, MN, USA).

The second part of study, in order to increase nutritional values of the best cake decided in previous part, the wheat germ was replaced with wheat flour in different amounts and 8 different cakes were produced. Among these cakes, the best cake formulation was optimized according to the physical, textural and sensorial properties by using Design-Expert (version 7.0.3, Statease Inc., Minneapolis, MN, USA). The results were given in Appendix E.

3.1. Chemical and Physical Properties of Wheat Flour

Wheat flour standard of TSI (TS 4500, Anonymous, 2010) was used to decide which methods should be used in the analysis of moisture content (TS EN ISO 712, 2012), ash (TS EN ISO 2171, 2010), protein (TS 1620, 2016), dry gluten (TS EN ISO 21415-4, 2008), sedimentation and delayed sedimentation (TS EN ISO 5529, 2013). Also wet gluten and gluten index (AACC Method 38-12, 2000), falling number (ICC No:107/1, 1995), fat (TS 6317, 1989) and sugar (TS 1466, 2008) analyses were performed. The physical and chemical properties of wheat flour that was used in this study, are given in Table 3.1. Moisture content was lower than the maximum limit of moisture (14.5 %) given in wheat flour (TS 4500, Anonymous, 2010) standard. Protein and dry gluten content were higher than the minimum limit (7.0 and 8.5 % respectively) of special purpose flour according to the standard.

Table 3.1. Results of wheat flour analysis

Analysis	Result
Moisture content (%, w.b.)	10.63
Ash content (%, d.b.)	0.65
Protein content (%, d.b.)	11.70
Wet gluten content (%, w.b.)	27.40
Gluten index content (%, d.b.)	89.00
Dry gluten content (%, d.b.)	9.10
Sedimentation content (ml)	27.00
Delayed sedimentation content (ml)	33.00
Falling number content (sec)	396.00
Fat content (%, d.b.)	1.30
Sugar content (%, d.b.)	1.20

The quality parameters of two different flours using in cakes were analyzed by Yavaş (2012). The parameters were moisture (%), ash (%, d.b.), protein (%, d.b.), wet gluten (%), gluten index (%), falling number (sec), sedimentation (ml) and delayed sedimentation (ml) in his study. He found the results of first flour 14.41 %, 0.806 %, 12.51 %, 28.1 %, 99 %, 370 sec, 34 ml and 40 ml, respectively. He also found the results of second flour 10.58 %, 0.632 %, 9.48 %, 21.3 %, 66 %, 426 sec, 22 ml and 22 ml, respectively. The results of this study (Table 3.1) indicated that using the flour in cakes were suitable according to results of Yavaş (2012).

High falling number means low alpha amylase activity is expected for flour in the production of cakes (Aurand et al., 1987). Alpha amylase activity is evaluated low when the falling number is higher than 300 (sec) for flour (Boyacıoğlu, 1994). The result of falling number was 396 (sec) in this study so the flour was considered as suitable for cakes according to literature.

The moisture (%), ash (%, d.b.), fat (%), protein (%, d.b.) and carbohydrate (%) analyses results of wheat flour in Aydın's study (2012) were 10.40 ± 0.03 (%), 0.76 ± 0.01 %, 2.42 ± 0.01 (%), 8.66 ± 0.02 (%) and 77.77 ± 0.07 (%). He found higher ash and fat, however, lower protein results than in this study. The differences may be because of the different types of wheat flour he used. Ulusoy (2011) calculated the sugar ratio and she found glucose (%) and fructose (%) in wheat flour. The results were 0.056 ± 0.001 % and 0.065 ± 0.002 %, respectively in her study. It was considered that the differences between the results of her study and the current study could be due to the analysis methods and calculated types of sugar.

3.2. Cake Dough Prepared with Wheat Flour Analysis

3.2.1. Bulk Density

The density of cake dough is an important parameter that it should be measured because it affects the crispness, textural properties and the volume of cakes (Yıldız and Doğan, 2004). The densities of cakes dough were between 1.01 and 1.16 g/ml. The results were given in Appendix C (Table C1). The bulk density of control cake was found as 1.10 g/ml. PC1 had the minimum and PC10 had the maximum bulk density.

Giritlioğlu (2017) made two types of dough in his study. One was made by wheat flour with sucrose and the other one was made by wheat flour with stevia. He found the density of first cake dough 1.10 g/ml and second cake dough 1.07 g/ml. The control cake in this study was prepared with wheat flour and sucrose. Our result is in agreement with that of Giritlioğlu (2017). The 20 types of cakes were made by wheat flour with sugar, carob flour and stevia in this study. There were differences between the results. It may be due to the contribution of carob flour in this study.

3.2.2. Resistance and Elasticity Analysis

It was determined by the researchers that for the flours, which had low water absorption capasity, moderate kneading were required for the production of cakes (Mercan and Boyacıoğlu, 1999b). Resistance and elasticity analysis results in this study were given in Appendix C (Table C2). Mercan (1998) experimented three different flour to obtain water absorption (%) and she determined 48.7 %, 50.2 % and

55.0 %, respectively. The results in this study were in agreement with the literature values so moderate kneading were done for the cakes.

3.3. Carob Flour Analysis

The results of moisture content (%), protein (%), fat (%) and sugar (%) of carob flour were 7.80 %, 5.49 %, 0.35 % and 39.80 %, respectively and the remaining being carbohydrates (excluding sucrose), dietary fiber, vitamins A and E, calcium, magnesium, iron, phosphorus and potassium. The sugar composition of flour was 41.55 % and it was also reported that this product was highly source of calcium, potassium, magnesium, sodium and phosphorus according to Özcan et al. study (2007). Carob has high sugar, rich mineral substances and vitamins (A, B1, B2, B3, B5, B6, B12, C, D, E) content so it is considered as a source of natural power and food (Owen et al., 2003; Iıpumbu, 2008). The results of carob flour in this study are given in Table 3.2.

Table 3.2. Results of carob flour analysis

Analysis	Result
Moisture content (%, w.b.)	7.80
Protein content (%, d.b.)	5.49
Fat content (%, d.b.)	0.35
Sugar content (%, d.b.)	39.80

Carob flour contains 91-92 % total dry matter and 62-67 % total soluble dry matter. A significant proportion of soluble dry matter is composed of sucrose (34-42 %), fructose (10-12 %) and glucose (7-10 %) (Karkacıer and Artık, 1995). The sugar content (sucrose, %) result of this study was in the range of their study.

3.4. Wheat Germ Analysis

Wheat germ had protein (25 %), sugar (18 %, sucrose and raffinose), oil (16 % of the embryonic axis and 32 % of the scutellum were oil). It had also high amounts of vitamin B and many enzymes according to Hoseney (1994). Wheat germ contains protein (27 %), fat (9 %), carbohydrates (46 %), crude fiber (2 %) and minerals (4 %) (Çiftçi, 2002). The results of wheat germ in this study are given in Table 3.3. There was considerable variations in the literature and it was decided that the wheat germ could be used in cakes.

Table 3.3. Results of wheat germ analysis

Analysis	Result
Moisture content (%, w.b.)	10.10
Protein content (%, d.b.)	28.68
Fat content (%, d.b.)	9.33
Sugar content (%, d.b.)	8.44

3.5. Production of 20 Types of Cakes

3.5.1. Structural Analysis

In the structural analysis of cake; volume, symmetry and uniformity indices, shrinkage values and total volume index values (Bath et al., 1992) were determined. Structural analysis results were found by using the measurement template. The results were given in Appendix C (Table C3). VI is volume index (mm), SI is symmetry index (mm), UI is uniformity index (mm), SSV is sub shrinkage value (mm), TSV is top shrinkage value (mm) and TVI is total volume index (mm) in the tables, figures and results of this study.

The criteria used to determine the structural characteristics of cakes; HI (volume index), THI (total volume index), SI (symmetry index), TI (uniformity index) and BD (shrinkage value). Both the HI and THI values are based on the same principle. However, 3 points are taken in the calculation of the HI value, and 7 points are taken in the calculation of THI. HI and THI values are examined by the vertical development of the cake, whereas BD is examined by the horizontal development of the cake. If both values are examined together, a better idea about the volume of cakes can be obtained. SI is the degree of the camber on the top surface of the cake. TI shows if two sides of the camber are symmetrical, in other words, whether the camber formation is uniform or not (Dizlek et al., 2008).

In order to determine effect of independent variables on the dependent variables Response Surface Methodology was used and the significant models were detected. Multiple linear regression equations of first and second order polynomial model were generated relating structural analysis as system parameters to coded levels of variables for 20 types of cake. The regression models allowed the prediction of the effects of independent variables on structural analysis (Table 3.4).

ANOVA was conducted to assess the significant effects of the independent variables on the responses and the responses significantly affected by the varying processing conditions. The significance of coefficient of fitted quadratic model was evaluated by using the F-test, p-value and lack-of-fit.

The modified quadratic model was significant ($p<0.01$) and it was used in VI, SI, UI, SSV, TSV and TVI as structural analysis. The regression models allowed the prediction of the effects of independent variables on structural analysis and regression analysis indicated that the fitted model had coefficient of determination (R^2) of 0.9120, 0.9788, 0.9286, 0.9261, 0.9643 and 0.9287 for VI, SI, UI, SSV, TSV and TVI, respectively in the experimental data (Table 3.4). The lack-of-fit was significant ($p<0.01$) for SSV. However, it was not significant ($p>0.05$) for the other parameters. A negative coefficient means a decrease in response when the level of the variable (sugar, carob flour and stevia) is increased, whereas a positive coefficient indicates an increase in response. The interactions suggest that the level of one of the interactive variables may increase while that of the other may decrease for a constant value of the response.

Table 3.4. Regression equation in terms of coded factors and coefficient of determinations for structural analysis

Structural analysis	Equation in terms of coded factors	R^2
VI	$122.69 + 4.57*A - 5.62*B + 5.00*C + 13.54*A*B - 11.91*B*C - 6.43*A^2 - 17.05*C^2$	0.9120
SI	$5.03 + 1.20*A - 0.79*B + 0.78*A*C - 7.36*B*C - 1.07*A^2 - 5.17*C^2$	0.9788
UI	$-0.18 + 0.74*A + 0.91*B + 1.11*C - 1.69*A*B + 1.12*A*C - 2.10*B*C - 1.14*A^2 + 1.26*B^2$	0.9286
SSV	$0.98 + 1.35*B - 0.34*C - 0.41*C^2$	0.9261
TSV	$14.11 - 0.40*A - 5.61*B*C + 0.80*A^2 + 0.76*C^2$	0.9643
TVI	$275.61 - 8.48*B + 16.08*A*B + 8.41*A*C - 2.10*A^2 + 8.14*B^2 - 8.06*C^2$	0.9287

Where A is the sugar, B is the carob flour and C is the stevia content.

3.5.1.1. Volume Index (VI)

The volume index is used to compare the volume indices of control cake with the studied cakes. It does not measure the actual volume of cakes but gives an idea about the volume (Çelik and Kotancılar, 1998). VI was calculated from the equation Eq. 2.10. VI of the control cake was 118 mm in this study. Mercan (1998) calculated volume indices (mm) of cakes prepared by 3 different flours. The results of control cakes were 117.0 mm, 113.0 mm, 125.7 mm, respectively in her study. The volume indices of control cakes were found 112 mm by Bath et al. (1992); 123.9 mm by Guy and Vettel (1973) and 164.5 mm by Kim and Walker (1992b). The results of VI were close to each other apart from the study of Kim and Walker (1992b).

Effect of sugar and carob flour on the volume index of the 20 types of cake is shown in Figure 3.1. The VI of cakes varied from 99 to 126 mm. As it can be seen from Figure 3.1, increases in carob flour and decreases in sugar lead to lower VI. As shown in equation (Table 3.4), the model obtained for predicting the VI of 20 types of cakes explained the main linear effects of factors affecting the VI. Also, it seems that sugar and carob flour effected VI. The model is significant statistically ($p<0.01$). The lowest VI of cakes was obtained at the maximum carob flour and minimum sugar ratios.

At low carob flour ratio, the increase in sugar resulted in a slight decrease in VI. However, at high carob flour ratio, the increase in sugar led to sharp increase in VI significantly ($p<0.01$). At low sugar ratio, the increase in carob flour ratio led to decrease in VI. İlhan (2013) found low volume of cakes when adding 20 % or more carob flour in cakes. Whereas at high sugar ratio, the increase in carob flour ratio led to sharp increase in VI significantly ($p<0.01$). According to Figure 3.1, sugar and carob flour both had effect on VI of the cakes. The increase in sugar and carob flour caused sharp increase in VI of 20 types of cakes significantly ($p<0.01$). Sugar effects the volume of cakes significantly due to increasing the gelatinization temperature of the starch to expand the dough because of carbon dioxide and water vapor (Kim and Walker, 1992b).

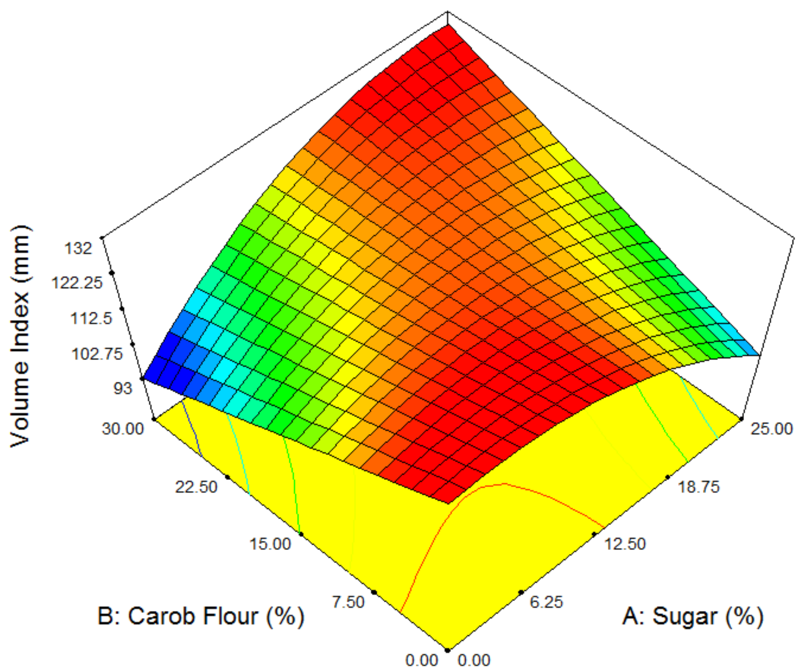

Figure 3.1. Effect of sugar (A) and carob flour (B) on the VI of the 20 types of cake

3.5.1.2. Symmetry Index (SI)

The symmetry index is used to determine the profiles of the outlines of cakes in the cake industry (Mercan 1998). SI was calculated from the equation Eq. 2.11. SI of the control cake was 3 mm in this study. Mercan (1998) calculated the symmetry indices (mm) of cakes prepared by 3 different flours. The results of control cakes were 3.0 mm, 1.0 mm and 0.3 mm, respectively in her study. It was seen that the symmetry index of control cake in this study was equal to one of her results.

The negative (-) result of the SI meaned that the camber form upper part of the cake was inward slump. There was an inward slump on PC11. PC7 and PC8 had zero SI value and there was no camber on the upper part of these cakes so they had a flat structure. If symmetry index increased it shows that there is a camber from top of the cake and if symmetry index decreased it shows that there is a flat form from top of the cake (Mercan 1998). If it is zero, it shows the surface of the cake is flat (without curve) (Dizlek et al., 2008).

Effect of carob flour and stevia on the symmetry index of the 20 types of cake is shown in Figure 3.2. The SI of cakes varied from -1 mm to 7 mm. As it can be drawn from Figure 3.2, decreases in carob flour and stevia lead to lower SI. As shown in equation (Table 3.4), the model obtained for predicting the SI of 20 types of cakes explained the main linear effects of factors affecting the SI. Also, it seems that carob flour and stevia effected SI, the model is significant statistically ($p<0.01$). The lowest SI of cakes was obtained at the minimum carob flour and stevia ratios.

At low stevia ratio, the increase in carob flour resulted in a sharp increase in SI. However, at high stevia ratio, the increase in carob flour led to sharp decrease in SI significantly ($p<0.01$). In contrast to this study, Yücel (2009) reported that using combinations of gums increased symmetry index of cakes. This difference is because of usage of both carob flour and stevia. Figure 3.2 shows that carob flour and stevia both had effect on SI of the cakes. At low carob flour ratio, the increase in stevia ratio led to sharp increase in SI. But at high carob flour ratio, the increase in stevia ratio led to sharp decrease in SI. The decrease in carob flour and increase in stevia also the decrease in stevia and increase in carob flour caused sharp increase in SI of 20 types of cakes significantly ($p<0.01$).

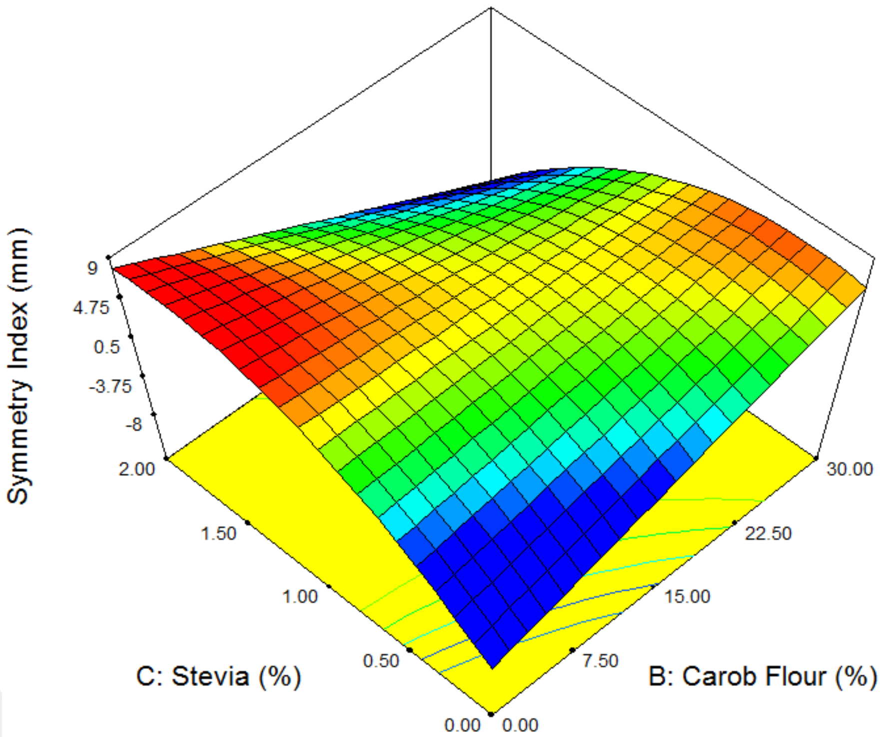

Figure 3.2. Effect of carob flour (B) and stevia (C) on the SI of the 20 types of cake

3.5.1.3. Uniformity Index (UI)

Uniformity indices of cakes are used to determine the symmetries of cakes in the cake industry. UI was calculated from the equation Eq. 2.12. UI of the control cake was 1 mm. Mercan (1998) calculated uniformity indices (mm) of 3 different cakes. The results of control cakes were 1.0 mm, 2.0 mm and 0.7 mm, respectively in her study. The uniformity indices of control cakes were found 2.0 mm by Bath et al. (1992). UI of control cake in this study was close to their results.

Effect of carob flour and stevia on the uniformity index of the 20 types of cake is shown in Figure 3.3. As shown in the related equation (Table 3.4), the model obtained for predicting the UI of 20 types of cakes explained the main linear effects of factors affecting the UI. The model is significant statistically ($p<0.01$). The lowest UI of cakes was obtained at the minimum carob flour and stevia ratios.

At low stevia ratio, the increase in carob flour resulted in a sharp increase in UI. However, at high stevia ratio, the increase in carob flour led to decrease in UI significantly ($p<0.01$). At low carob flour ratio, the increase in stevia ratio led to sharp increase in UI. On the other hand, at high carob flour ratio, the increase in stevia ratio led to decrease in UI significantly (p<0.01). According to Figure 3.3, carob flour and stevia both had effect on UI of the cakes. The increase in carob flour and stevia caused sharp increase in UI of 20 types of cakes significantly (p<0.01). The figure of UI (Figure 3.3) was nearly similar to the figure of SI (Figure 3.2) despite the increase in carob flour and stevia led to increase in UI. The uniformity index is used to determine the lateral symmetry of cakes and it should be close to zero or be zero (Dizlek et al., 2008). As it was seen in Appendix C (Table C3) the results were generally close to zero or just zero.

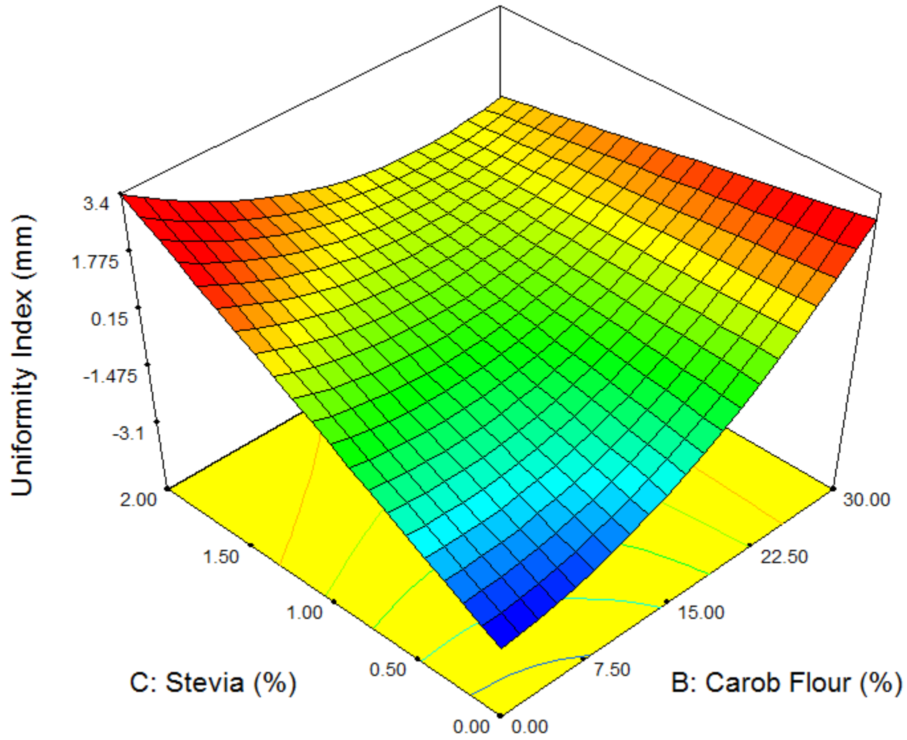

Figure 3.3. Effect of carob flour (B) and stevia (C) on the UI of the 20 types of cake

3.5.1.4. Sub Shrinkage Value (SSV)

Sub shrinkage value expresses the decrease of bottom diameter of dough which is filled into capsules (Dizlek, et al., 2008). The sub shrinkage values were calculated from the equation Eq. 2.13. The sub shrinkage value of the control cake was 0 mm. Giritlioğlu (2017) found the sub shrinkage value of cake, which was prepared from wheat flour and sucrose, 0 mm in his study. It was seen the results were the same.

Effects of carob flour and stevia on the sub shrinkage value of the 20 types of cake are shown in Figure 3.4. As shown in equation (Table 3.4), the model obtained for predicting the SSV of 20 types of cakes explained the main linear effects of factors affecting the SSV. The model is significant statistically ($p<0.01$). Also, it seems that carob flour and stevia effected SSV. The lowest SSV of cakes was obtained at the minimum carob flour and maximum stevia ratios.

At low and high stevia ratios, the increase in carob flour resulted in a sharp increase in SSV significantly ($p<0.01$). At low and high carob flour ratios, the increase in stevia ratio led to slight decrease in SSV significantly ($p<0.01$). According to Figure 3.4, carob flour had highest effect on SSV of the cakes than stevia. The increase in carob flour cause increase in SSV of 20 types of cakes significantly ($p<0.01$). It was associated with high dietary fibres content of carob flour that it collapse water of cake dough and it decreased the spreading of dough. Dietary fibres content of carob flour is from 2.6 to 39.8 (g/100 g) (Iıpumbu, 2008). Also Berk et al. (2017) reported that due to high water holding capacity of carob flour with high dietary fibres, the viscosity of cake dough increased.

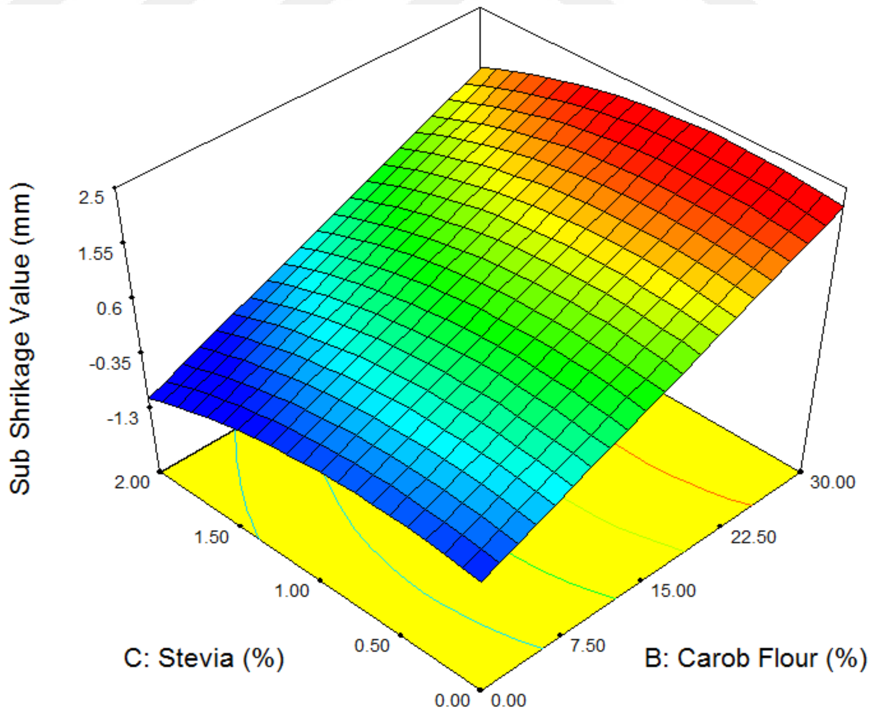

Figure 3.4. Effect of carob flour (B) and stevia (C) on the SSV of the 20 types of cake

3.5.1.5. Top Shrinkage Value (TSV)

Top shrinkage value expresses the decreasing of top diameter of dough which is filled into capsules (Dizlek et al., 2008). The top shrinkage values were calculated from the equation Eq. 2.14. The top shrinkage value of the control cake was 10 mm. Giritlioğlu (2017) found the top shrinkage value of cake, which was prepared from wheat flour and sucrose, 9.5 mm in his study. It was seen the results were close to each other.

Effect of carob flour and stevia on the top shrinkage value of the 20 types of cake is shown in Figure 3.5. As shown in equation (Table 3.4), the model obtained for predicting the TSV of 20 types of cakes explained the main linear effects of factors affecting the TSV. The model is significant statistically ($p<0.01$). Also, it seems that carob flour and stevia effected TSV. The lowest TSV of cakes was obtained at the minimum carob flour and stevia ratios moreover at the maximum carob flour and stevia ratios.

At low stevia ratio, the increase in carob flour resulted in a sharp increase in TSV. However, at high stevia ratio, the increase in carob flour led to sharp decrease in TSV. At low carob flour ratio, the increase in stevia ratio led to sharp increase in TSV. On the other hand, at high carob flour ratio, the increase in stevia ratio led to sharp decrease in TSV significantly ($p<0.01$). According to Figure 3.5, carob flour and stevia both had effect on TSV of the cakes. The decrease in carob flour and increase in stevia, also the decrease in stevia and increase in carob flour caused sharp increase in TSV of 20 types of cakes significantly ($p<0.01$).

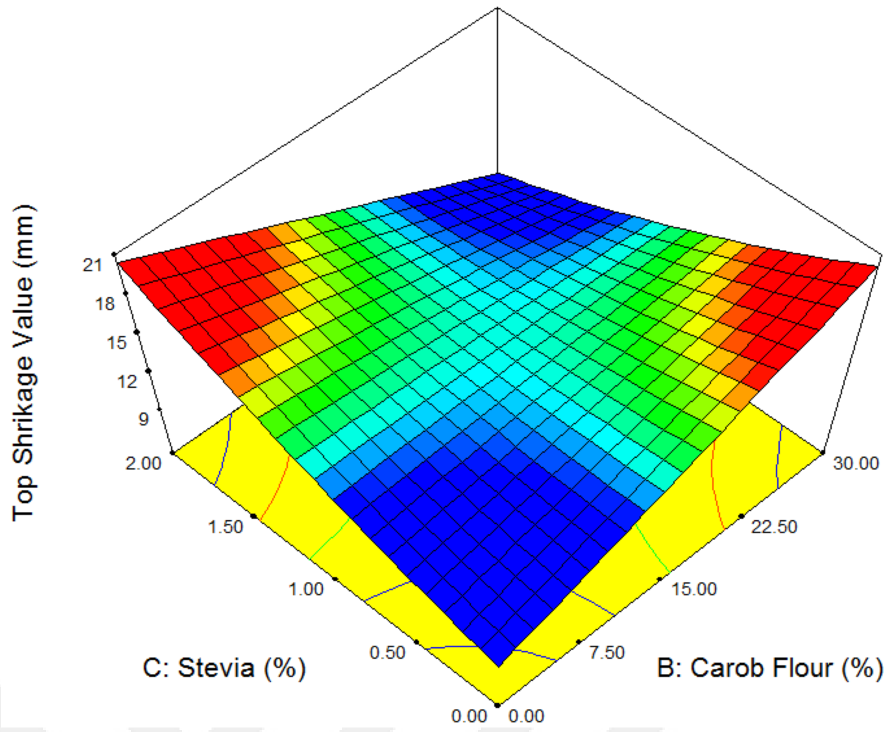

Figure 3.5. Effect of carob flour (B) and stevia (C) on the TSV of the 20 types of cake

3.5.1.6. Total Volume Index (TVI)

Total volume index value is based on the same principles of volume index. It was measured from 7 different points of the cakes (Bath et al., 1992). Total volume indices were calculated from the Eq. 2.15. The total volume index of the control cake was 302 mm. Giritlioğlu (2017) found the total volume index of cake, which was prepared from wheat flour and sucrose, as 247 mm in his study. In our study it was found higher than his result. It was considered to be because of using amounts of wheat flour and sucrose in the cakes. On the other hand, Yücel (2009) found the total volume index of control cake 583 mm that it was higher than result of this study. The difference between the results could be due to the different type of cake that she produced (sponge cake).

Effect of sugar and carob flour on the total volume index of the 20 types of cake is shown in Figure 3.6. The TVI of cakes varied from 255 to 298 mm. As it can be seen from Figure 3.6, increase in carob flour and decrease in sugar lead to lower TVI. As shown in equation (Table 3.4), the model obtained for predicting the TVI of 20 types of cakes explained the main linear effects of factors affecting the TVI. Also, it seems that sugar and carob flour effected TVI. The model is significant statistically ($p<0.01$). The lowest TVI of cakes was obtained at the maximum carob flour and minimum sugar ratios.

At low carob flour ratio, the increase in sugar resulted in decrease in TVI. However, at high carob flour ratio, the increase in sugar led to sharp increase in TVI. At low sugar ratio, the increase in carob flour ratio led to decrease in TVI but at high sugar ratio, the increase in carob flour ratio led to sharp increase in TVI significantly ($p<0.01$). According to Figure 3.6, sugar and carob flour both had effect on TVI of the cakes. The increase in sugar and carob flour caused sharp increase in TVI of 20 types of cakes significantly ($p<0.01$). It was seen the results of VI (Figure 3.1) and TVI (Figure 3.6) were parallel to each other.

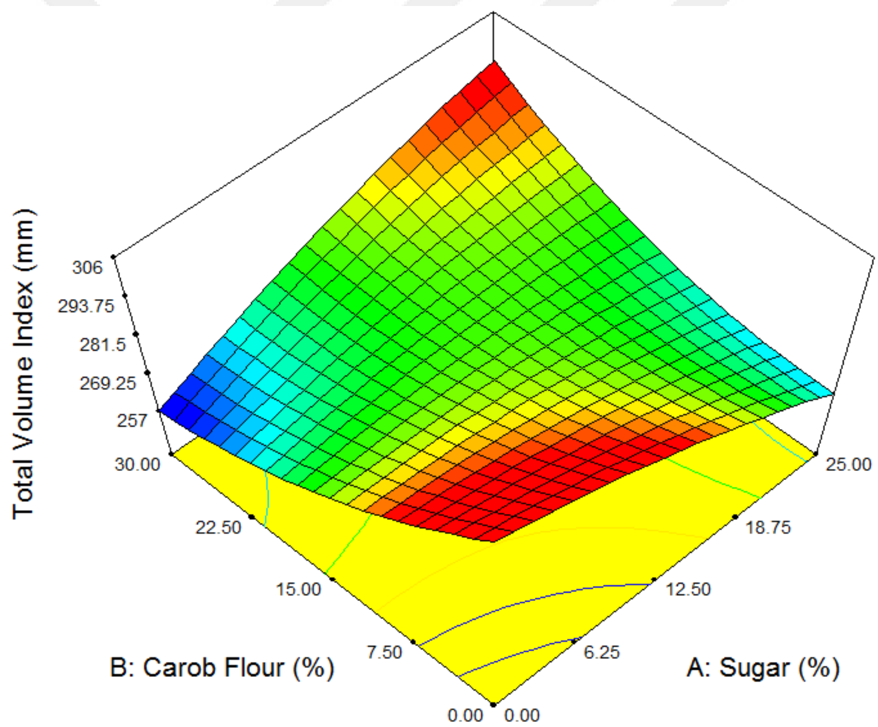

Figure 3.6. Effect of sugar (A) and carob flour (B) on the TVI of the 20 types of cake

3.5.2. Textural Analysis

In the textural analysis of cakes; hardness, springiness, cohesiveness, gumminess, chewiness and resilince values of cakes were determined. Textural analysis results were found by using TPA/TA, XTplus Texture Analyzer and using P/36R probe. The results were given in Appendix C (Table C4).

Multiple linear regression equations of first and second order polynomial models were generated relating textural analysis as system parameters to coded levels of variables for 20 types of cake. The regression models allowed the prediction of the effects of independent variables on structural analysis (Table 3.5).

ANOVA was conducted to assess the significant effects of the independent variables on the responses and the responses significantly affected by the varying processing conditions. The significance of coefficient of fitted quadratic model was evaluated by using the F-test, p-value and lack-of-fit.

The modified quadratic model was significant ($p<0.01$) and it was used in hardness, springiness, cohesiveness, gumminess, chewiness and resilience as textural analysis. The regression models allowed the prediction of the effects of independent variables on textural analysis. Regression analysis indicated that the fitted model had coefficient of determination (R^2) of 0.9982, 0.9687, 0.9946, 0.9929, 0.9938 and 0.9668 for hardness, springiness, cohesiveness, gumminess, chewiness and resilience, respectively (Table 3.5). The lack-of-fit was significant ($p<0.01$) for gumminess, ($p<0.05$) for cohesiveness and resilience. However, it was not significant ($p>0.05$) for hardness, springiness and chewiness. A negative coefficient means decrease in response when the level of the variable (sugar, carob flour and stevia) is increased. Whereas, a positive coefficient indicates an increase in response. The interactions suggest that the level of one of the interactive variables may increase while that of the other may decrease for a constant value of the response.

Table 3.5. Regression equations in terms of coded factors and coefficient of determinations for textural analysis

Textural analysis	Equation in terms of coded factors	R^2
Hardness	$3335.16 + 110.80*A – 594.47*B - 545.47*C + 869.06*A*B + 234.34*A*C – 763.74*B*C – 60.50*A^2 – 560.97*B^2 – 1396.39*C^2$	0.9982
Springiness	$0.870 + 0.012*C + 0.037*B^2 + 0.051*C^2$	0.9687
Cohesiveness	$0.460 + 0.009*A - 0.057*B - 0.023*C + 0.011*A*B - 0.092*B*C – 0.016*A^2 + 0.063*B^2 – 0.010*C^2$	0.9946
Gumminess	$1531.94 + 61.92*A – 424.42*B - 287.36*C + 427.77*A*B + 84.45*A*C – 562.64*B*C – 71.81*A^2 – 648.59*C^2$	0.9929
Chewiness	$1345.21 + 58.63*A – 383.26*B - 246.68*C + 382.04*A*B + 74.63*A*C – 506.61*B*C – 67.64*A^2 – 525.04*C^2$	0.9938
Resilience	$0.200 + 0.014*A - 0.038*B - 0.045*C – 0.027*A^2$	0.9668

Where A is the sugar, B is the carob flour and C is the stevia content.

3.5.2.1. Hardness

Hardness is a quality criteria that can be determined by touch and it is one of the most important quality criteria that affects the quality of consumption especially in bakery products. Hardness is defined as the maximum force measured during the compression of the cake (Bourne, 2002). Hardness value of the control cake was 1909 in this study. Topkaya (2017) found hardness value of the control cake as

1897.30 in her study. The result for hardness value of the control cake was nearly the same according to result of her study.

Effect of sugar and carob flour on the hardness of the 20 types of cake is shown in Figure 3.7. The hardness of cakes varied from 1319 to 3408. As it can be observed from Figure 3.7. Increase in carob flour and decrease in sugar lead to lower hardness. As shown in equation (Table 3.5), the model obtained for predicting the hardness of 20 types of cakes explained the main linear effects of factors affecting the hardness. Also, it seems that sugar and carob flour effected hardness and the model is significant statistically ($p<0.01$). The lowest hardness of cakes was obtained at the maximum carob flour and minimum sugar ratios.

At low carob flour ratio, the increase in sugar resulted in decrease in hardness. In a study performed by Mercan and Boyacıoğlu (1999b), sugar showed softening effect on the cake. Therefore, it effects the hardness of the cake. However at high carob flour ratio, the increase in sugar led to sharp increase in hardness significantly ($p<0.01$). At low sugar ratio, the increase in carob flour ratio led to decrease in hardness. At high sugar ratio, the increase in carob flour ratio led to increase in hardness significantly ($p<0.01$). Magda et al. (2008) reported that the addition of carob flour to biscuits increased the hardness values of biscuit doughs because of increasing the fiber content. According to Figure 3.7, sugar and carob flour both had effect on hardness of the cakes. The increase in sugar and carob flour caused sharp increase in hardness of 20 types of cakes significantly ($p<0.01$). The hardness value of the cake sample with 15 % carob pulp, increased when compared to the control sample according to a study of İlhan (2013).

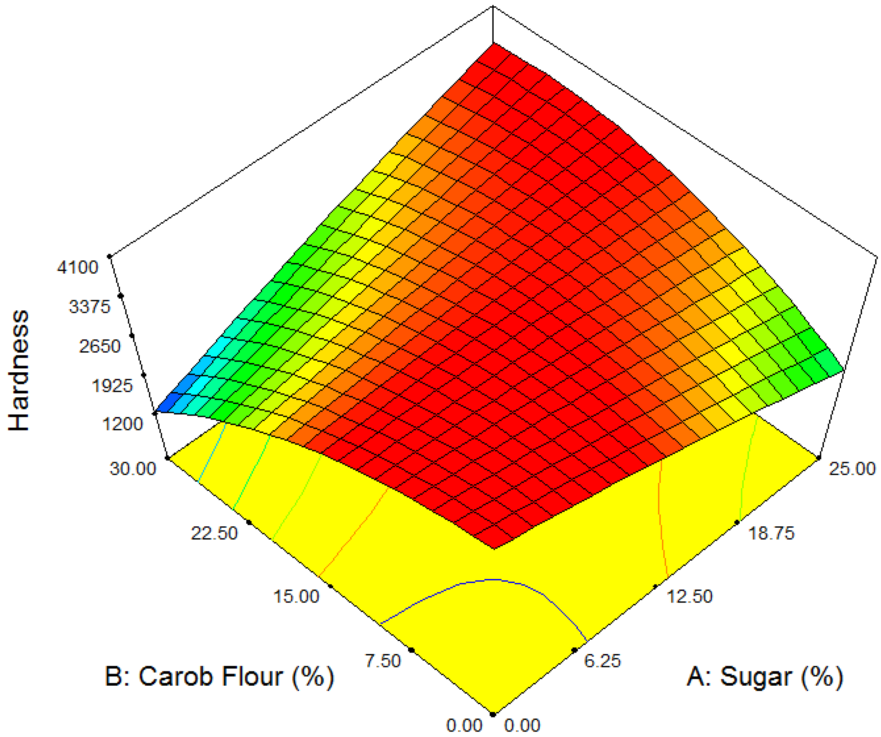

Figure 3.7. Effect of sugar (A) and carob flour (B) on the hardness of the cakes

3.5.2.2. Springiness

Springiness is defined as recovery of food shape when first bite was ended then the second bite was began (Szczesniak 2002). Springiness value of the control cake was 0.914 in this study. There was a study by Memeli (2015) that she found the springiness value of control cake 0.910 ± 0.01 and another study by Bozdoğan (2015) that the springiness value of control cake was 0.910 ± 0.02. The result of this study was close to their results.

Springiness of the 20 types of cake is shown in Figure 3.8. Sugar did not effect springiness of cakes but stevia did significantly ($p<0.01$). At low and high sugar, the increase in stevia ratio resulted in a sharp decrease until 1 % ratio of stevia and after increase in 1.5 % ratio of stevia led to sharp increase in springiness of cakes. This is in agreement with the literature findings. The study of Bozdoğan (2015) showed that the springiness value decreased then increased depending on powder ratios. According to Memeli (2015), using powders decreased the springiness of cakes statistically. Carob flour had dietary fibres and it did not effect the springiness of cakes. The same situation was observed in the study of Memeli (2015) that she reported using dietary fibres did not effect the springiness of cakes.

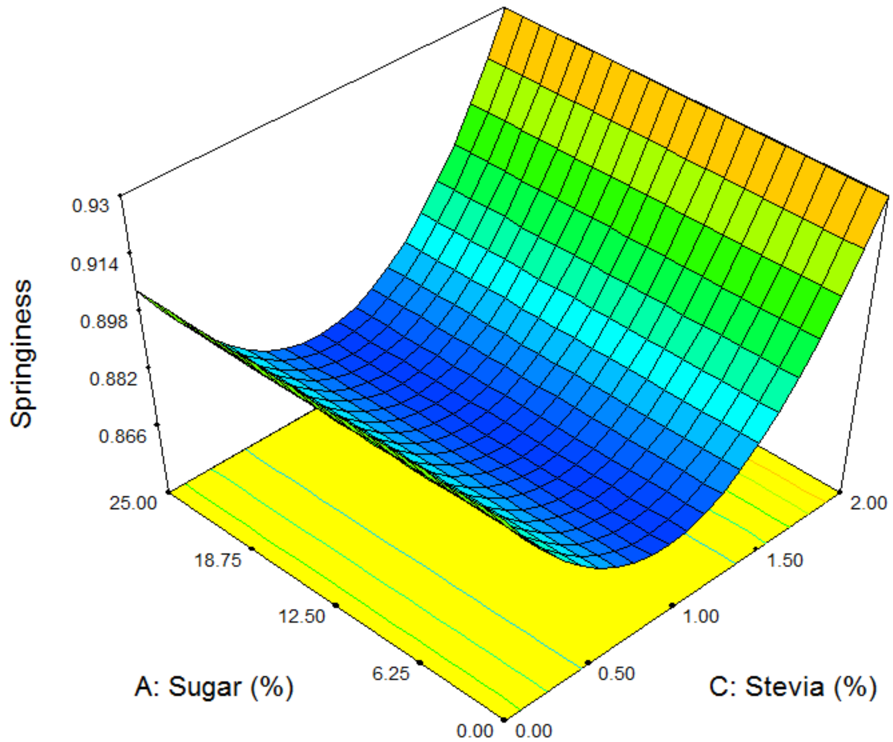

Figure 3.8. Effect of sugar (A) and stevia (C) on the springiness of the cakes

3.5.2.3. Cohesiveness

Cohesiveness refers to the strength of the bonds that form the structure of the cake (Bourne, 2002). Cohesiveness is the force required to resist the forces between the surface of the food and the tongue, tooth and palate (Ertaş and Doğruer 2010). Cohesiveness value of the control cake was 0.561 in this study. There was a study by Yıldız (2010) that he found cohesiveness value of the control cakes changing from 0.442 to 0.580. It was seen that the result was in the range of his study.

Effect of sugar and carob flour on the cohesiveness of the 20 types of cake is shown in Figure 3.9. The cohesiveness of cakes varied from 0.385 to 0.584. As it can be understood from Figure 3.9, increase in carob flour and sugar lead to lower cohesiveness. As shown in equation (Table 3.5), the model obtained for predicting the cohesiveness of 20 types of cakes explained the main linear effects of factors affecting the cohesiveness. The model is significant statistically ($p<0.01$). Also, it seems that sugar and carob flour effected cohesiveness. The lowest cohesiveness of cakes was obtained at the maximum carob flour and sugar ratios.

At low and high carob flour ratios, the increase in sugar resulted in slight decrease in cohesiveness significantly ($p<0.01$). At low and high sugar ratio, the increase in carob flour ratio led to sharp decrease in cohesiveness significantly ($p<0.01$). It was releated with high water absorption capasity of carob flour that decreasing water ratio in dough decreased cohesiveness of cakes. It was reported in the study of Yıldız (2010) that increasing water ratio increased cohesiveness of cakes. According to Figure 3.7, carob flour had highest effect on cohesiveness of the cakes than sugar. The increase in carob flour caused sharp decrease in cohesiveness of 20 types of cakes significantly ($p<0.01$).

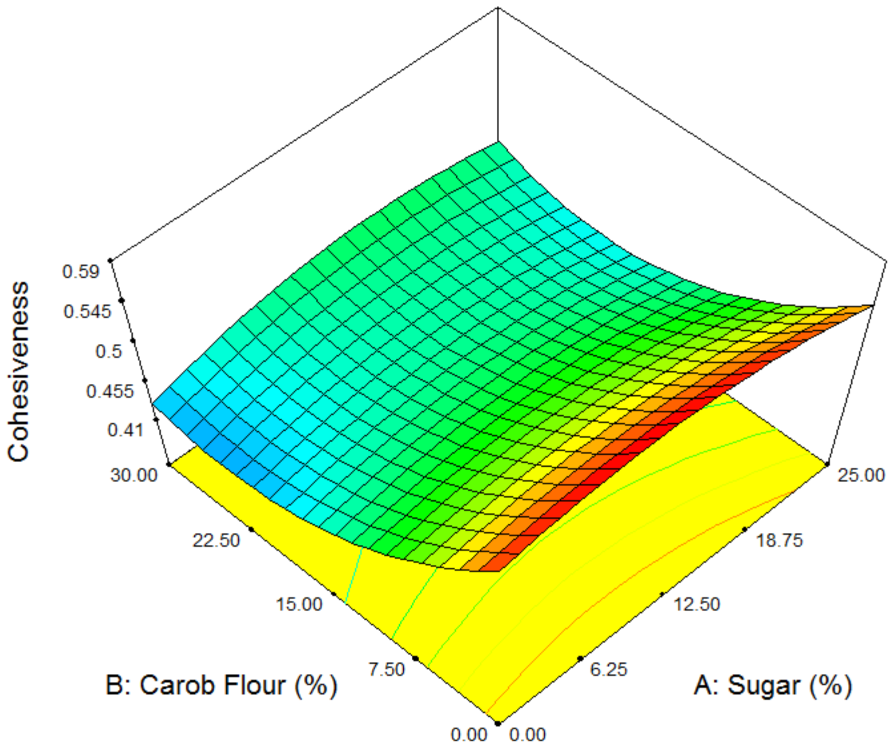

Figure 3.9. Effect of sugar (A) and carob flour (B) on the cohesiveness of the cakes

3.5.2.4. Gumminess

Gumminess refers to the strength of the bonds that form the structure of the cake (Bourne, 2002). Gumminess results were calculated after analyzing the cakes by the texture analyzer. It was calculated the results by multipling hardness with cohesiveness values. Textural analyses results were given in Appendix C (Table C4). It can be seen that increase in hardness led to increase in gumminess of cakes. Gumminess value of the control cake was 1071 in this study. Topkaya (2017) found gumminess value of the control cake as 1049.6 in her study. The result for gumminess value of the control cake was nearly same according to result of her study.

Effect of sugar and carob flour on the gumminess of the 20 types of cake is shown in Figure 3.10. The gumminess of cakes varied from 508 to 1840. As it can be seen from Figure 3.10, increase in carob flour and decrease in sugar lead to lower gumminess. As shown in equation (Table 3.5), the model obtained for predicting the gumminess of 20 types of cakes explained the main linear effects of factors affecting the gumminess. Also, it seems that sugar and carob flour effected gumminess, the model is significant statistically ($p<0.01$). The lowest gumminess of cakes was obtained at the maximum carob flour and minimum sugar ratios.

At low carob flour ratio, the increase in sugar resulted in decrease in gumminess but at high carob flour ratio, the increase in sugar resulted in sharp increase in gumminess significantly ($p<0.01$). At low sugar ratio, the increase in carob flour ratio led to sharp decrease in gumminess. The study conducted by Noğay (2014) reported that increase in pomegranate seed powders in cakes led to decrease in gumminess significantly. However at high sugar ratio, the increase in carob flour ratio led to slight increase in gumminess significantly ($p<0.01$). According to Figure 3.10, sugar and carob flour had effect on gumminess of 20 types of cake significantly ($p<0.01$).

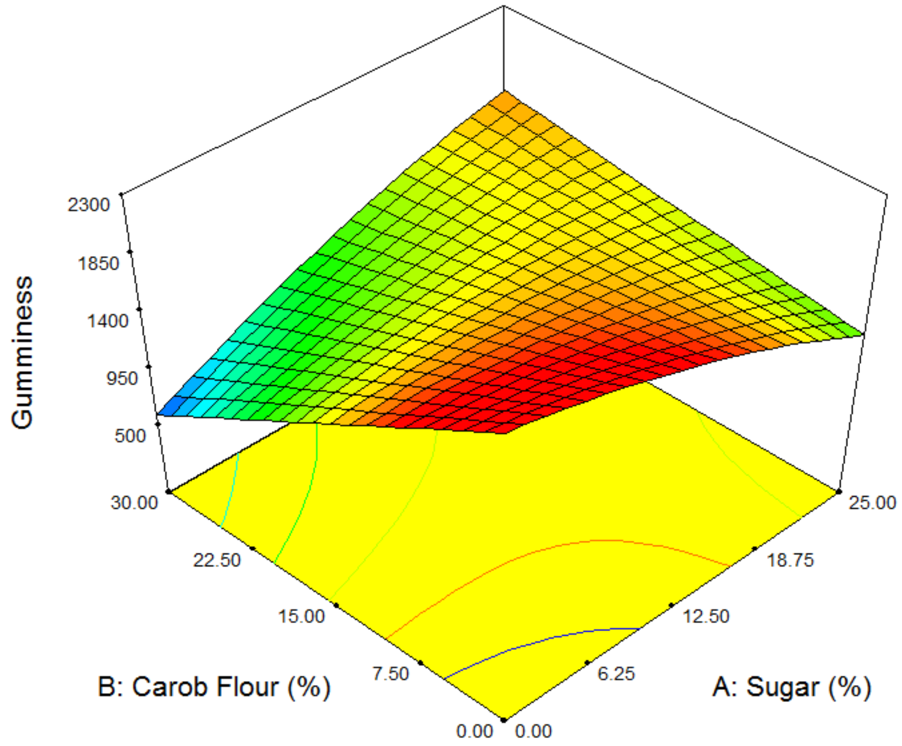

Figure 3.10. Effect of sugar (A) and carob flour (B) on the gumminess of the cakes

3.5.2.5. Chewiness

Chewiness value is a feature of the amount of energy spent, chewing time and chewing until food is ready to swallow (Ertaş and Doğruer 2010). Also, chewiness is defined as the work required to break down the cake until it is ready to be swallowed (Bourne, 2002). Chewiness results were calculated by multiplying springiness with gumminess values. Chewiness value of the control cake was 979 in this study. The chewiness value of the control cake in the study of Köksel (2009) was 940. The result of this study was higher than her study due to the different sugar ratio used in the control cake dough. She used only sugar in cakes. But in the current study interaction with sugar and carob flour as shown in Figure 3.11 led to increase in chewiness.

Effect of sugar and carob flour on the chewiness of the 20 types of cake is shown in Figure 3.11. The chewiness of cakes varied from 461 to 1673. As it can be drawn from Figure 3.11, increases in carob flour and decreases in sugar lead to lower chewiness. As shown in equation (Table 3.5), the model obtained for predicting the chewiness of 20 types of cakes explained the main linear effects of factors affecting the chewiness. Also, it seems that sugar and carob flour effected chewiness, the model is significant statistically ($p<0.01$). The lowest chewiness of cakes was obtained at the maximum carob flour and minimum sugar ratios.

At low carob flour ratio, the increase in sugar resulted in slight decrease in chewiness. But at high carob flour ratio, the increase in sugar resulted in sharp increase in chewiness significantly ($p<0.01$). At low sugar ratio, the increase in carob flour ratio led to sharp decrease in chewiness. The same situation was observed from study of Noğay (2014) that increase in pomegranate seed powders in cakes led to decrease in chewiness significantly. However at high sugar ratio, the increase in carob flour ratio led to slight increase in chewiness significantly ($p<0.01$). According to Figure 3.11, sugar and carob flour had effect on chewiness of 20 types of cake significantly ($p<0.01$). Chewiness was mostly depended on gumminess value that increase in gumminess (Figure 3.10) led to increase in chewiness (Figure 3.11).

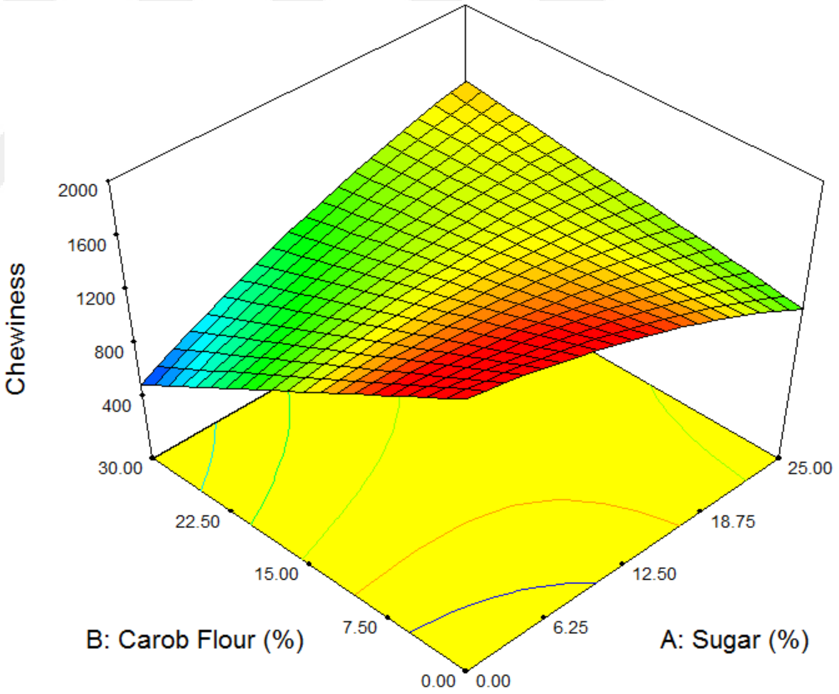

Figure 3.11. Effect of sugar (A) and carob flour (B) on the chewiness of the cakes

3.5.2.6. Resilience

Resilience is a measurement of how a sample compensate from deformation in connection of forces and speed (Szczesniak 2002). Resilience value of the control cake was 0.212 in this study. Yıldız (2010) found resilience of the control cakes from 0.116 to 0.221. The result of this study is in agreement with the literature values.

Effect of sugar and carob flour on the resilience of the 20 types of cake is shown in Figure 3.12. As it can be seen from Figure 3.12, increase in carob flour and decrease in sugar lead to decrease resilience. As shown in equation (Table 3.5), the model obtained for predicting the resilience of 20 types of cakes explained the main linear effects of factors affecting the resilience. Also, it seems that sugar and carob flour effected resilience and the model is significant statistically ($p<0.01$). The lowest resilience of cakes was obtained at the maximum carob flour and minimum sugar ratios.

At low and high carob flour ratios, the increase in sugar resulted in slight decrease in resilience. At low and high sugar ratio, the increase in carob flour ratio led to sharp decrease in resilience significantly ($p<0.01$). It was the same situation with cohesiveness that reported by Yıldız (2010) where increase in water ratio led to increase in resilience. Carob flour decreases the water ratio so it led to decrease in resilience. According to Figure 3.12, carob flour had higher effect on resilience of the cakes than sugar. The increase in carob flour caused sharp decrease in resilience of 20 types of cakes significantly ($p<0.01$).

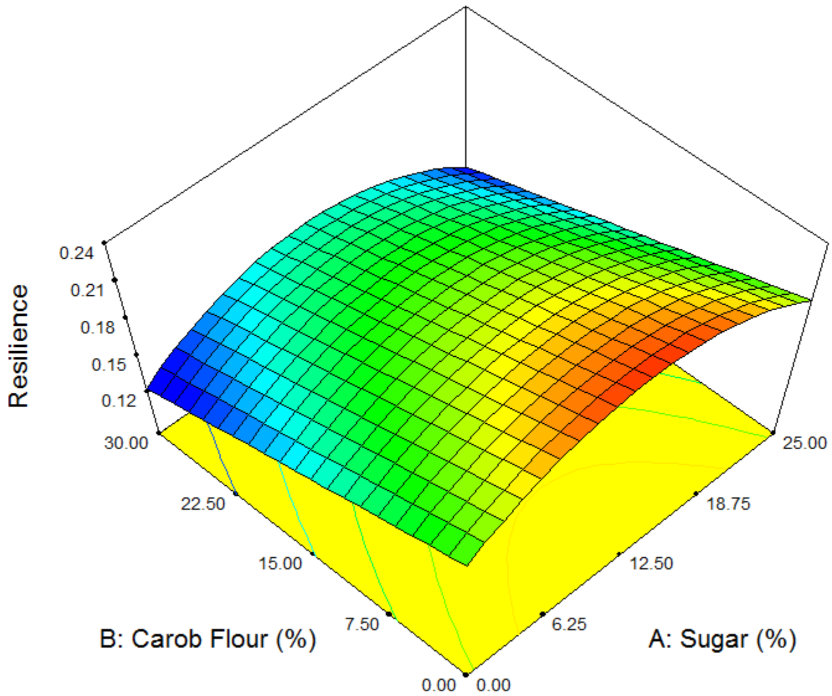

Figure 3.12. Effect of sugar (A) and carob flour (B) on the resilience of the cakes

3.5.3. Color Determination

Color is a sign of chemical changes occuring in the cake such as caramelization and browning (Johnson et. al., 1989). Hunter L, a, b system was used in the measurement of inside and surface of the cake color (Koçer, 1999). The results were given in Appendix C (Table C5). According to the Hunter system, L* value indicates the whiteness or blackness of the color, a* value indicates changing from red to green, b* value refers to changing from yellowness to blue color (Etseller et al., 2006).

Multiple linear regression equations of first and second order polynomial models were generated relating color determination as system parameters to coded levels of variables for 20 types of cake. The regression models allowed the prediction of the effects of independent variables on color determination (Table 3.6).

ANOVA was conducted to assess the significant effects of the independent variables on the responses and the responses significantly affected by the varying processing conditions. The significance of coefficient of fitted quadratic model was evaluated by using the F-test, p-value and lack-of-fit.

The modified quadratic model was significant ($p<0.01$) but it was not significant for inside a* and surface a* ($p>0.05$). In terms of cake production, it is stated that a* value is not important (Koçer, 1999). The model was generated for inside L*, b* and surface L*, b* values. The regression models allowed the prediction of the effects of independent variables on color determination. Regression analysis indicated that the fitted model had coefficient of determination (R^2) of 0.9617, 0.8968, 0.9031 and 0.9618 for inside L*, inside b*, surface L* and surface b*, respectively (Table 3.6). The lack-of-fit was significant for inside L*, surface L* and surface a* ($p<0.01$). It was also significant for inside a* and surface b* ($p<0.05$) but not significant for inside b* ($p>0.05$). The 3-D figures of models of inside a* and surface a* were given in Appendix D (Figure D1 and Figure D2).

A negative coefficient means a decrease in response when the level of the variable (sugar, carob flour and stevia) is increased, whereas a positive coefficient indicates an increase in the response. The interactions suggest that the level of one of the interactive variables may increase while that of the other may decrease for a constant value of the response.

Table 3.6. Regression equation in terms of coded factors and coefficient of determinations for color analysis

Color analysis	Equation in terms of coded factors	R^2
Inside L*	$29.88 + 3.08*A – 10.61*B – 7.49*B*C – 4.38*A^2 + 21.83*B^2 – 9.61*C^2$	0.9617
Inside b*	$11.11 - 5.14*B + 10.30*B^2$	0.8968
Surface L*	$25.35 - 9.81*B + 3.91*A*C – 6.48*B*C + 9.30*B^2 – 3.77*C^2$	0.9031
Surface b*	$5.19 - 5.76*B + 4.21*A*C + 18.12*B^2$	0.9618

Where A is the sugar, B is the carob flour and C is the stevia content.

The inside Hunter L* and b* color values of control cake were 73.94 and 34.44 respectively in this study. Hunter color values; 76.4 as L* and 35.31 as b* were found by Kıranlı (2006), 73.85 as L* and 19.83 as b* by Malek (2013), 74.11 as L* and 17.10 as b* by Zabihollahi (2014), respectively. Also, the surface Hunter L* and b* color values of control cake were 53.32 and 32.36, respectively in the current study. The literature values were reported; 53.69 as L* and 26.49 as b* by Malek (2013), from 62.01 to 79.73 as L* and from 36.78 to 43.80 as b* by Yıldız (2010), 53.51 as L* and 30.54 as b* by Zabihollahi (2014). There were diffferent results found for L* and b* color values. The differences may be because of variety of ingredients and their mass in the composition.

Moreover, İlhan (2013) found 60.68 as inside Hunter L* value and 45.79 as inside Hunter b* values of control cakes. She added carob pulp at 5 %, 10 % and 15 % ratio in the cakes. She determined 33.47, 26.45 and 23.84 as L* value and 14.45, 10.56 and 9.16 as b* value, respectively from different carob pulp ratios. The Hunter L* and b* values of the control cake were higher than the cakes were produced with carob flour. The same situation was observed in this study that was given in Appendix C (Table C5). The control cake had the highest inside Hunter L* and b* values among cakes produced by carob flour. On the other hand PC13 had the highest inside and surface L* values than control cake because it had no carob flour but contained stevia. According to the study conducted by Vatankhah et al. (2015), the use of stevia as sugar substitutes led to increase in L* value of biscuits. Also, Kıranlı (2006) reported that when the L* value increased, the color became bright. Zabihollahi (2014) found the highest L* value in the cakes produced by using stevia.

3.5.3.1. Inside Color

Effect of carob flour and stevia on the inside Hunter L* value of the 20 types of cake is shown in Figure 3.13. As it can be observed from Figure 3.13, increase in carob flour and stevia lead to lower inside Hunter L* value. As shown in equation (Table 3.6), the model obtained for predicting the inside Hunter L* value of 20 types of cakes explained the main linear effects of factors affecting the inside Hunter L* value. Also, it seems that carob flour and stevia effected inside Hunter L* value. The model was found significant statistically ($p<0.01$). The lowest inside Hunter L* value of cakes was obtained at the maximum carob flour and stevia ratios. At low and high stevia ratios, the increase in carob flour resulted sharp decrease in inside Hunter L* value significantly ($p<0.01$). İlhan (2013) reported in her study that carob flour has a dark color, so that Hunter L* and b* values of the cakes were decreased significantly. At low carob flour ratio, the increase in stevia ratio led to sharp increase in inside Hunter L* value significantly ($p<0.01$). However at high carob flour ratio, the increase in stevia ratio led to decrease in inside Hunter L* value significantly ($p<0.01$). According to Figure 3.13, carob flour had higher effect on inside Hunter L* value of the cakes than stevia. The increase in carob flour caused sharp decrease in inside Hunter L* value of 20 types of cakes significantly ($p<0.01$).

Inside Hunter b* value of the 20 types of cake is shown in Figure 3.14. Stevia did not effect inside Hunter b* value of cakes but carob flour did ($p<0.01$). At low and high stevia ratios, the increase in carob flour ratio resulted in a sharp decrease until 15 % ratio of carob flour and after increase in 22.50 % ratio of carob flour led to slight increase in inside Hunter b* value of cakes. This is in agreement with the İlhan (2013) findings.

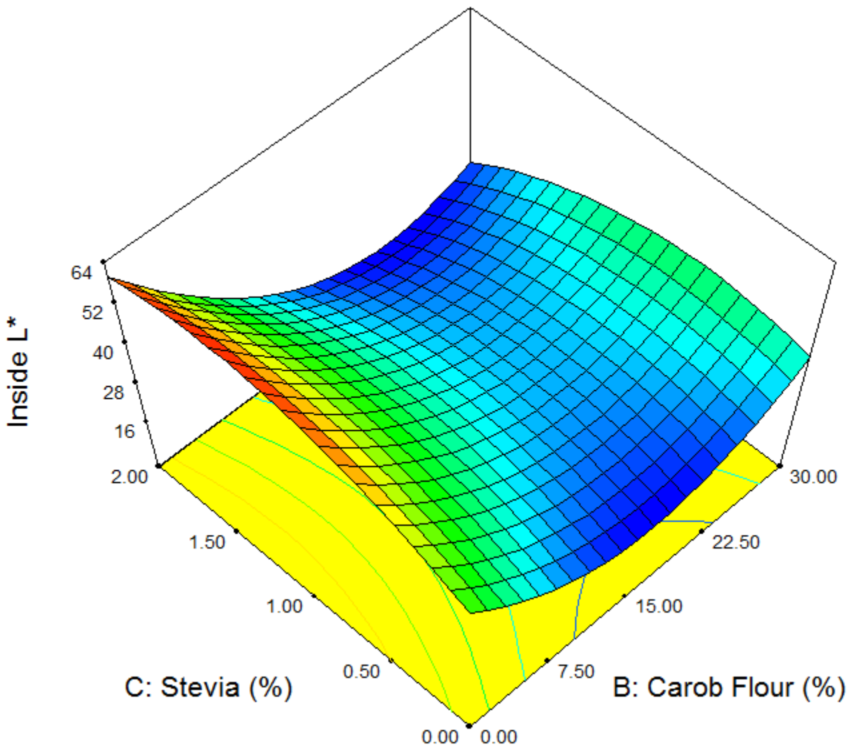

Figure 3.13. Effect of carob flour and stevia on the inside Hunter L* value of the cakes

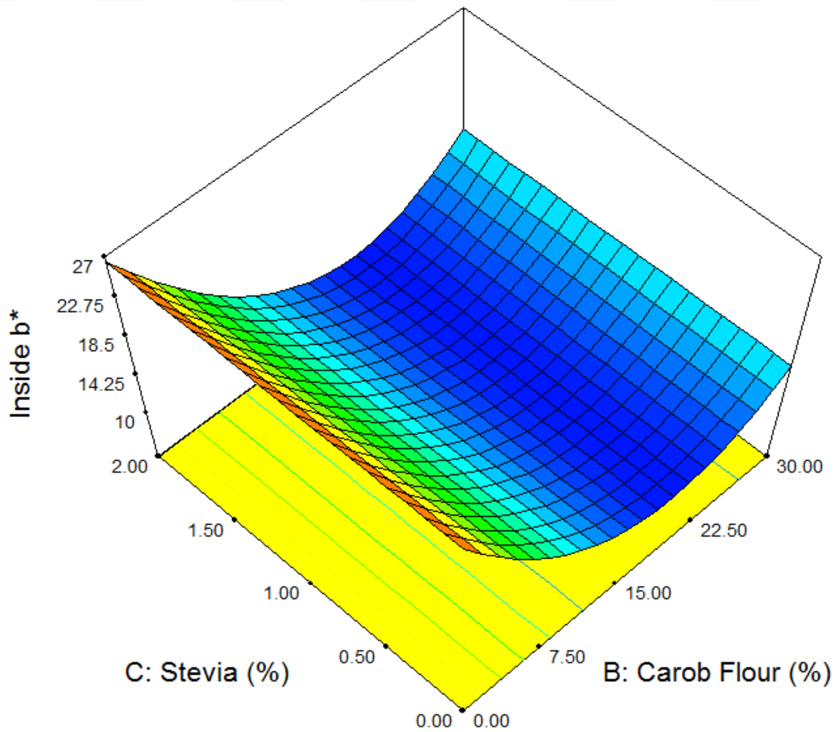

Figure 3.14. Effect of carob flour and stevia on the inside Hunter b* value of the cakes

3.5.3.2. Surface Color

Effect of carob flour and stevia on the surface Hunter L* value of the 20 types of cake is shown in Figure 3.15. As it can be drawn from Figure 3.15, increase in carob flour and stevia lead to lower surface Hunter L* value. As shown in equation (Table 3.6), the model obtained for predicting the surface L* value of 20 types of cakes explained the main linear effects of factors affecting the surface Hunter L* value. The model is significant statistically ($p<0.01$). Also, it seems that carob flour and stevia affected surface Hunter L* value ($p<0.05$). The lowest surface Hunter L* value of cakes was obtained at the maximum carob flour and stevia ratios. At low and high stevia ratios, the increase in carob flour resulted sharp decrease in surface Hunter L* value significantly ($p<0.01$). In a study performed by Aydın (2012) it was reported that increase in carob flour led to decrease in Hunter L* and b* values of biscuits. At low carob flour ratio, the increase in stevia ratio led to sharp increase in surface Hunter L* value significantly ($p<0.05$). However at high carob flour ratio, the increase in stevia ratio caused decrease in surface Hunter L* value significantly ($p<0.05$). According to Figure 3.15, carob flour had higher effect on surface Hunter L* value of the cakes than stevia. The increase in carob flour caused sharp decrease in surface Hunter L* value of 20 types of cakes significantly ($p<0.01$).

Surface Hunter b* value of the 20 types of cake is shown in Figure 3.16. Stevia did not affect surface Hunter b* value of cakes but carob flour did significantly ($p<0.01$). At low and high stevia ratios, the increase in carob flour ratio resulted in a sharp decrease until 15 % ratio of carob flour. After 22.50 % ratio of carob flour, there was significant increase in surface Hunter b* value of cakes.

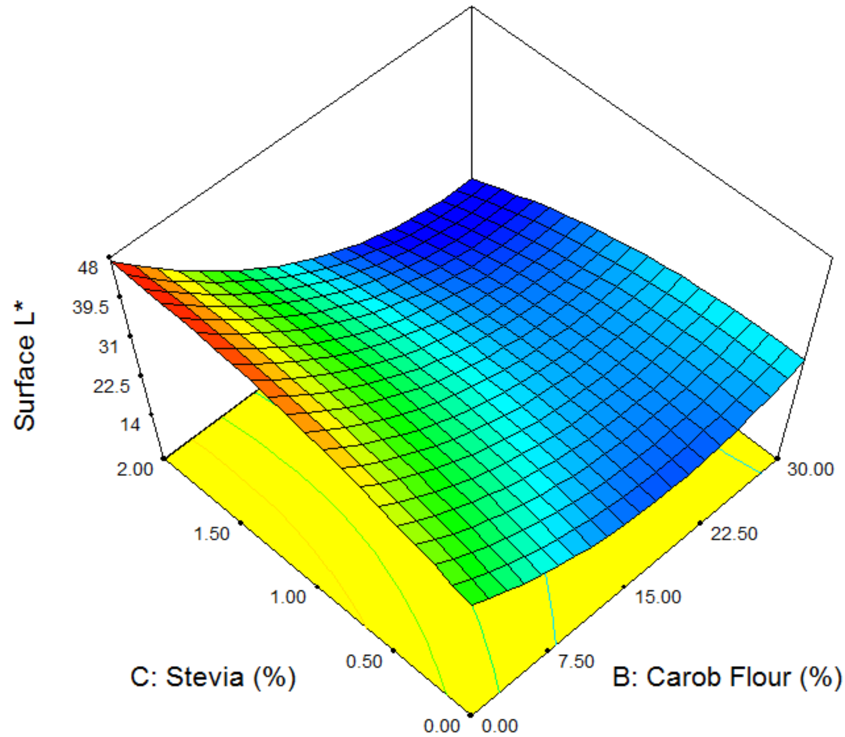

Figure 3.15. Effect of carob flour and stevia on the surface Hunter L* value of the cakes

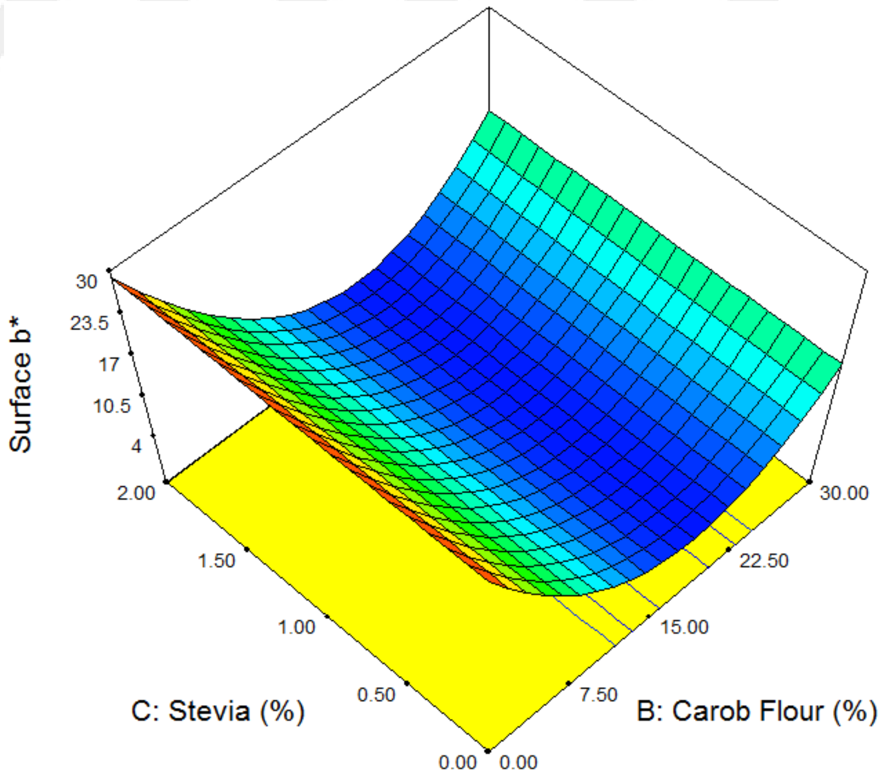

Figure 3.16. Effect of carob flour and stevia on the surface Hunter b* value of the cakes

3.5.4. Pore Number and Pore Size Analysis

Pore structure and pore distribution are utilized in the evaluation of the quality of cakes (Koçer, 1999). Cakes were cut into halves and the pores in one part were counted to determine the number of pores. The pore sizes were measured with the ruler from the bottom, middle and top parts of the cake. The results were given in Appendix C (Table C6).

The model was not significant ($p>0.05$) for pore number and pore sizes (bottom, middle and top). The 3-D figures of models of pore number, bottom size, middle size and top size were given in Appendix D (Figure D3, D4, D5 and D6, respectively). Kıranlı (2006) reported that pore numbers and sizes of cakes were not affected by the sugar substitutes. There was no changing in pore numbers and sizes according to control cake. Whereas there was a study by Tsatsaragkou et al. (2012) that porosity value of bread was affected both from carob flour and water content. It was reported in their study that increase in carob flour led to decrease in porosity but increase in water increased that value.

The model had coefficient of determination (R^2) of 0.3365, 0.5966, 0.3844 and 0.6199 for pore number, bottom size, middle size and top size, respectively. The lack-of-fit significant for pore number ($p<0.01$). Moreover, it was not significant for the pore sizes ($p>0.05$).

3.5.5. Volume Analysis

Volume is an important criteria for physical properties of cakes. People want to consume cake which has symmetrical volume. Volume analysis was performed by AACC 10-05 method according to rapeseed displacement principle (AACC, 2000). The results were given in Appendix C (Table C7).

The volume of the control cake was 85.55 cm^3 that it had the highest volume among 20 types of cake. The same situation occured in the study of Kıranlı (2006). ANOVA was conducted to assess the significant effects of the independent variables on the responses. The response was significantly affected by the varying processing conditions. The significance of coefficient of fitted quadratic model was evaluated by using the F-test, p-value and lack-of-fit. The regression models allowed the prediction of the effects of independent variables on volume analysis and regression analysis indicated that the fitted model had coefficient of determination (R^2) of 0.8483. The lack-of-fit was significant for volume analysis of cakes ($p<0.01$).

Effect of sugar and carob flour on the volume of the cakes is shown in Figure 3.17. The volume of cakes varied from 64.30 to 84.47 cm^3. As it can be seen from Figure 3.17, increase in carob flour and decrease in sugar lead to lower volume like VI and TVI. The model (Eq. 3.1) obtained for predicting the volume of 20 types of cake explained the main linear effects of factors affecting the volume. Also, it seems that sugar and carob flour effected volume and the model was found significant statistically ($p<0.05$).

At low carob flour ratio, the increase in sugar resulted in decrease in volume of the cakes. However, at high B ratio, the increase in sugar caused sharp increase in volume. At low sugar ratio, the increase in carob flour ratio led to decrease in volume significantly ($p<0.01$). This may be because of the amount of dietary fibers present in carob flour. Dietary fibers have high water absorption capacity so amount of water required for form of gluten is not presented. Because of this, gas bubbles formed in the fermentation stage has not been retained. Therefore, low volume of cakes are produced (Romano et al., 2008). Whereas at high sugar ratio, the increase in carob flour ratio led to sharp increase in volume significantly ($p<0.01$). Sugar effects the volume of cakes significantly due to increasing the gelatinization temperature of the starch to expand the dough with the aid of carbon dioxide and water vapor (Kim and Walker, 1992b). According to Figure 3.17, sugar and carob flour both had effect on volume of the cakes. The increase in sugar and carob flour caused sharp increase in volume of 20 types of cakes significantly ($p<0.01$).

$$\text{Volume} = 75.58 - 5.50*B + 10.21*A*B + 6.61*A*C - 1.90*A^2 + 4.22*B^2 \quad \text{(eq. 3.1)}$$

Where A is the sugar, B is the carob flour and C is the stevia content.

A positive correlations were found between the volume and TVI at $R^2 = 0.8335$ however there was no relationship according to correlations of volume and VI at $R^2 = 0.4237$. It may be due to the calculation method of VI, there were 3 points but in calculation of TVI there were 7 points. VI indicated only vertical volume, whereas, TVI indicated both vertical and horizontal volume.

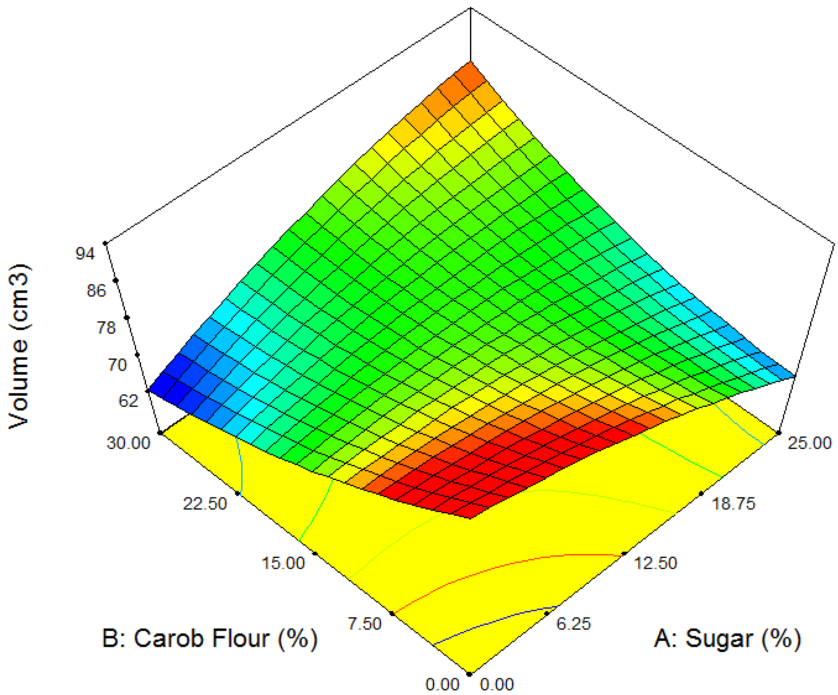

Figure 3.17. Effect of sugar (A) and carob flour (B) on the volume of the cakes

3.5.6. Sensory Analysis

Sensory analysis is an important criteria to determine expectations of cakes consumers. All of the 20 types of cake and control cake samples were in sensory analysis. The sensory analysis was carried out by 10 panellists and the results were averaged. The results were given in Appendix C (Table C8). According to these results, sample number 12 (PC12) got the highest score from the taste and general evaluation features of the samples points of view. Sample 4 (PC4) and 13 (PC13) got the highest score in terms of color and 14 (PC14) in terms of firmness among the cakes. Also, having high hardness, cohesiveness, gumminess and chewiness values makes the P13 difficult to choose for a favourite cake. On the other hand, all these characteristics of cake are acceptable for PC12. This product contained the highest amount of stevia. It is understood from those results that stevia has an important effect on taste and general evaluation in sensory analysis. According to study of Koç (2018) there was no bitter and metalic taste due to stevia in cakes. Appearance properties of cakes produced by stevia had the lowest score. However taste / smell properties had the highest score according to participants in her study. Also, she reported that general evaluation scores of cakes produced by stevia was at the medium level.

Multiple linear regression equations of first and second order polynomial models were generated relating sensory analysis as system parameters to coded levels of variables for 20 types of cake. The regression models allowed the prediction of the effects of independent variables on sensory analysis (Table 3.7). ANOVA was conducted to assess the significant effects of the independent variables on the responses. The responses significantly affected from the varying processing conditions. The significance of coefficient of fitted quadratic model was evaluated by using the F-test, p-value and lack-of-fit.

The modified quadratic model was significant for taste and general evaluation ($p<0.01$), whereas, it was not significant for color and firmness ($p>0.05$). Due to this the model was used in taste and general evaluation only. The regression models allowed the prediction of the effects of independent variables on sensory analysis. Regression analysis indicated that the fitted model had coefficient of determination (R^2) of 0.9600 and 0.9423 for taste and general evaluation (Table 3.7), respectively. The lack-of-fit was not significant for taste and general evaluation ($p>0.05$). However it was significant for color ($p<0.05$) and firmness ($p<0.01$). The 3-D figures of models of color and firmness were given in Appendix D (Figure D7 and Figure D8). A negative coefficient means a decrease in response when the level of the variable (sugar, carob flour and stevia) is increased. A positive coefficient indicates an increase in response. The interactions suggest that the level of one of the interactive variables may increase while that of the other may decrease for a constant value of the response.

Table 3.7. Regression equations in terms of coded factors and coefficient of determinations for sensory analysis

Sensory analysis	Equation in terms of coded factors	R^2
Taste	$4.35 + 0.60*A + 0.35*B + 0.97*C - 0.56*A*C – 0.70*B*C - 0.45*A^2 - 0.95*B^2 - 0.56*C^2$	0.9600
General Evaluation	$4.31 + 0.19*A + 1.02*C - 0.98*A*C - 0.37*B^2 - 0.41*C^2$	0.9423

Where A is the sugar, B is the carob flour and C is the stevia content.

Effect of sugar and stevia on the taste of the 20 types of cake is shown in Figure 3.18. The average of taste scores of cakes varied from 2.2 to 4.9. As it can be seen from Figure 3.18, decrease in sugar and stevia caused lower taste score. As shown in equation (Table 3.7), the model obtained for predicting the taste of 20 types of cakes explained the main linear effects of factors affecting the taste. Also, it seems that sugar and stevia effected taste, the model is significant statistically ($p<0.01$). The lowest taste score of cakes was obtained at the minimum sugar and stevia ratios.

At low stevia ratio, the increase in sugar resulted in a sharp increase in taste. However, at high stevia ratio, the increase in sugar (until 12.5 % ratio) first led to increase in taste but then it decreased (after 12.5 % ratio of sugar) significantly ($p<0.01$). At low sugar ratio, the increase in stevia ratio led to sharp increase in taste. On the other hand, at high sugar ratio, the increase in stevia ratio slightly effected taste.

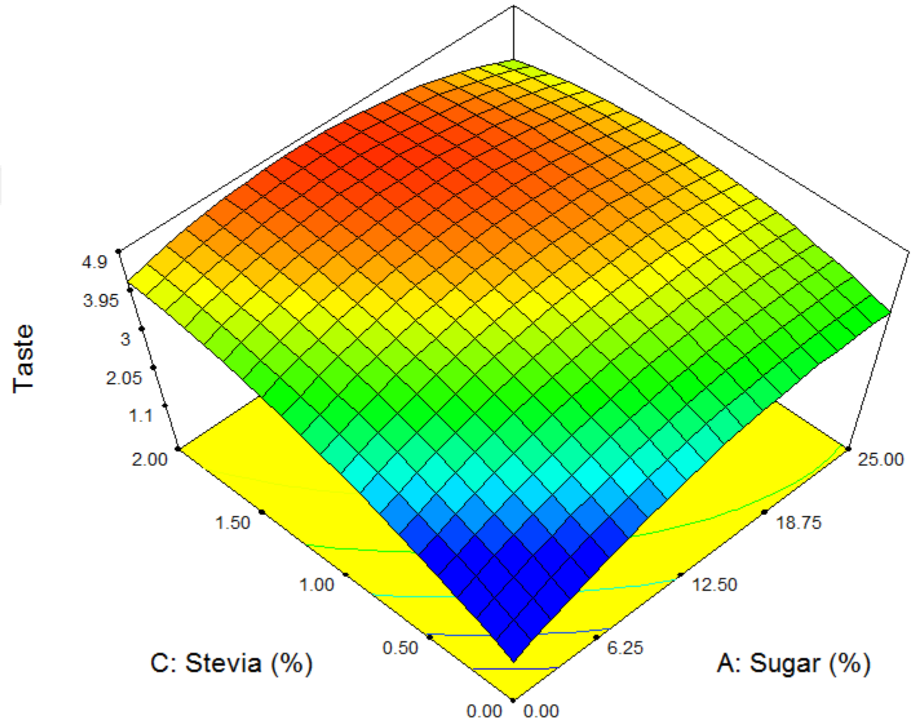

Figure 3.18. Effect of sugar (A) and stevia (C) on the taste of the cakes

Effect of sugar and stevia on the general evaluation of the 20 types of cake is shown in Figure 3.19. The general evaluation average scores of cakes varied from 3.0 to 4.9. As it can be drawn from Figure 3.19, decrease in sugar and stevia resulted in lower general evaluation score. As shown in equation (Table 3.7), the model obtained for predicting the general evaluation of 20 types of cakes explained the main linear effects of factors affecting the general evaluation. The model is significant statistically ($p<0.01$). Also, it seems that sugar and stevia effected general evaluation scores of cakes. The lowest general evaluation of cakes was obtained at the minimum sugar and stevia ratios.

At low stevia ratio, the increase in sugar resulted in a sharp increase in general evaluation. On the other hand, at high stevia ratio, the increase in sugar led to decrease in general evaluation significantly ($p<0.01$). At low sugar ratio, the increase in stevia ratio led to sharp increase in general evaluation scores. However, at high sugar ratio, the increase in stevia ratio led to decrease in general evaluation significantly ($p<0.01$).

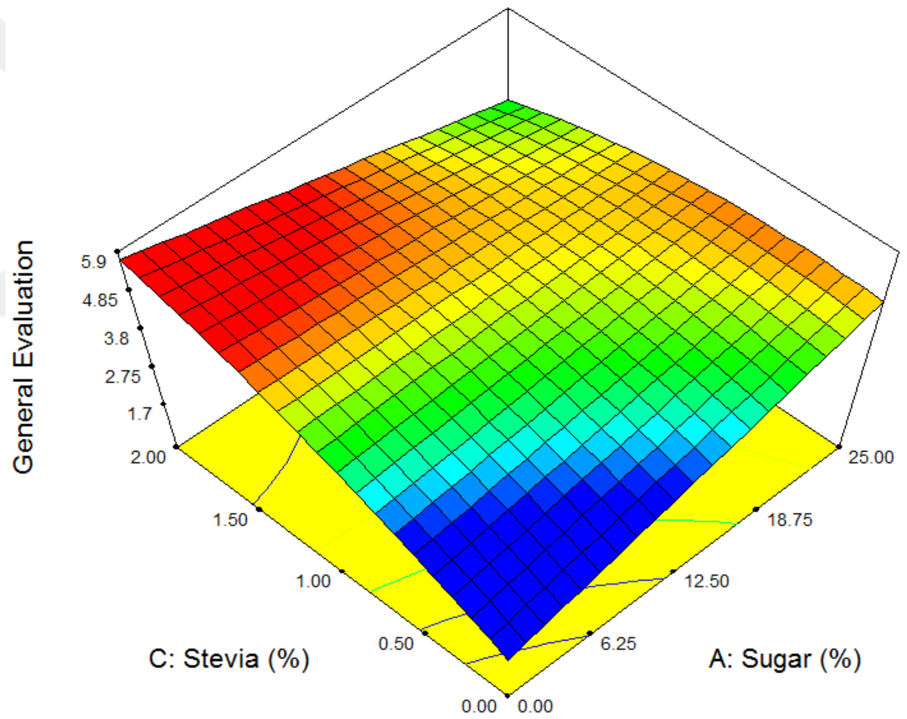

Figure 3.19. Effect of sugar (A) and stevia (C) on the general evaluation of the cakes

3.6. Optimization

Optimization can be defined as the processing conditions that give the optimum (maximum or minimum) value of a function of certain decided variables subject to constraints that are imposed. Optimization may be the process maximizing a desired quantity or minimizing an undesired one. The values of the processing variables that produce the desired optimum value are called optimum conditions (Altan et al., 2008; Horuz, 2011). According to literature a good cake described by the following properties; high volume, light circular camber, uniform structure, soft-moist spongy texturing and low shrinkage values, easily be chewed, not sticking to the hand and palate and has a delicious taste and aroma (Stinson, 1986). The uniformity index value of a good cake should be close to zero or zero (Bath et al., 1992). There is a close relationship between cohesivity and easy consumption in foods. Foods that have high cohesiveness are difficult to detect and break in the mouth. For this reason, too high cohesiveness values are undesirable but it varies according to the type of food (Park et al. 2012).

The process variables were optimized by using Design-Expert (version 7.0.3, Statease Inc., Minneapolis, MN, USA) to obtain the best cake among 20 types of cake produced from experimental design study and 8 types of cake enriched with wheat germ. For the structural analysis; volume, symmetry and total volume indices values were not included in the optimization because they did not show the exact value. They were used to predict the other values such as volume of the cakes. Uniformity index was desired to be zero so it was set as zero. Also, sub and top shrinkage values were desired to be minimum. So that, they were set at minimum as structural analysis for the optimization of the cakes. The parameters of textural analysis for the optimization of cakes were minimum for hardness, cohesiveness, gumminess, chewiness and resilience, but maximum for springiness. Color determination (inside and surface Hunter L*, a*, b* values), pore number and pore sizes (bottom, middle and top) analysis results were not used for the parameters of the optimization. Moreover, volume of the cakes desired to be maximum in the optimization. Taste and general evaluation values were used but color and firmness values were not used in the optimization. Because of insignificant ($p>0.05$) model for color determination (inside and surface Hunter a* value), pore number and pore sizes (bottom, middle and top) and sensory analysis (color and firmness) were not used in the optimization. To determine the optimum conditions of the cakes, response surface of desirability function was used for numerical optimization.

3.6.1. Optimization of 20 Types of Cake

Optimization ranges were sugar concentration (0-25 %), carob flour concentration (0-30 %) and stevia concentration (0-2 %) for 20 types of cake. The parameters for the optimization were chosen and the desirability for the 20 types of cake is given in Figure 3.20 and the 3-D graph is given in Figure 3.21. According to the optimization the highest desirability of the cakes was 0.747. This corresponds to 12.55 % sugar, 15.38 % carob flour and 2.00 % stevia (stevia is an actual factor for desirability) for the best cake. According to optimization the best cake was Product Code 12 (PC12) among 20 types of cake. It had the responses 1 mm UI, 0 mm SSV and 14 mm TSV for structural properties. Also, it had the values 1475 hardness, 0.933 springiness, 0.439 cohesiveness, 648 gumminess, 605 chewiness and 0.145 resilience for textural properties. Moreover, it had the values for 78.54 cm^3 volume. Taste and general evaluation averages were 4.9 for sensory properties of the best cake (PC12). The photo of the PC12 was given in Appendix A (Figure A3).

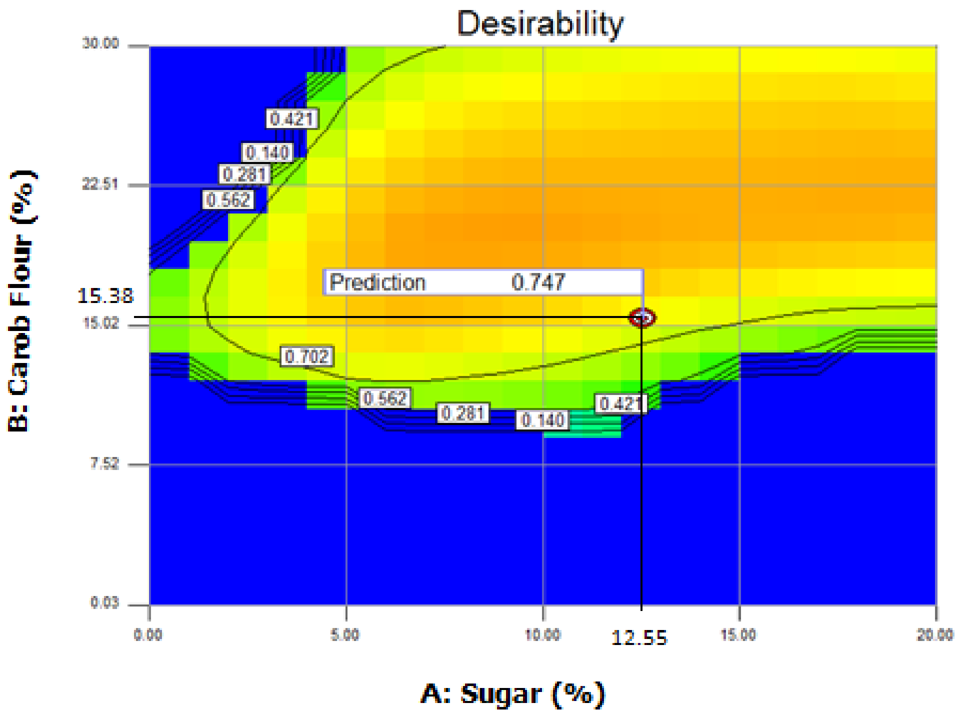

Figure 3.20. The desirability for the 20 types of cake

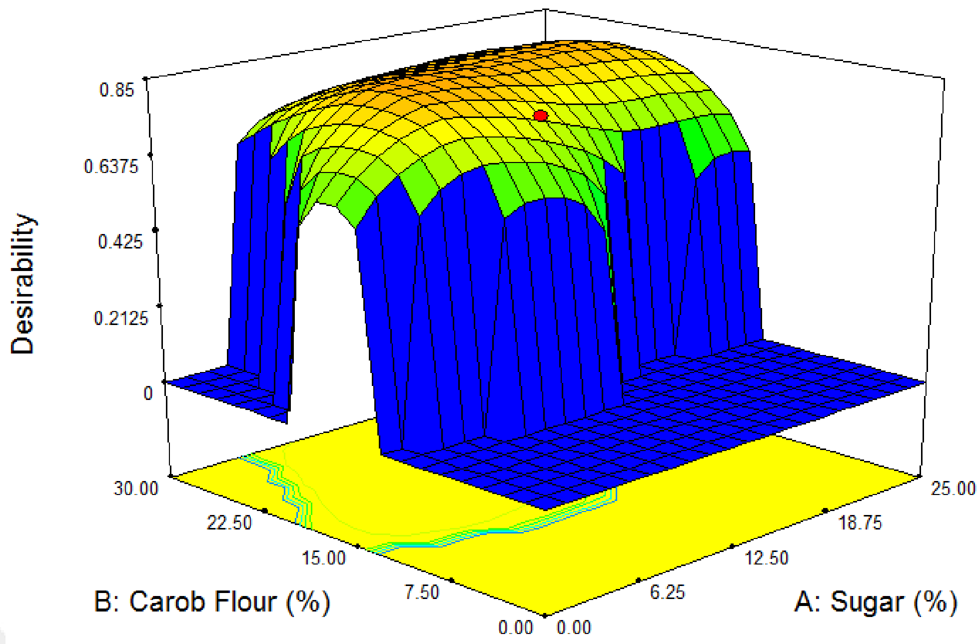

Figure 3.21. The 3-D graph of desirability for the 20 types of cake

3.6.2. Optimization of 8 Types of Cake (Cakes Enriched with Wheat Germ)

In this part of study, the cake that was obtained at optimum process variables (PC12) in the previous study dicussed above was used to enrich with wheat germ. The wheat germ was replaced with wheat flour in different amounts and 8 different cakes were produced. Among these cakes, the best cake formulation was optimized according to the same parameters of optimization decided for 20 types of cake. The analysis results of 8 types of cake were given in Appendix E. Optimization ranges were wheat flour (0-100 %) and wheat germ (0-10 %) for 8 types of cake. The parameters of optimization were UI (set as zero), SSV and TSV (minimum), hardness, cohesiveness, gumminess, chewiness and resilience (minimum) and springiness (maximum), volume (maximum), taste and general evaluation (maximum). The desirability for the 8 types of cake is given in Figure 3.22 and the 3-D graph is given in Figure 3.23.

According to the optimization the highest desirability of the cakes was obtained as 0.729. At this optimum point the composition of wheat flour is 95 % and wheat germ 5 %. According to optimization the best cake was cake number 5 (CC5) among 8 types of cake. It had the values for 0 mm UI and SSV and 12 mm TSV for structural properties. Also, it had the values for 1813 hardness, 0.985 springiness, 0.376

cohesiveness, 682 gumminess, 671 chewiness and 0.113 resilience for textural properties. Moreover, it had the values for 74.08 cm^3 volume. Taste and general evaluation score averages were 5.6 and 5.7, respectively for sensory properties of the best cake (CC5). The photo of the CC5 was given in Appendix A (Figure A5).

Enrichment with wheat germ led to increase some properties of cakes such as UI value got zero. TSV, cohesiveness and resilience were decreased that they were wanted to be minimum. Also, addition of wheat germ led to increase springiness of cakes that it was desired as maximum for cakes. Moreover, it effected the sensorial properties that both taste and general evaluation were increased. On the other hand, addition of wheat germ had negative effect for cakes such as increasing of hardness, gumminess and chewiness that they wanted to be minimum for cakes. Also, it decreased the volume of cakes that it was unwanted situation. Besides all of them, the addition of wheat germ had no effect on SSV.

Pomeranz et al. (1970a) studied that wheat germ can be used in bread, macaroni, biscuits and cakes for enrichment. They reported that after eliminating the negative effect of wheat germ, it can be used until 20 % ratio in products. Also, Shurpalerkar et al. (1977) defined the usage of wheat germ in bread, biscuits and cakes until 15 % ratio without any doubt. Moreover, Rao et al. (1980) reported that wheat germ was added until 20 % ratio in biscuits to obtain good quality. In the present study, lower limits of wheat germ (5 %) was gave the preferable cake from the mechanical and sensorial analyses points of view.

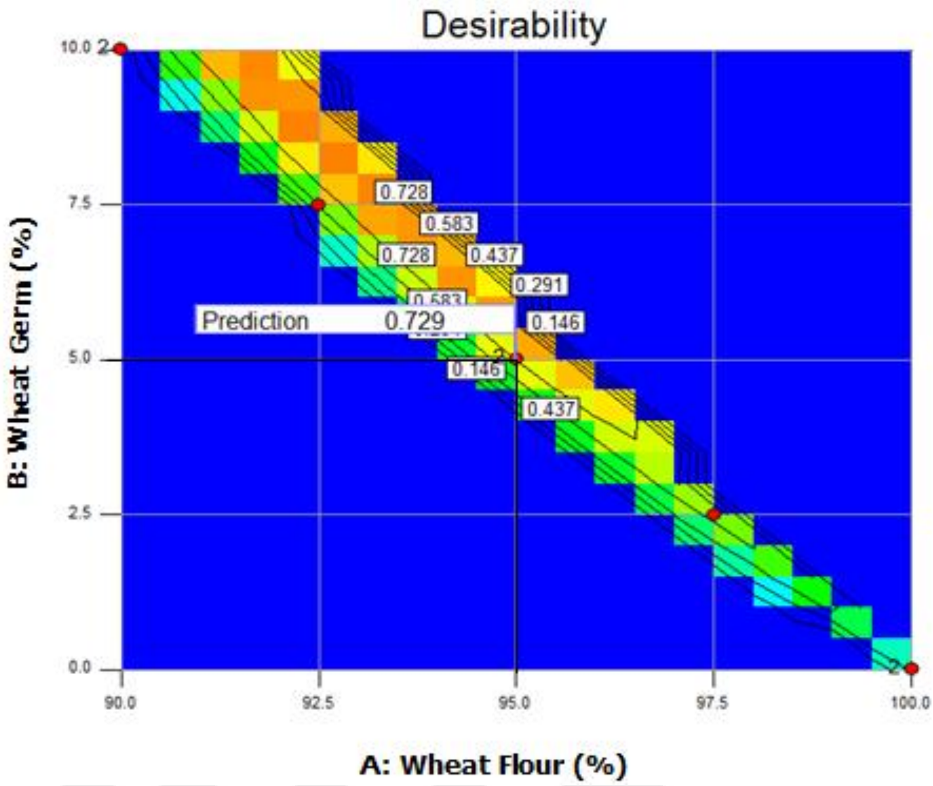

Figure 3.22. The desirability for the 8 types of cake

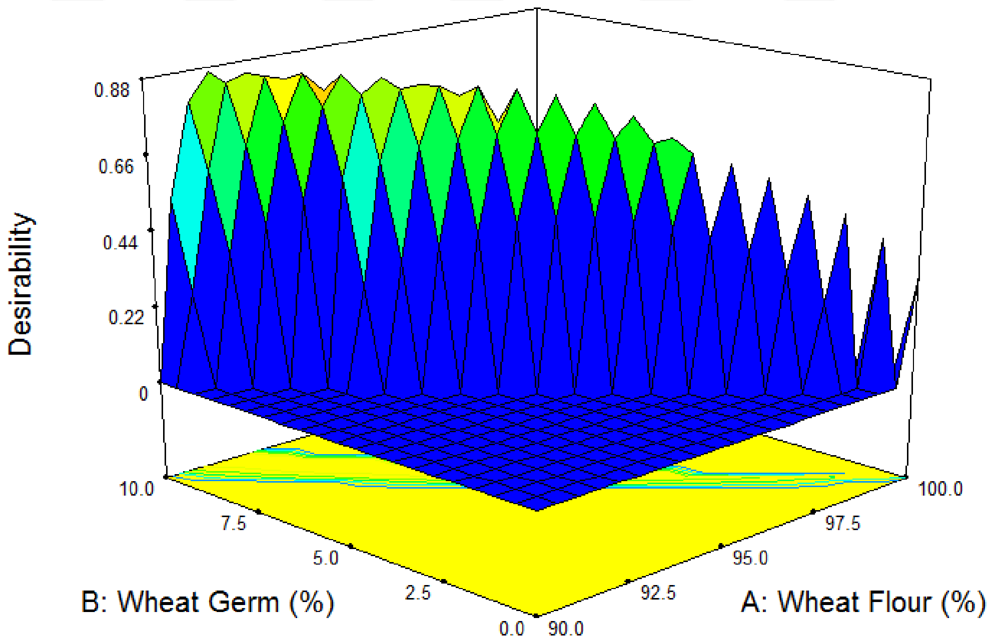

Figure 3.23. The 3-D graph of desirability for the 8 types of cake

3.7. Cake Dough Prepared with Wheat Flour and Wheat Germ

3.7.1. Bulk Density

The bulk densities of cake dough, which were prepared with wheat flour and wheat germ, were calculated as 1.03 to 1.06 g/ml. The results were given in Appendix E (Table E2). CC7 had the minimum and CC1 had the maximum bulk density of dough. The results were very close to each other. It was concluded in the study of Giritlioğlu (2017) that the type of flour was effective slightly on the density of the dough, while the sweetener type was more effective.

3.7.2. Resistance and Elasticity Analysis

The resistance and elasticity analysis results for dough which was prepared with wheat flour and wheat germ were given in Appendix E (Table E3).

The water absorptions of the dough decreased in this study. Increasing the amount of wheat germ decreased the resistance but it did not affect the elasticity according to Avcıoğlu (2014). However, increasing wheat germ content decreased the resistance of dough in the current study but increased the elasticity randomly. The results were different from Moss et al. (1984) and Avcıoğlu (2014) studies.

Kahveci and Özkaya (1990) reported in their study that the effect of wheat germ on the extensibility of dough varied according to flour type and this difference did not show a regular change depending on the rate of wheat germ involved. Sümbül and Tanju (1982) reported that extensibility increased when adding crude germ into flour. It was reported that wheat germ without fat decreased the extensibility of dough in a study of Mostafa (1982). It was seen that there was a non-regular change in the extensibility of dough in the current study.

CHAPTER IV
CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

In this thesis, the use of carob flour and stevia as sugar substitutes for the cake production and enrichment with wheat germ was studied. In the first part of the study, carob flour and stevia were used instead of sugar in production of cakes. Process variables were sugar (0-25 %), stevia concentration (0-2 %) and carob flour concentrations (0-30 %) in constant amount of wheat flour. From these variables, 20 different cakes were produced. The best cake formulation was decided from optimization and it was PC12 among these cakes. It has sugar (12.55 %), stevia concentration (2 %) and carob flour concentrations (15.38 %) ratios. In optimization process, UI was set as zero. SSV, TSV, hardness, cohesiveness, gumminess, chewiness and resilience were minimum; springiness, volume, taste and general evaluation values were set as maximum. For the best cake; UI, SSV and TSV were determined as 1, 0 and 14 mm, respectively. Hardness, springiness, cohesiveness, gumminess, chewiness and resilience were determined as 1475, 0.933, 0.439, 648, 605 and 0.145, respectively. Volume was 78.54 cm^3. Both taste and general evaluation values were determined as 4.9. In the second part of the study, wheat germ was used to enrich nutritional values of the best cake chosen from the first part. The wheat germ was replaced with wheat flour in different amounts (0-10 %) and 8 different cakes were produced. Among these cakes, the best cake formulation was decided from optimization of the parameters mentioned above and it was CC5. It has wheat germ (5 %) and wheat flour (95 %) ratios. Enrichment with wheat germ increased some properties of cakes such as UI value got zero. TSV, cohesiveness and resilience were decreased. Springiness, taste and general evaluation were increased. On the other hand, addition of wheat germ had negative effect on cakes such as increasing of hardness, gumminess and chewiness. Also, it decreased the volume of cakes. Production of the cake using carob flour, stevia and wheat germ can help obese and diabetic people to consume cake without doubt for their health.

4.2. Recommendations

Carob flour and stevia can be used as sugar substitutes in cakes. Also, carob flour can be used instead of cacao in cakes. However, the mass of stevia in cakes must be selected carefully because of its acceptable daily intake (4 mg/kilogram of body weight). In the cakes to be consume by children, mass of the stevia must be decreased. Wheat germ can be used to enrich nutritional values of cakes but negative effects must be eliminated such as decreasing volume of cakes.

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APPENDICES

APPENDIX A

Figure A1. The photo of dough mixer

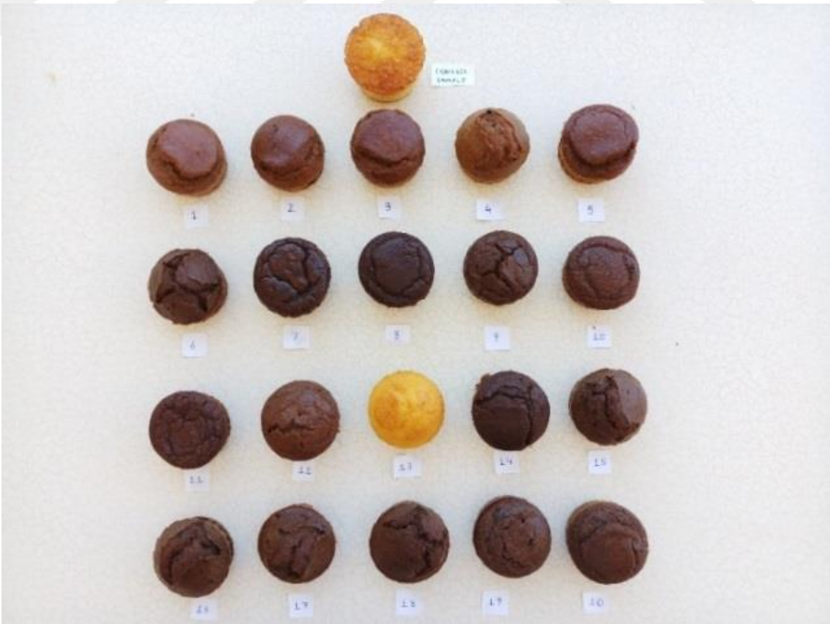

Figure A2. The photo of 20 types of cake

Figure A3. The photo of PC12

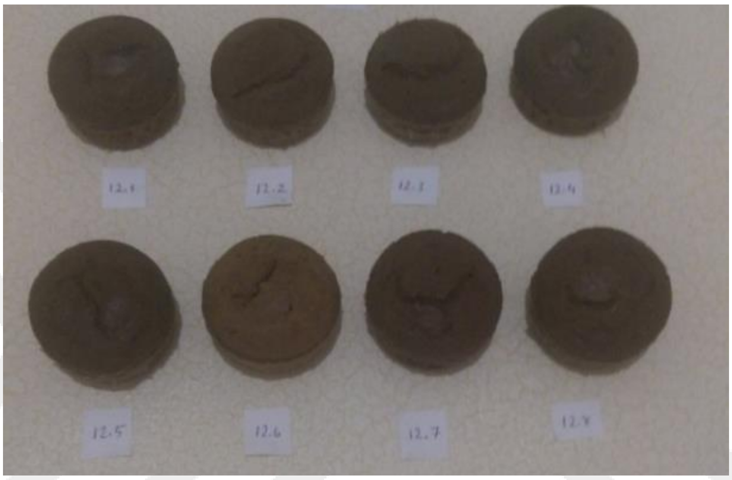

Figure A4. The photo of 8 types of cake

Figure A5. The photo of CC5

APPENDIX B

Table B1. Sensory evaluation form of 20 types of cake

PC	COLOR	TASTE	FIRMNESS	GENERAL EVALUATION
PC1				
PC2				
PC3				
PC4				
PC5				
PC6				
PC7				
PC8				
PC9				
PC10				
PC11				
PC12				
PC13				
PC14				
PC15				
PC16				
PC17				
PC18				
PC19				
PC20				

Type the hedonic rating that best describes your feelings about the product.	
7: I really like **6**: Moderately like **5**: little like **4**: Both like and unlike **3**: little unlike **2**: Moderately unlike **1**: I really unlike	**COMMENTS**

Table B2. Sensory evaluation form of 8 types of cake

CC	COLOR	TASTE	FIRMNESS	GENERAL EVALUATION
CC1				
CC2				
CC3				
CC4				
CC5				
CC6				
CC7				
CC8				

Type the hedonic rating that best describes your feelings about the product.	
7: I really like **6**: Moderately like **5**: little like **4**: Both like and unlike **3**: little unlike **2**: Moderately unlike **1**: I really unlike	**COMMENTS**

APPENDIX C

Table C1. Bulk density values of cake dough prepared with wheat flour

PC	Bulk Density (g/ml)	PC	Bulk Density (g/ml)
PC1	1.01	PC11	1.08
PC2	1.14	PC12	1.06
PC3	1.02	PC13	1.10
PC4	1.10	PC14	1.07
PC5	1.12	PC15	1.10
PC6	1.13	PC16	1.10
PC7	1.08	PC17	1.10
PC8	1.12	PC18	1.10
PC9	1.04	PC19	1.10
PC10	1.16	PC20	1.10

Table C2. Resistance and elasticity results of cake dough prepared with wheat flour

Analysis	Result
T (mm H_2O)	85.00
A (mm)	80.00
Ex	20.90
Fb (10E-4J)	227.00
T/A	1.06
Iec (%)	50.90
HYD2200 (%b 15)	53.40

Table C3. Structural analysis results of 20 types of cake

PC	VI* (mm)	SI* (mm)	UI* (mm)	SSV* (mm)	TSV* (mm)	TVI* (mm)
PC1	118	1	-3	0	13	295
PC2	99	1	-2	0	13	255
PC3	123	5	0	0	17	284
PC4	123	7	2	0	17	275
PC5	105	5	1	2	17	263
PC6	122	5	-2	2	17	274
PC7	105	0	0	2	13	268
PC8	117	0	0	1	13	273
PC9	112	3	-2	1	15	276
PC10	114	4	-1	1	15	262
PC11	101	-1	-1	1	15	258
PC12	111	6	1	0	14	296
PC13	124	6	1	0	14	276
PC14	122	4	2	2	14	297
PC15	121	5	0	1	14	276
PC16	126	5	0	1	14	282
PC17	122	5	0	1	14	265
PC18	124	6	0	1	14	292
PC19	123	6	0	1	14	275
PC20	125	5	0	1	14	298

*VI is the volume index (mm), SI is the symmetry index (mm), UI is the uniformidy index (mm), SSV is the sub shrinkage value (mm), TSV is the top shrinkage value (mm) and TVI is the total volume index (mm).

Table C4. Textural analysis results of 20 types of cake

PC	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
PC1	3340	0.887	0.494	1650	1464	0.228
PC2	2420	0.890	0.483	1169	1040	0.241
PC3	3070	0.902	0.525	1612	1454	0.187
PC4	2601	0.900	0.518	1347	1212	0.189
PC5	2647	0.892	0.485	1284	1145	0.187
PC6	3299	0.890	0.493	1626	1447	0.192
PC7	1319	0.907	0.385	508	461	0.133
PC8	2358	0.906	0.397	936	848	0.142
PC9	3102	0.862	0.440	1365	1177	0.166
PC10	3408	0.870	0.442	1506	1310	0.149
PC11	2431	0.907	0.473	1150	1043	0.245
PC12	1475	0.933	0.439	648	605	0.145
PC13	3150	0.909	0.584	1840	1673	0.231
PC14	2495	0.901	0.471	1175	1059	0.164
PC15	3372	0.870	0.467	1575	1370	0.205
PC16	3356	0.868	0.465	1561	1355	0.207
PC17	3340	0.863	0.462	1543	1332	0.201
PC18	3327	0.863	0.464	1544	1332	0.198
PC19	3391	0.874	0.464	1573	1375	0.207
PC20	3373	0.870	0.461	1555	1353	0.204

Table C5. Color values of 20 types of cake

PC	İnside of Cake			Surface of Cake		
	L*	a*	b*	L*	a*	b*
PC1	36.34	8.29	15.01	30.48	25.48	16.81
PC2	35.23	8.54	16.80	28.58	20.58	10.43
PC3	36.18	10.28	17.69	29.17	32.17	11.25
PC4	40.83	7.93	15.78	37.59	27.59	16.06
PC5	32.91	8.79	11.34	28.26	28.26	9.53
PC6	29.29	7.79	10.86	23.10	23.10	5.98
PC7	22.74	7.31	10.08	18.83	18.83	6.11
PC8	23.52	8.06	10.59	21.73	21.73	8.21
PC9	21.24	9.57	13.14	24.45	24.45	6.02
PC10	26.08	8.30	10.22	25.55	35.55	5.50
PC11	21.57	10.83	12.14	22.16	28.16	4.17
PC12	20.22	11.26	12.29	21.17	21.17	6.92
PC13	76.05	4.02	28.97	58.29	38.29	31.45
PC14	36.92	4.56	16.80	20.47	20.47	16.92
PC15	30.47	7.68	10.35	25.55	28.55	6.25
PC16	30.36	8.31	12.06	25.38	25.38	6.51
PC17	30.43	8.60	12.19	25.76	26.76	5.94
PC18	30.41	8.57	12.43	25.57	27.57	5.68
PC19	30.43	7.65	10.92	25.77	25.77	5.18
PC20	30.42	8.26	11.63	25.23	25.23	5.14

Table C6. Pore number and pore sizes results of 20 types of cake

PC	Pore Number	Pore Sizes (mm)			PC	Pore Number	Pore Sizes (mm)		
		Bottom	Middle	Top			Bottom	Middle	Top
PC1	6	2	10	4	PC11	11	2	6	2
PC2	11	5	8	5	PC12	13	3	2	1
PC3	13	1	1	4	PC13	11	1	7	8
PC4	13	3	9	5	PC14	10	2	2	11
PC5	10	1	4	7	PC15	15	9	11	9
PC6	15	4	4	6	PC16	14	10	9	9
PC7	9	2	2	4	PC17	14	9	10	8
PC8	9	3	6	5	PC18	14	9	8	8
PC9	9	3	5	3	PC19	14	10	10	9
PC10	14	6	8	5	PC20	15	10	10	8

Table C7. Volume of 20 types of cake

PC	Volume (cm^3)	PC	Volume (cm^3)
PC1	81.69	PC11	73.09
PC2	68.71	PC12	78.54
PC3	78.07	PC13	84.47
PC4	76.69	PC14	78.88
PC5	70.15	PC15	76.60
PC6	75.06	PC16	75.71
PC7	64.30	PC17	77.21
PC8	81.22	PC18	75.03
PC9	75.12	PC19	76.60
PC10	71.28	PC20	76.60

Table C8. Sensory analysis of 20 types of cake

PC	Color	Taste	Firmness	General Evaluation	PC	Color	Taste	Firmness	General Evaluation
PC1	4.4	2.2	3.6	3.2	PC11	4.7	3.0	5.1	3.0
PC2	4.5	3.3	3.7	4.3	PC12	5.1	4.9	4.9	4.9
PC3	4.3	4.1	4.1	4.7	PC13	5.7	3.2	5.6	4.0
PC4	5.7	4.2	4.1	4.2	PC14	4.4	4.0	5.7	4.0
PC5	4.8	3.0	5.2	3.0	PC15	4.6	4.2	4.7	4.2
PC6	4.9	4.3	5.4	4.3	PC16	4.6	4.5	5.1	4.5
PC7	4.9	3.9	5.6	4.8	PC17	4.6	4.6	5.2	4.6
PC8	4.7	4.2	5.3	4.2	PC18	4.6	4.7	5.1	4.4
PC9	4.7	3.5	5.2	4.0	PC19	4.2	4.5	4.8	4.5
PC10	4.7	4.1	5.0	4.4	PC20	4.4	4.3	5.2	4.3

APPENDIX D

Table D1. ANOVA for response surface reduced quadratic model for volume index of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	1259.02	7	179.86	17.76	< 0.0001
Sugar (A) (%)	110.10	1	110.10	10.87	0.0064
Carob flour (B) (%)	125.05	1	125.05	12.35	0.0043
Stevia (C) (%)	122.08	1	122.08	12.05	0.0046
AB	287.98	1	287.98	28.44	0.0002
BC	144.50	1	183.96	14.27	0.0026
A^2	183.96	1	183.96	18.16	0.0011
C^2	532.70	1	532.70	52.60	< 0.0001
Lack of Fit	104.03	7	14.86	4.25	0.0653

Table D2. ANOVA for response surface reduced quadratic model for symmetry index of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	114.33	6	19.05	100.27	< 0.0001
Sugar (A) (%)	7.57	1	7.57	39.82	< 0.0001
Carob flour (B) (%)	2.93	1	2.93	15.41	0.0017
AC	1.17	1	1.17	6.14	0.0277
BC	55.13	1	55.13	290.10	< 0.0001
A^2	5.06	1	5.06	26.61	0.0002
C^2	48.98	1	48.98	257.73	< 0.0001
Lack of Fit	1.14	8	0.14	0.53	0.7956

Table D3. ANOVA for response surface reduced quadratic model for uniformity index of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	30.83	8	3.85	17.88	< 0.0001
Sugar (A) (%)	2.92	1	2.92	13.54	0.0036
Carob flour (B) (%)	3.28	1	3.28	15.20	0.0025
Stevia (C) (%)	5.00	1	5.00	23.22	0.0005
AB	4.50	1	4.50	20.88	0.0008
AC	2.00	1	2.00	9.28	0.0111
BC	4.50	1	4.50	20.89	0.0008
A^2	5.82	1	5.82	27.01	0.0003
B^2	2.71	1	2.71	12.57	0.0046
Lack of Fit	2.37	6	0.40	3.26	0.0879

Table D4. ANOVA for response surface reduced quadratic model for sub shrinkage value of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	9.48	3	3.16	66.80	< 0.0001
Carob flour (B) (%)	8.62	1	8.62	182.40	< 0.0001
Stevia (C) (%)	0.56	1	0.56	11.87	0.0033
C^2	0.30	1	0.30	6.41	0.0222
Lack of Fit	0.76	11	0.069	59331.73	< 0.0001

Table D5. ANOVA for response surface reduced quadratic model for top shrinkage value of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	35.63	4	8.91	101.40	< 0.0001
Sugar (A) (%)	0.86	1	0.86	9.84	0.0068
BC	32.00	1	32.00	364.29	< 0.0001
A^2	2.85	1	2.85	32.48	< 0.0001
C^2	1.04	1	1.04	11.89	0.0036
Lack of Fit	1.32	10	0.13	2.18	0.2026

Table D6. ANOVA for response surface reduced quadratic model for total volume index of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	921.77	6	153.63	28.22	< 0.0001
Carob flour (B) (%)	284.63	1	284.63	52.27	< 0.0001
AB	406.07	1	406.07	74.58	< 0.0001
AC	135.37	1	135.37	24.86	0.0002
A^2	28.08	1	28.08	5.16	0.0408
B^2	111.84	1	111.84	20.54	0.0006
C^2	118.36	1	118.36	21.74	0.0004
Lack of Fit	45.28	8	5.66	1.11	0.4758

Table D7. ANOVA for response surface reduced quadratic model for hardness of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	$75.66*10^5$	9	$84.07*10^4$	599.89	< 0.0001
Sugar (A) (%)	64696.81	1	64696.81	46.17	< 0.0001
Carob flour (B) (%)	$13.98*10^5$	1	$13.98*10^5$	997.66	< 0.0001
Stevia (C) (%)	$12.12*10^5$	1	$12.12*10^5$	864.52	< 0.0001
AB	$11.86*10^5$	1	$11.86*10^5$	846.23	< 0.0001
AC	87780.50	1	87780.50	62.64	< 0.0001
BC	$59.40*10^4$	1	$59.40*10^4$	423.91	< 0.0001
A^2	16173.68	1	16173.68	11.54	< 0.0001
B^2	$52.94*10^4$	1	$52.94*10^4$	377.80	< 0.0001
C^2	$35.47*10^5$	1	$35.47*10^5$	2531.10	< 0.0001
Lack of Fit	11234.72	5	2246.94	4.04	0.0757

Table D8. ANOVA for response surface reduced quadratic model for springiness of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	$73.03*10^{-4}$	3	$24.34*10^{-4}$	165.19	< 0.0001
Stevia (C) (%)	$72.79*10^{-5}$	1	$72.79*10^{-5}$	49.39	< 0.0001
B^2	$23.59*10^{-4}$	1	$23.59*10^{-4}$	160.09	< 0.0001
C^2	$46.95*10^{-4}$	1	$46.95*10^{-4}$	318.57	< 0.0001
Lack of Fit	$14.18*10^{-5}$	11	$12.89*10^{-6}$	0.69	0.7209

Table D9. ANOVA for response surface reduced quadratic model for cohesiveness of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	0.035	8	$43.86*10^{-4}$	255.27	< 0.0001
Sugar (A) (%)	$38.82*10^{-5}$	1	$38.82*10^{-5}$	22.59	0.0006
Carob flour (B) (%)	0.013	1	0.013	759.59	< 0.0001
Stevia (C) (%)	$25.68*10^{-4}$	1	$25.68*10^{-4}$	149.45	< 0.0001
AB	$18.05*10^{-5}$	1	$18.05*10^{-5}$	10.51	0.0079
BC	$25.68*10^{-4}$	1	$25.68*10^{-4}$	499.36	< 0.0001
A^2	$11.22*10^{-4}$	1	$11.22*10^{-4}$	65.27	< 0.0001
B^2	$66.63*10^{-4}$	1	$66.63*10^{-4}$	387.82	< 0.0001
C^2	$17.90*10^{-5}$	1	$17.90*10^{-5}$	10.42	0.0080
Lack of Fit	$16.62*10^{-5}$	6	$27.69*10^{-6}$	6.06	0.0334

Table D10. ANOVA for response surface reduced quadratic model for gumminess of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	$22.25*10^5$	8	$27.81*10^4$	191.65	< 0.0001
Sugar (A) (%)	20254.07	1	20254.07	13.96	0.0033
Carob flour (B) (%)	$71.38*10^4$	1	$71.38*10^4$	491.91	< 0.0001
Stevia (C) (%)	$33.62*10^4$	1	$33.62*10^4$	231.70	< 0.0001
AB	$28.73*10^4$	1	$28.73*10^4$	197.99	< 0.0001
AC	11400.50	1	11400.50	7.86	0.0172
BC	$32.22*10^4$	1	$32.22*10^4$	222.17	< 0.0001
A^2	22958.62	1	22958.62	15.82	0.0022
C^2	$77.08*10^4$	1	$77.08*10^4$	531.19	< 0.0001
Lack of Fit	15010.88	6	2501.81	13.15	0.0063

Table D11. ANOVA for response surface reduced quadratic model for chewiness of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	$16.60*10^5$	8	$20.76*10^4$	220.61	< 0.0001
Sugar (A) (%)	18157.71	1	18157.71	19.30	0.0011
Carob flour (B) (%)	$58.21*10^4$	1	$58.21*10^4$	618.69	< 0.0001
Stevia (C) (%)	$24.78*10^4$	1	$24.78*10^4$	263.34	< 0.0001
AB	$22.92*10^4$	1	$22.92*10^4$	243.57	< 0.0001
AC	8902.05	1	8902.05	9.46	0.0105
BC	$26.14*10^4$	1	$26.14*10^4$	277.81	< 0.0001
A^2	20369.74	1	20369.74	21.65	0.0007
C^2	$50.51*10^4$	1	$50.51*10^4$	536.89	< 0.0001
Lack of Fit	8693.87	6	1448.98	4.38	0.0633

Table D12. ANOVA for response surface reduced quadratic model for resilience of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	0.020	4	$49.42*10^{-4}$	109.08	< 0.0001
Sugar (A) (%)	$98.08*10^{-5}$	1	$98.08*10^{-5}$	21.65	0.0003
Carob flour (B) (%)	$67.50*10^{-4}$	1	$67.50*10^{-4}$	148.99	< 0.0001
Stevia (C) (%)	$97.56*10^{-4}$	1	$97.56*10^{-4}$	215.36	< 0.0001
A^2	$32.24*10^{-4}$	1	$32.24*10^{-4}$	71.16	< 0.0001
Lack of Fit	$61.62*10^{-5}$	10	$61.62*10^{-6}$	4.86	0.0474

Table D13. ANOVA for response surface reduced quadratic model for inside Hunter L* value of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	1811.94	6	301.99	54.47	< 0.0001
Sugar (A) (%)	50.15	1	50.15	9.05	0.0101
Carob flour (B) (%)	532.62	1	532.62	96.07	< 0.0001
BC	57.14	1	57.14	10.31	0.0068
A^2	84.82	1	84.82	15.30	0.0018
B^2	801.94	1	801.94	144.64	< 0.0001
C^2	167.87	1	167.87	30.28	0.0001
Lack of Fit	72.07	8	72.07	7037.99	< 0.0001

Table D14. ANOVA for response surface reduced quadratic model for inside Hunter a* value of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	8.35	9	0.93	0.90	0.5566
Sugar (A) (%)	0.90	1	0.90	0.88	0.3705
Carob flour (B) (%)	0.13	1	0.13	0.13	0.7252
Stevia (C) (%)	0.12	1	0.12	0.11	0.7425
AB	0.43	1	0.43	0.42	0.5333
AC	0.09	1	0.09	0.09	0.7730
BC	0.84	1	0.84	0.82	0.3877
A^2	0.33	1	0.33	0.32	0.5834
B^2	2.96	1	2.96	2.88	0.1203
C^2	1.98	1	1.98	1.92	0.1956
Lack of Fit	9.40	5	1.88	10.65	0.0107

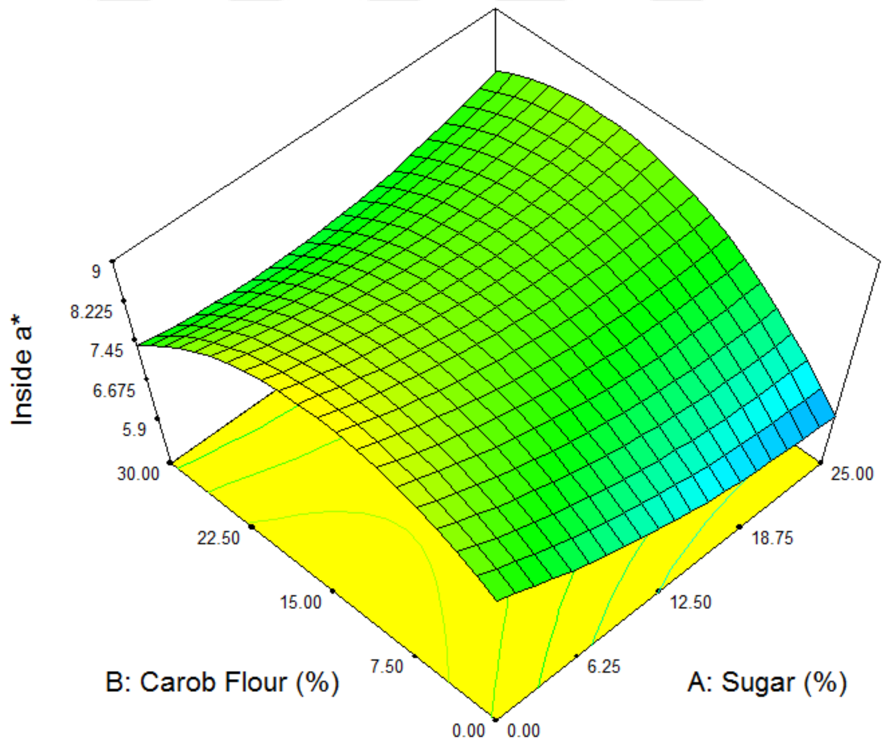

Figure D1. The 3-D graph of inside Hunter a* value for the 20 types of cake

Table D15. ANOVA for response surface reduced quadratic model for inside Hunter b* value of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	320.21	2	160.10	73.85	< 0.0001
Carob flour (B) (%)	124.82	1	124.82	57.57	< 0.0001
B^2	181.07	1	181.07	83.52	< 0.0001
Lack of Fit	33.58	12	2.80	4.27	0.0599

Table D16. ANOVA for response surface reduced quadratic model for surface Hunter L* value of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	736.30	5	147.26	26.11	< 0.0001
Carob flour (B) (%)	454.92	1	454.92	80.65	< 0.0001
AC	29.28	1	29.28	5.19	0.0389
BC	42.79	1	42.79	7.59	0.0155
B^2	146.80	1	146.80	26.02	0.0002
C^2	26.03	1	26.03	4.62	0.0497
Lack of Fit	78.75	9	8.75	195.37	< 0.0001

Table D17. ANOVA for response surface reduced quadratic model for surface Hunter a* value of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	275.59	9	30.62	1.61	0.2345
Sugar (A) (%)	0.24	1	0.24	0.01	0.9127
Carob flour (B) (%)	139.60	1	139.60	7.34	0.0220
Stevia (C) (%)	11.39	1	11.39	0.60	0.4571
AB	6.53	1	6.53	0.34	0.5710
AC	8.78	1	8.78	0.46	0.5125
BC	75.06	1	75.06	3.94	0.0751
A^2	3.68	1	3.68	0.19	0.6696
B^2	1.20	1	1.20	0.06	0.8071
C^2	27.68	1	27.68	1.45	0.2556
Lack of Fit	181.51	5	36.30	20.62	0.0024

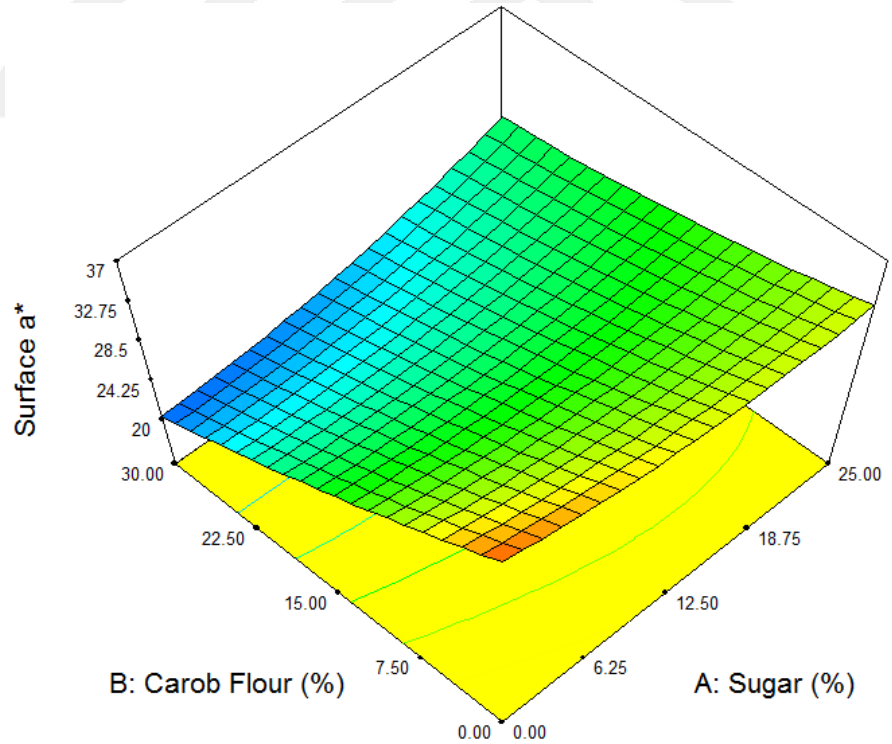

Figure D2. The 3-D graph of surface Hunter a* value for the 20 types of cake

Table D18. ANOVA for response surface reduced quadratic model for surface Hunter b* value of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	779.44	3	259.81	134.18	< 0.0001
Carob flour (B) (%)	156.75	1	156.75	80.95	< 0.0001
AC	33.89	1	33.89	17.50	0.0007
B^2	560.34	1	560.34	289.38	< 0.0001
Lack of Fit	29.42	11	2.67	8.58	0.0140

Table D19. ANOVA for response surface reduced quadratic model for pore number of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	103.02	9	11.45	0.56	0.7992
Sugar (A) (%)	42.89	1	42.89	2.11	0.1769
Carob flour (B) (%)	$21.70*10^{-5}$	1	$21.70*10^{-5}$	$10.68*10^{-6}$	0.9975
Stevia (C) (%)	2.65	1	2.65	0.13	0.7257
AB	1.13	1	1.13	0.06	0.8185
AC	10.13	1	10.13	0.50	0.4964
BC	15.11	1	15.11	0.74	0.4086
A^2	42.45	1	42.45	2.09	0.1789
B^2	21.33	1	21.33	1.05	0.3297
C^2	9.76	1	9.76	0.48	0.5040
Lack of Fit	187.68	5	37.54	12.11	0.0080

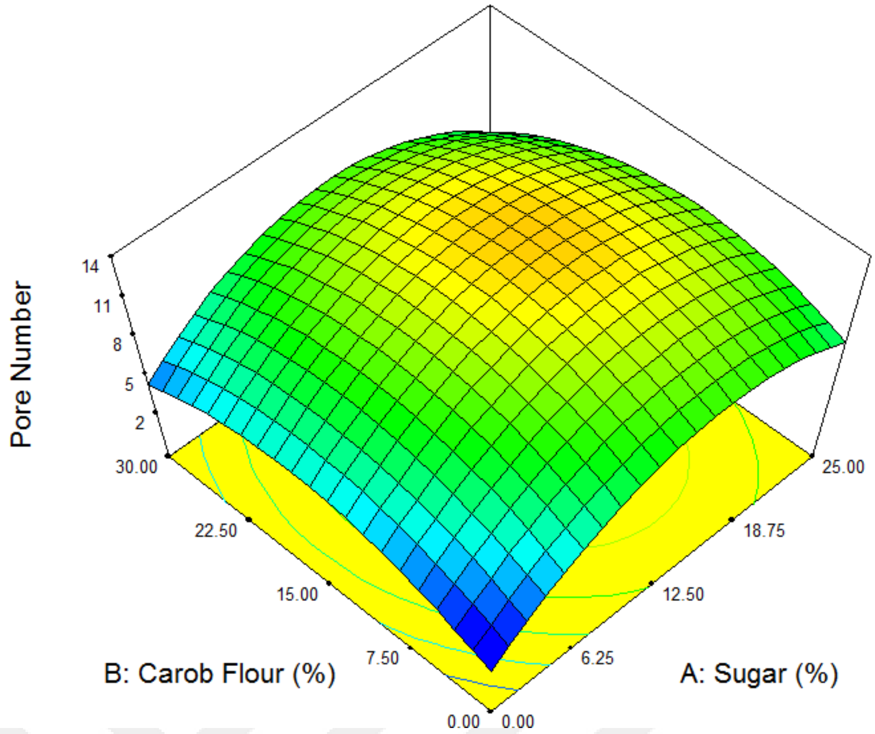

Figure D3. The 3-D graph of pore number for the 20 types of cake

Table D20. ANOVA for response surface reduced quadratic model for bottom size of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	253.53	9	28.17	1.64	0.2249
Sugar (A) (%)	41.66	1	41.66	2.43	0.1501
Carob flour (B) (%)	0.37	1	0.37	0.02	0.8856
Stevia (C) (%)	0.25	1	0.25	0.02	0.9064
AB	0.50	1	0.50	0.03	0.8676
AC	2.00	1	2.00	0.12	0.7397
BC	$44.48*10^{-8}$	1	$44.48*10^{-8}$	$25.95*10^{-9}$	0.9999
A^2	95.64	1	95.64	5.58	0.0398
B^2	112.04	1	112.04	6.54	0.0285
C^2	83.57	1	83.57	4.88	0.0517
Lack of Fit	16.59	5	3.32	0.11	0.9858

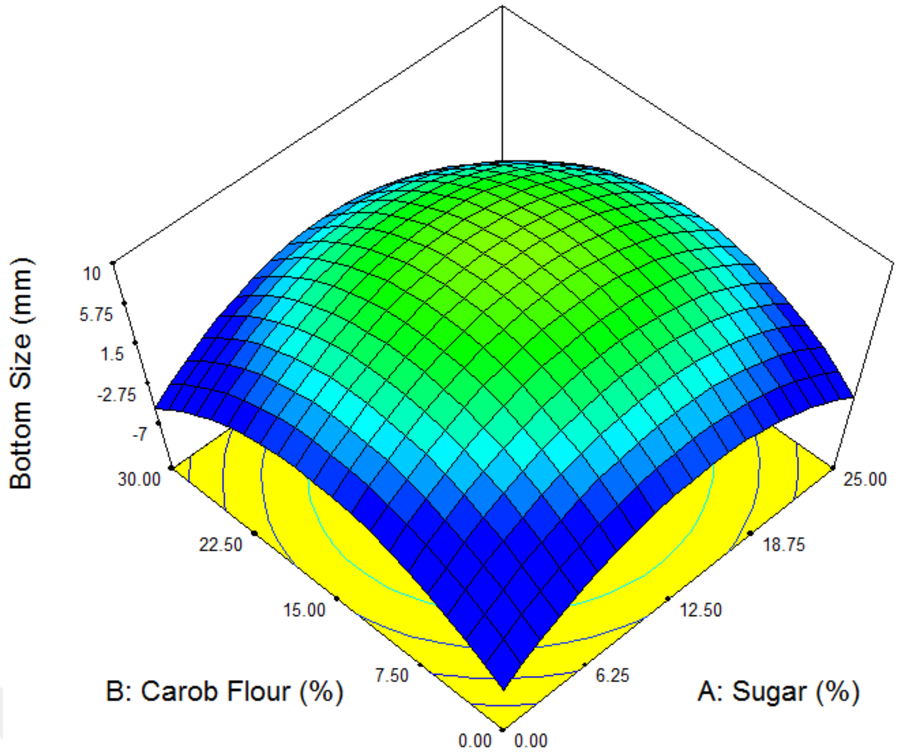

Figure D4. The 3-D graph of bottom size for the 20 types of cake

Table D21. ANOVA for response surface reduced quadratic model for middle size of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	341.04	9	37.89	0.69	0.7031
Sugar (A) (%)	71.21	1	71.21	1.30	0.2801
Carob flour (B) (%)	90.95	1	90.95	1.67	0.2259
Stevia (C) (%)	46.89	1	46.89	0.86	0.3760
AB	2.00	1	2.00	0.04	0.8519
AC	50.00	1	50.00	0.92	0.3612
BC	4.51	1	4.51	0.08	0.7798
A^2	51.83	1	51.83	0.95	0.3530
B^2	47.34	1	47.34	0.87	0.3738
C^2	42.30	1	42.30	0.77	0.3995
Lack of Fit	409.33	5	81.87	2.99	0.1272

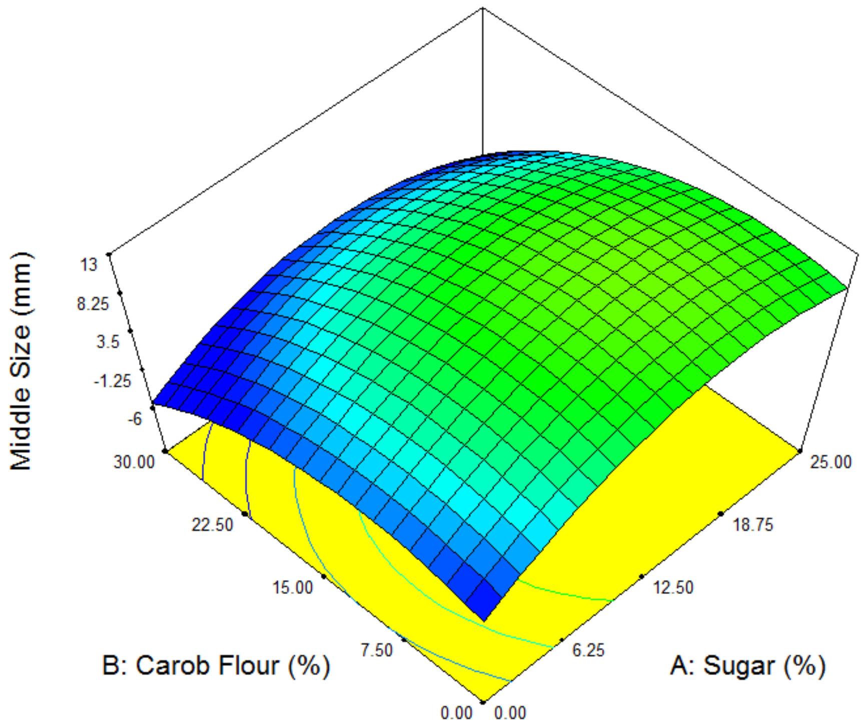

Figure D5. The 3-D graph of middle size for the 20 types of cake

Table D22. ANOVA for response surface reduced quadratic model for top size of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	340.82	9	37.87	1.81	0.1837
Sugar (A) (%)	19.47	1	19.47	0.93	0.3572
Carob flour (B) (%)	33.05	1	33.05	1.58	0.2371
Stevia (C) (%)	21.61	1	21.61	1.03	0.3331
AB	0.13	1	0.13	$60.06*10^{-4}$	0.9398
AC	1.13	1	1.13	0.05	0.8212
BC	1.12	1	1.12	0.05	0.8214
A^2	136.19	1	136.19	6.52	0.0287
B^2	8.44	1	8.44	0.40	0.5393
C^2	136.58	1	136.58	6.54	0.0285
Lack of Fit	113.60	5	22.72	1.19	0.4261

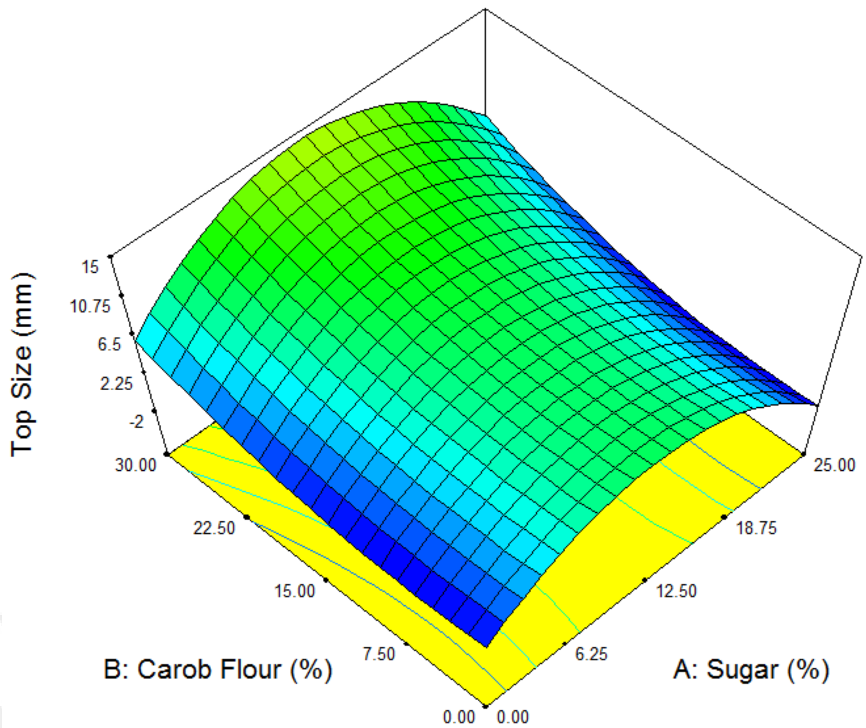

Figure D6. The 3-D graph of top size for the 20 types of cake

Table D23. ANOVA for response surface reduced quadratic model for volume of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	347.69	5	69.54	15.66	< 0.0001
Carob flour (B) (%)	119.88	1	119.88	26.99	0.0001
AB	163.70	1	163.70	36.86	< 0.0001
AC	83.63	1	83.63	18.83	0.0007
A^2	22.93	1	22.93	5.16	0.0394
B^2	30.31	1	30.31	6.82	0.0205
Lack of Fit	59.12	9	6.57	10.74	0.0088

Table D24. ANOVA for response surface reduced quadratic model for color as sensory analysis of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	1.77	9	0.20	1.61	0.2333
Sugar (A) (%)	0.05	1	0.05	0.42	0.5303
Carob flour (B) (%)	0.04	1	0.04	0.28	0.6063
Stevia (C) (%)	0.07	1	0.07	0.60	0.4583
AB	0.32	1	0.32	2.62	0.1367
AC	0.12	1	0.12	1.02	0.3358
BC	0.18	1	0.18	1.47	0.2529
A^2	0.03	1	0.03	0.21	0.6545
B^2	0.42	1	0.42	3.47	0.0920
C^2	0.18	1	0.18	1.49	0.2499
Lack of Fit	1.08	5	0.22	7.73	0.0212

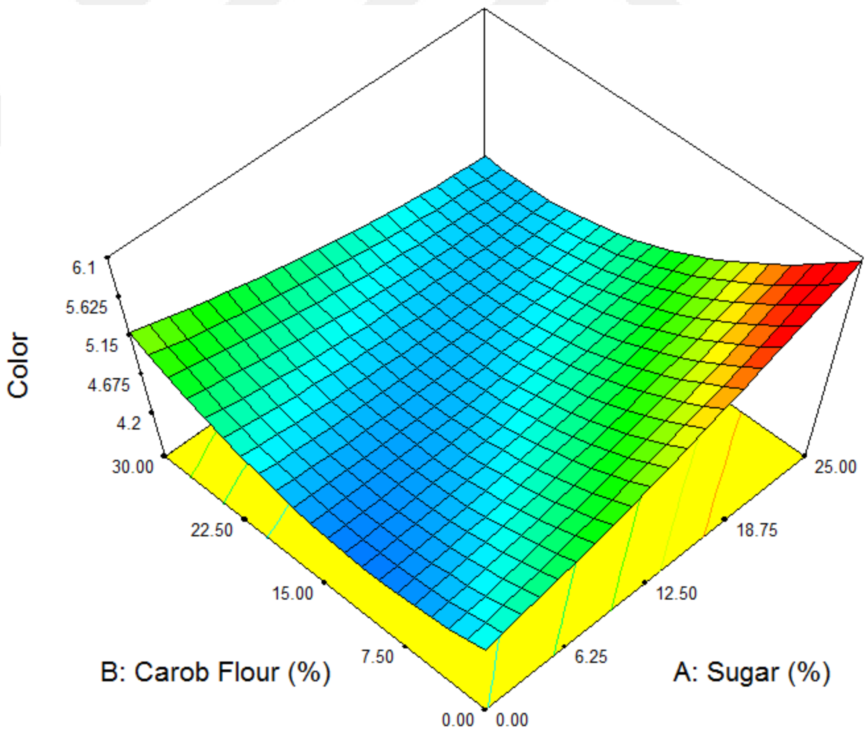

Figure D7. The 3-D graph of color as sensory analysis for the 20 types of cake

Table D25. ANOVA for response surface reduced quadratic model for taste as sensory analysis of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	8.66	8	1.08	33.04	< 0.0001
Sugar (A) (%)	1.93	1	1.93	58.73	< 0.0001
Carob flour (B) (%)	0.57	1	0.57	17.34	0.0016
Stevia (C) (%)	3.87	1	3.87	118.00	< 0.0001
AC	0.50	1	0.50	15.25	0.0025
BC	0.50	1	0.50	15.25	0.0025
A^2	0.91	1	0.91	27.76	0.0003
B^2	1.51	1	1.51	46.12	< 0.0001
C^2	0.58	1	0.58	17.59	0.0015
Lack of Fit	0.19	6	0.03	0.90	0.5572

Table D26. ANOVA for response surface reduced quadratic model for firmness as sensory analysis of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	3.59	9	0.40	1.18	0.3966
Sugar (A) (%)	0.02	1	0.02	0.07	0.8035
Carob flour (B) (%)	2.47	1	2.47	7.32	0.0221
Stevia (C) (%)	0.09	1	0.09	0.27	0.6151
AB	$50.06*10^{-4}$	1	$50.06*10^{-4}$	0.02	0.9055
AC	0.05	1	0.05	0.13	0.7226
BC	0.05	1	0.05	0.13	0.7224
A^2	0.17	1	0.17	0.49	0.4985
B^2	0.15	1	0.15	0.44	0.5205
C^2	0.30	1	0.30	0.90	0.3652
Lack of Fit	3.15	5	0.63	13.78	0.0060

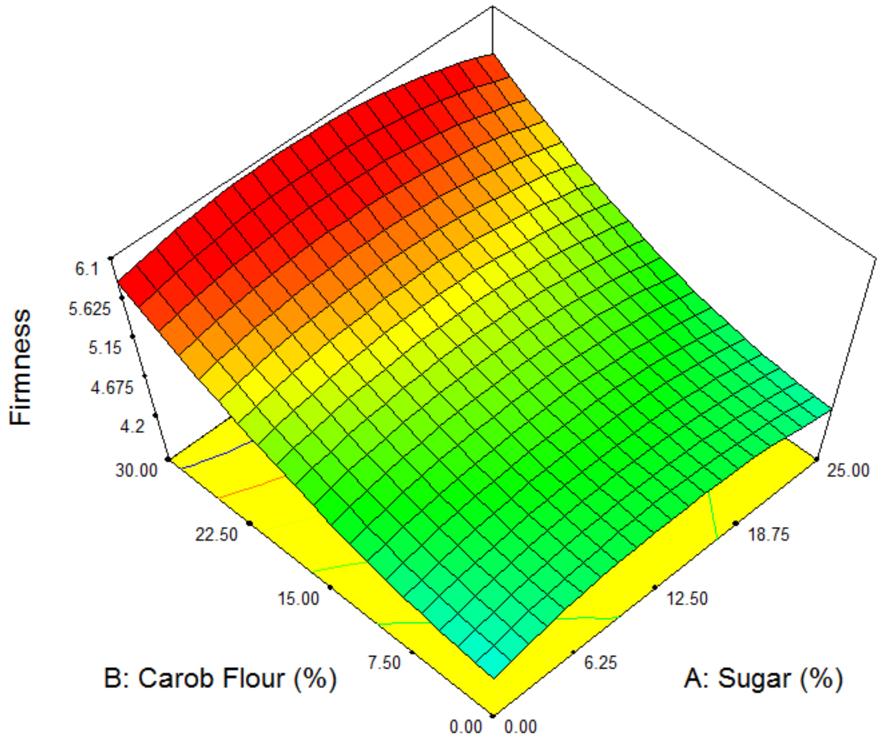

Figure D8. The 3-D graph of firmness as sensory analysis for the 20 types of cake

Table D27. ANOVA for response surface reduced quadratic model for general evaluation as sensory analysis of 20 types of cake

Source of Variation	Sum of Squares	df	Mean Square	F test	p-value Prob > F
Model	5.22	5	1.04	45.75	< 0.0001
Sugar (A) (%)	0.29	1	0.29	12.52	0.0033
Stevia (C) (%)	4.24	1	4.24	185.73	< 0.0001
AC	1.53	1	1.53	67.12	< 0.0001
B^2	0.24	1	0.24	10.41	0.0061
C^2	0.31	1	0.31	13.43	0.0026
Lack of Fit	0.21	9	0.02	1.08	0.4921

APPENDIX E

Table E1. The analysis results of 8 types of cake

CC	UI	SSV	TSV	Hardness	Springiness	Cohesiveness
CC1	1	1	15	1489	0.926	0.449
CC2	1	0	14	1477	0.935	0.445
CC3	0	1	14	1723	0.983	0.386
CC4	1	0	13	1816	0.988	0.378
CC5	0	0	12	1813	0.985	0.376
CC6	0	1	16	2563	0.991	0.370
CC7	-1	1	15	3210	0.995	0.365
CC8	-1	1	15	3201	0.994	0.366

Table E1 (continue). The analysis results of 8 types of cake

CC	Gumminess	Chewiness	Resilience	Volume	Taste	General
CC1	669	619	0.140	77.14	4.2	4.5
CC2	657	615	0.143	77.89	4.4	4.4
CC3	665	654	0.129	76.56	2.7	2.6
CC4	686	678	0.114	74.38	5.4	5.5
CC5	682	671	0.113	74.08	5.6	5.7
CC6	948	940	0.110	72.11	4.3	4.2
CC7	1172	1166	0.103	70.78	4.2	4.2
CC8	1172	1165	0.105	69.84	4.3	4.3

Table E2. Bulk density values of cake dough prepared with wheat flour and wheat germ

CC	Bulk Density (g/ml)	CC	Bulk Density (g/ml)
CC1	1.06	CC5	1.05
CC2	1.06	CC6	1.04
CC3	1.06	CC7	1.03
CC4	1.05	CC8	1.03

Table E3. Resistance and elasticity results of cake dough prepared with wheat flour and wheat germ

CC	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8
T (mm H_20)	87	85	68	60	63	60	61	56
A (mm)	80	81	83	85	84	69	60	70
Ex	19.9	20.0	20.3	20.5	20.4	18.5	17.2	18.6
Fb (10E-4J)	227	227	160	133	132	103	95	98
T/A	1.09	1.05	0.82	0.71	0.75	0.87	1.02	0.80
Iec (%)	50.5	51.1	41.8	37.0	35.2	29.1	26.7	29.1
HYD2200 (%b 15)	52.6	53.0	52.4	51.5	51.9	51.1	51.7	52.3