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Research Article

Functional Cake Production from Red Rosehip (*Rosa canina* L.) and Black Rosehip (*Rosa spinosissima* L.) Fruits Supplied from Bayburt Province

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Abstract

RC (*Rosa canina* L.) and RS (*Rosa spinosissima* L.) powders were incorporated into cake formulations by substituting wheat flour at rates of 5%, 10%, and 15%. In total, seven different cake samples were produced, including a control group. RS powder was determined to have higher pH and moisture levels, mineral (Fe, K, Mn), total phenolic and flavonoid content, and antioxidant activities compared to RC powder. Colour parameters (L*, a*, and b*) indicated that RC had lighter, redder, and more yellowish hues than RS. The addition of RC and RS powders resulted in a significant decrease in the pH values of the dough and cakes. Compared to the control group, the highest ash content was detected in the RC15 and RS15 groups (1.22±0.03%), and the highest moisture content was found in the RS15 group (23.39±0.47%). The specific volume of the cake treatments decreased compared to the control group. With the addition of RC and RS powders, increases in total phenolic content, total flavonoids, and antioxidant activities (DPPH and RPA) were observed. These increases were particularly high in the cakes with RS powder. In the cakes, the RC-added samples had darker, redder, and more yellowish colours compared to the control group, while the RS-added cakes were darker and redder, but less yellowish. Considering all parameters, the cake formulation supplemented with RS15 was determined to be the most suitable and effective approach for the development of functional cakes.

Keywords: Functional Food, Cake, Fruit Powder, *Rosa canina* L., *Rosa spinosissima* L.

Bayburt İlinden Temin Edilen Kırmızı Kuşburnu (*Rosa canina* L.) ve Siyah Kuşburnu (*Rosa spinosissima* L.) Meyvelerinden Fonksiyonel Kek Üretimi

Öz

RC (*Rosa canina* L.) ve RS (*Rosa spinosissima* L.) tozları, buğday ununa %5, %10 ve %15 oranlarında ikame edilerek kek formülasyonlarına dahil edilmiş ve kontrol grubu ile birlikte toplam yedi farklı kek örneği üretilmiştir. RS tozunun, RC tozuna kıyasla daha yüksek pH ve nem seviyelerine, mineral (Fe, K, Mn), toplam fenolik ve flavonoid içeriğine ve antioksidan aktivitelere sahip olduğu belirlenmiştir. Renk parametreleri (L*, a* ve b*) değerlendirildiğinde RC'nin RS'ye göre daha açık, kırmızımsı ve sarımsı renk tonlarına sahip olduğu belirlenmiştir. RC ve RS tozlarının muamelelere eklenmesiyle, hamur ve keklerin pH değerlerinde belirgin bir azalma meydana gelmiştir. Kontrol grubuna kıyasla en yüksek kül RC15 ve RS15 gruplarında (%1.22±0.03) ve en yüksek nem ise RS15 (%23.39±0.47) grubunda saptanmıştır. Kek muamelelerinin spesifik hacmi kontrol grubuna kıyasla düşüş göstermiştir. RC ve RS tozlarının keklere ilavesiyle, toplam fenolik madde, toplam flavonoid ve antioksidan aktivitelerinde (DPPH ve RPA) artma tespit edilmiştir. Bu artışın, özellikle RS tozu ilavesi yapılan keklerde daha yüksek olduğu bulunmuştur. Keklerin iç kısımlarında, RC ilavesi yapılan örneklerin kontrol grubuna göre daha koyu, kırmızımsı ve sarımsı renklere sahip olduğu; RS ilavesi yapılan keklerin ise daha koyu ve kırmızımsı, ancak daha az sarımsı tonlar içerdiği belirlenmiştir. Tüm parametreler değerlendirildiğinde, RS15 ilaveli kek formülasyonunun fonksiyonel kek geliştirme çalışmaları için en uygun ve etkili yaklaşım olarak öne çıktığı belirlenmiştir.

Anahtar Kelimeler: Fonksiyonel Gıda, Kek, Meyve Tozu, *Rosa canina* L., *Rosa spinosissima* L.

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1. Introduction

The relationship between diet, nutrition, and health has gained increasing scientific and public attention in recent years [1]. Food products have a significant impact on human health and well-being, and their formulations and product development strategies continuously evolve [2]. In this context, consumers' interest in healthy foods that reduce the incidence and spread of diseases such as diabetes, cardiovascular disease, and obesity is increasing day by day [3]. These foods can contain naturally nutrient-rich components such as fruits and vegetables, and may also be enriched with vitamins, minerals, probiotics, prebiotics, and fiber [4,5].

Many functional foods with various properties have been developed using grains and other food groups for new product development. Grains are fundamental, processable, popular, and healthy raw materials for nutrition, health, diversity, and innovation, offering extensive possibilities in this context [6]. Flours derived from grains are used as the main ingredient in numerous products. The most notable are industrial baked goods, which include bread, noodles, pasta, bulgur, biscuits, cakes, and breakfast cereals, all with many variations [7]. In our country, baked goods make up 65% of the food industry [8]. Cake, one of these baked goods, is among the most common and popular products. It is primarily consumed as a breakfast or afternoon snack and is especially popular among children and adolescents [9]. Many components such as flour, water, sugar, milk, salt, baking powder, flavors, additives, and other ingredients are used in cake production. The quality and quantity of these components are important and affect the properties of the final product and the stability of its quality throughout its shelf life [10].

The demand for healthier cakes (low-fat, low-sugar, and high-fiber formulations) and for products that address food intolerances and special dietary requirements (sports nutrition, veganism, children, women, the elderly, and individuals with diabetes) has encouraged the food industry to develop products in this area [11].

Various fruits such as plums, cherries, apples, nectarines, peaches, pears, and rosehips belong to the Rosaceae family. These fruits are generally high in fiber and are rich sources of antioxidants, especially polyphenols and flavonols [12]. Many of these fruits grow naturally in Turkey and increase the variety of traditional products in the regions where they are cultivated. Although these fruits are rich in B vitamins, potassium, and magnesium, their use in the food industry is still not widespread enough [13].

Rosehip, a wild fruit, is abundant in our country, with a total of 27 species (*Rosa canina*, *Rosa dumalis, Rosa gallica*, *Rosa hirtissima*, *Rosa villosa*, *Rosa spinosissima*, etc.) identified [14-16]. Rosa species are a rich natural source of bioactive compounds, including flavonoids, phenolic compounds, proanthocyanidins, carotenoids (such as beta-carotene, lycopene, zeaxanthin, lutein), anthocyanins, tocopherols, tannins, essential oils, and pectins. They are also a source of many vitamins (B1, B2, B3, B5, B6, and especially C) and minerals (K, Mg, Na, Fe, Mn, etc.) [16-18]. In addition, not only the fruit itself but also its by-products have significant potential for utilization [19].

Although the nutritional and bioactive properties of rosehip fruit have been widely reported, studies comparing the effects of different rosehip species in baking formulations are limited. In particular, the comparative effects of powders from *Rosa canina* L. (red rosehip) and *Rosa spinosissima* L. (black rosehip) on the quality and functional properties of cake products have not been sufficiently investigated. Therefore, this study aimed to develop functional cake formulations by incorporating powders derived from *Rosa canina* L. and *Rosa spinosissima* L. fruits at different substitution levels and to evaluate their effects on the physicochemical, functional, and sensory properties of the cakes. It was hypothesised that the two rosehip species would exhibit different effects on cake quality and bioactive properties due to their distinct compositional profiles.

2. Materials and Methods

2.1. Material

The rosehips used in cake production were traditionally collected from taxa in Yanıkçam Village within the borders of Bayburt province. Rose hip (Rosa spp.) samples were identified as *Rosa canina* L. (red rose hip) and *Rosa spinosissima* L. (black rose hip) by Prof. Dr. Ali Kandemir, a faculty member of the Botany Department, Biology Division, Faculty of Science and Literature, Erzincan Binali Yıldırım University, based on their morphological characteristics. The collected rose hip seeds were washed, cleaned, sorted, dried under natural conditions, and ground into powder using an 850W Lavion Grain Grinder (Figure 1.).

Other ingredients used in cake production, such as flour, milk, eggs, sunflower oil, sugar, and baking powder, were obtained from local markets in Erzincan province. Wheat flour (Type 550) with 12% moisture, 0.47% ash, and 11% protein on a dry matter basis was used. For the milk, a domestic brand of UHT cow's milk with 1.5% fat content was used.

Figure 1. a) Fresh fruit kernels b) Dried fruit kernels c) Fruit pollen

2.2. Extraction Procedure

The materials were ground into a fine powder. For each sample, 10 g of the powdered material was extracted with 100 mL of methanol by maceration overnight at room temperature. The extraction process was performed three times, and the obtained extracts were combined. The mixtures were filtered to remove residues, and the solvent was evaporated under reduced pressure to obtain the crude extracts. The extracts were then stored in dark at +4 °C until further analysis [20,21].

2.3. Method

Red (*Rosa canina* L.) and black (*Rosa spinosissima* L.) rosehip fruits were used whole for cake production. Ground fruit powders were incorporated into the cake formulation at 5%, 10%, and 15% levels to partially replace wheat flour. In this way, a total of 7 cake groups were prepared: one control group (wheat flour) and 6 cake groups (containing RC or RS powder) (Figure 2). By modifying the method of [22], all other ingredients in the cake formulation were kept constant across all groups. Cakes were produced using the formulation amount specified in Table 1. The addition and mixing times of the ingredients in the production process are shown in the flowchart in Figure 3.

- RC: Cake group in which 5%, 10%, or 15% *Rosa canina* L. powder is substituted for wheat flour
- RS: Cake group in which 5%, 10%, or 15% *Rosa spinosissima* L. powder is substituted for wheat flour

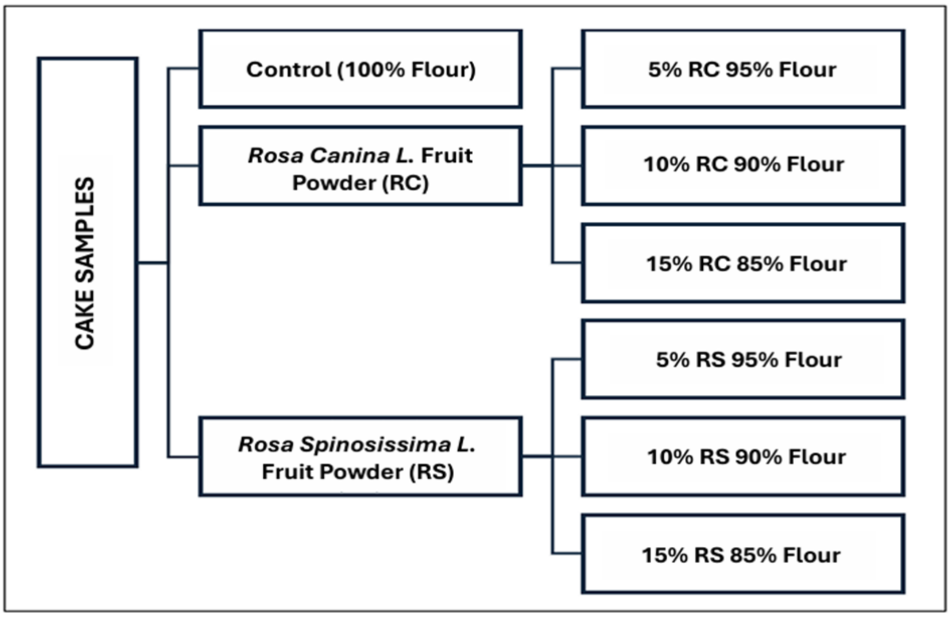

Figure 2. Percentage Values of Fruit Powders in Treatments

Table 1. Cake Formulation

Ingredients	**%**
Flour	29.42
Sugar	26.48
Milk	17.65
Oil	11.77
Egg white	11.77
Egg yolk	2.35
Baking powder	0.5
Salt	0.06
Rosehip powders*	5, 10 and 15

** Rosehip powders (RC and RS) were added separately as partial replacements for wheat flour, calculated on a flour weight basis.*

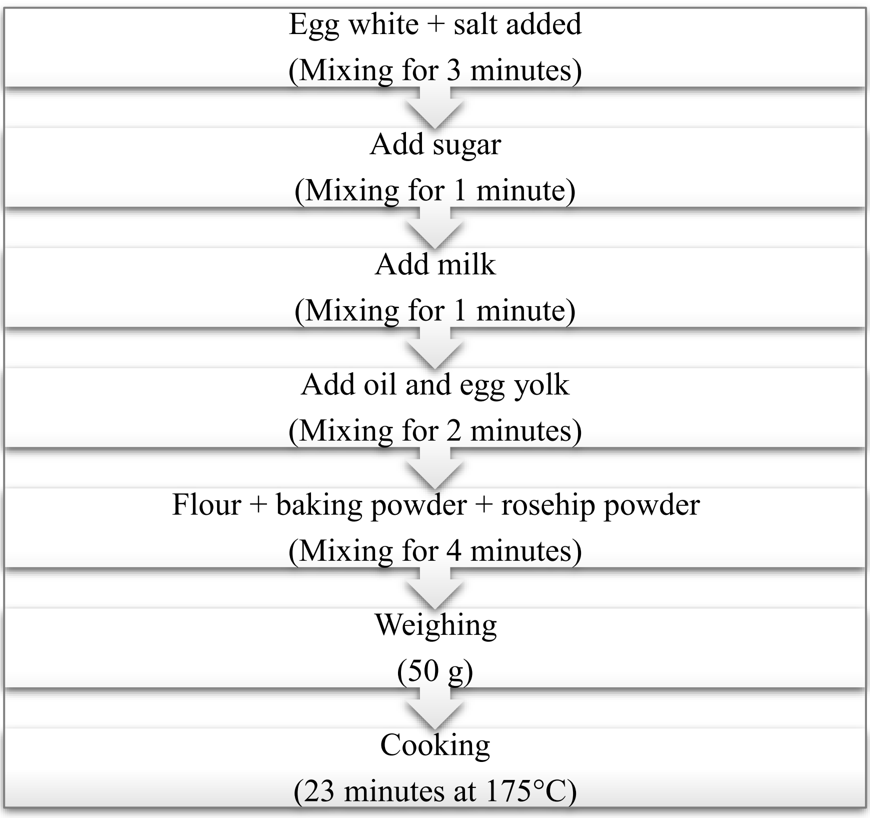

Figure 3. Cake Production Flowchart

2.3.1. pH

The pH of the samples was measured using a PL-700-pv brand pH meter. The pH meter was standardized with buffer solutions, and pH values were measured while ensuring they remained constant during measurement. For pH analysis, 10 grams of each sample were homogenized with 90 mL of distilled water using a magnetic stirrer, and measurements were taken.

2.3.2. Moisture

Moisture determination was performed according to the method of AOAC [23]. For this purpose, glass drying dishes were dried at 105±2ºC for 2 hours until a constant weight was reached. The homogenized samples were evenly distributed in glass drying dishes and dried at 105±2ºC for 24 hours. The moisture content of the samples was calculated by dividing the amount of moisture removed by the initial weight of the samples.

2.3.3. Ash

Ash determination was performed according to the method of AOAC [23]. Samples were weighed into porcelain crucibles previously brought to constant weight and incinerated in a muffle furnace (Electro-mag M1813, Turkey) at 550 ± 5 °C until white or light gray ash was obtained. After incineration, the mass of the samples remaining in the porcelain crucibles was compared to the initial sample mass. The percentage ash content of the samples was then calculated.

2.3.4. Protein

Protein determination was performed according to the method of AOAC [23]. The micro-Kjeldahl method was used to determine the nitrogen content of the samples. Crude protein content was calculated by multiplying the measured nitrogen content by a conversion factor of 5.7

2.3.5. Fat

Fat determination was performed according to the method of AOAC [23], using the Soxhlet method as a reference. For fat determination, approximately 4 g of sample was weighed in a cellulose cartridge, covered with cotton, and placed in a Soxhlet apparatus. After extraction with petroleum ether, the ether in the flasks was evaporated to determine the amount of oil in the sample.

2.2.6. Mineral content

Calcium (Ca), iron (Fe), magnesium (Mg), zinc (Zn), sodium (Na), potassium (K), manganese (Mn), and copper (Cu) concentrations were determined using inductively coupled plasma mass spectrometry (ICP-MS, Agilent Technologies 7700 Series). Before ICP-MS analysis, samples underwent a microwave-assisted decomposition procedure with minor modifications from the method described by [24]. Approximately 0.5 g of each sample was accurately weighed into a

100 mL Teflon microwave decomposition vessel, followed by the addition of 7 mL nitric acid and 2 mL hydrogen peroxide. The samples were decomposed using a two-stage temperature program. After decomposition, the resulting solutions were transferred to 100 mL volumetric flasks and diluted to the final volume with ultrapure water. Concentrations were calculated on a dry weight basis and expressed as μg kg^{-1} and mg kg^{-1} dry weight. Analytical accuracy was verified using a certified reference material for infant formula (CRM, muva-NEM-1609).

2.3.7. Weight, Volume and Specific Volume

The weights of the produced cakes were measured using an analytical balance with a precision of 0.01 grams (BEL, S1002, South Korea). Their volumes were determined using the rapeseed displacement method. Specific volume values were calculated in mL/g based on the measured weight and volume results [25].

2.3.8. Total Phenolic Compounds

The total phenolic content of the treatments was analyzed spectrophotometrically using the Folin-Ciocalteu reagent [26-28]. From the extracts, 100 µL of stock solutions prepared at a concentration of 1 mg/mL was taken, and 4.5 mL of distilled water was added. Then, 100 µL of Folin-Ciocalteu reagent was added to the mixture. After standing at room temperature for 10 minutes, 300 µL of 2% Na_2CO_3 solution was added. The mixture was thoroughly mixed using a vortex device and incubated at room temperature for 2 hours. After incubation, the absorbance of the mixture at a wavelength of 760 nm was measured with a spectrophotometer. The calibration curve (y=0.117x-0.011) was generated using various concentrations of gallic acid (1-1000 µg/mL). The results were expressed as mg gallic acid equivalent phenolic component (GAE) per gram of extract [29,30].

2.3.9. Total Flavonoids

The total flavonoid content of the treatments was determined by measuring the absorbance values of the colored complexes formed during the reaction with the $AlCl_3$ reagent. This analysis was performed using the aluminum chloride colorimetric method [31-33]. For the analysis, 100 µL of stock solution prepared at a concentration of 1 mg/mL was taken, and the volume was adjusted to 4.8 mL with methanol. Then, 100 µL of 1 M NH_4CH_3COO solution and 100 µL of 10% $AlCl_3$ solution were added to the mixture. The resulting mixture was vortexed and incubated at room temperature for 45 minutes. After incubation, the absorbance of the mixture at 415 nm was measured using a spectrophotometer. The results were reported as mg quercetin equivalent (QE) per gram extract, using a calibration curve drawn with varied quercetin concentrations (1-800 µg/mL) [34,35].

2.3.10. Antioxidant Activity

DPPH Free Radical Scavenging Activity

The free radical DPPH (2,2-diphenyl-1-picrylhydrazyl) scavenging activities of the treated extracts were determined using the method reported by [36-38] with some modifications. A

0.26 mM DPPH solution was prepared in methanol. Stock solutions (1 mg/mL) of the tested extracts were prepared, and different volumes (20–1000 µg/mL) were taken and adjusted to a final volume of 3 mL with methanol. Then, 1 mL of DPPH solution was added to each mixture, which was vortexed and incubated for 30 minutes in the dark at room temperature. After incubation, the absorbance of the mixtures at 517 nm was measured using a spectrophotometer. The absorbance values were used to calculate the IC_{50} (µg/mL) for each extract and converted to % activity [39,40].

Reducing Power Activity (RPA)

The reducing power activity test was performed according to the method reported by [41-43]. A total of 100 µL of stock solutions prepared at a concentration of 1 mg/mL of extracts was taken, and the volume was adjusted to 1.25 mL with phosphate buffer (0.2 M, pH 6.6). Then, 1.25 mL of 1% $K_3Fe(CN)_6$ solution was added to this mixture, and the mixture was incubated at 50°C for 20 minutes. After incubation, 1.25 mL of 10% TCA solution and 0.25 mL of 0.1% $FeCl_3$ solution were added to the reaction mixture, respectively. The absorbance of the final mixture was measured at 700 nm. Results were calculated based on a calibration curve created using different concentrations of Trolox and are expressed as mg Trolox equivalent/g extract [44-46].

2.3.11. Color

Color determination was performed using a Hunterlab (Colorflex-EZ, Hunterlab, Virginia, USA) colorimeter based on L*, a*, and b* values [47].

2.3.12. Statistical Analyses

Statistical analyses were performed using one-way analysis of variance (ANOVA) to determine the differences among the cake formulations (control, RC5, RC10, RC15, RS5, RS10, and RS15). The statistical analyses were conducted using SPSS software (version 21.0, IBM Corp., Armonk, NY, USA). When significant differences were detected, mean comparisons were performed using Duncan's multiple range test. Differences among means were considered statistically significant at $p < 0.05$. All analyses were carried out using two independent replicates.

3. Results and Discussion

3.1. Chemical Composition of Red (*Rosa canina* L.) and Black (*Rosa spinosissima* L.) Rosehip Fruits

The physicochemical properties, color parameters, antioxidant values, and mineral content of fruit powders are important for providing preliminary information about the potential product to be developed as a functional food. The moisture contents of RC and RS powders were found to be 10.38±0.02% and 11.63±0.09%, ash content 7.65±0.35% and 7.65±0.25%, and protein content 5.98±0.01% and 5.59±0.02%, respectively (Table 2.). The measured moisture values are below the critical moisture level (13.5–14%) specified for RC and RS powders [48].

Table 2. Some Physicochemical Analysis Results of RC and RS Powders

Analyses	RC	RS
Moisture (%)	10.38±0.02	11.63±0.09
Ash (%)	7.65±0.35	7.65±0.25
pH	3.81±0.01	5.01±0.02
Protein (%)	5.98±0.01	5.59±0.02
Fat (%)	4.94±0.15	2.76±0.09
Total phenolic compounds (mg GAE g-1)	24.19±1.45	60.19±1.68
Total Flavonoids (mg QE g-1)	5.62±0.44	9.90±1.08
DPPH (µg mL-1)	514.28±2.18	286.79±1.22
RPA (mg TE g-1)	46.66±0.35	68.38±2.52
Color parameters		
L*	60.66±0.01	34.30±0.01
a*	20.30±0.01	15.15±0.04
b*	48.4±0.01	8.07±0.04
Mineral content		
Ca (mg/kg)	802.51±27.19	602.93±27.19
Fe (µg/kg)	25315.39±840.94	34635.78±840.94
Mg (mg/kg)	2056.80±60.93	1739.93±60.93
Zn (µg/kg)	10902.61±649.06	8751.70±649.06
Na (mg/kg)	9.30±0.48	5.16±0.48
K (mg/kg)	11417.18±365.27	15018.37±365.27
Mn (µg/kg)	49114.37±1557.37	76006.55±1557.37
Cu (µg/kg)	5705.27±1194.40	3495.37±1194.40

RC: *Rosa canina* L powder, RS: *Rosa spinosissima* L.powder

In a study, the moisture content of rosehip (*Rosa canina* L.) powder was reported as 13.40±0.15%, the ash content as 6.50±0.07%, and the protein value as 4.89±0.11% [49]. The ash, protein, and moisture content values vary in this study. These differences can be attributed to the soil and climatic conditions in which the rosehip was grown [50]. Additionally, the difference in moisture values may also be due to technological factors such as drying conditions or the grinding process. The oil content of RC (*Rosa canina* L.) and RS (*Rosa spinosissima* L.) powders, obtained from the seeds and pseudo-fruit of these fruits, was found to be 4.94±0.15% and 2.76±0.09%, respectively. Studies in the literature have reported that the oil content of rosehip (*Rosa canina* L.) pseudo-fruit (peel) is 0.65±0.04% [51], and that of its seeds is 6.29±0.42% [52]. Another study reported the oil content of rosehip (*Rosa canina* L.) powder as 3.31±0.004%, suggesting that the soil and climate conditions in which the rosehip was grown may explain these differences [50]. When the pH values of RC and RS powders were examined, RC powder (3.81±0.01) was found to be more acidic than RS powder (5.01±0.02). In one study, the pH value of *Rosa canina* L. powder was found to be 3.73±0.01 [50]. Another study found the pH value of *Rosa spinosissima* L. powder to be 4.24±0.41 [53]. The data from these studies, consistent with the data obtained from RC and RS powders, supports the finding that *Rosa canina* L. powder is more acidic than *Rosa spinosissima* L. powder. Total phenolic content, total flavonoid content, DPPH, and RPA analyses were performed on RC and RS powders. The total phenolic content values of RC and RS powders were 24.19±1.45 mg GAE g^{-1} and 60.19±1.68 mg GAE g^{-1}, respectively, while the total flavonoid values were 5.62±0.44 mg QE g^{-1} and 9.90±1.08 mg QE g^{-1}, respectively. A study examined the total phenolic content, total flavonoid content, and DPPH values of different rosehip species, including *Rosa canina* L. and *Rosa spinosissima* L. The overall data were in the ranges of 70.58±6.23–142.08±2.16 mg GAE g^{-1}, 2.92±0.17–8.04±0.47 mg QE g^{-1}, and 60.69±0.94–208.58±2.26 µg mL^{-1}, respectively. The total phenolic content values in this study were higher than those of RC and RS powders. On the other hand, the total flavonoid content in this study was similar to that of RC and RS powders. In the same study, DPPH analyses of various rosehip species were also performed, and it was determined that they had higher antioxidant activity than RC (514.28±2.18 µg mL^{-1}) and RS (286.79±1.22 µg mL^{-1}) powders [54]. In another study conducted in Gümüşhane province, the total phenolic content, total flavonoid, and RPA analyses of *Rosa spinosissima* L. fruit were found to be 16.4±0.4 mg GAE g^{-1}, 5.2±0.2 mg QE g^{-1}, and 34.3±2.4 mg TE g^{-1}, respectively [55]. These values showed that RS powders had a higher antioxidant capacity compared to the samples in this study (Table 2.). When comparing RC and RS powders, the RPA values of RS powder were significantly higher than those of RC powder, indicating a stronger radical scavenging capacity (Table 2.). This is attributed to the higher amount of antioxidant compounds in RS powder. As the phenolic content of the fruit or food increases, the radical scavenging capacity also increases proportionally [56]. In another study, DPPH analyses were performed to examine the antioxidant activities of *Rosa canina*, Rosa sempervivens, and Pyrocantha coccinea fruit extracts, and the results were 100±7.0 µg mL^{-1}, 130±7.8 µg mL^{-1}, and 500±40.0 µg mL^{-1}, respectively [57]. The IC_{50} value obtained in DPPH analysis shows an inverse relationship to the ability to neutralize free radicals; therefore, as the IC_{50} value decreases, the antioxidant capacity increases [58]. In this context, the DPPH values of the Rosa species evaluated showed that they have a higher antioxidant capacity than the RC (514.28±2.18 µg mL^{-1}) and RS (286.79±1.22 µg mL^{-1}) powders used in this study. When examining the color parameters, the L* value of RC powder was 60.66±0.01, the a* value was 20.30±0.01, and the b* value was 48.4±0.01. In contrast, the L* value of RS powder was 34.30±0.01, the a* value was 15.15±0.04, and the b* value was 8.07±0.04. Significant differences were observed in the color parameters of RC and RS powders. RC powder is lighter, with more pronounced red and yellow tones compared to RS powder. Differences in color parameters can occur between cultivated and wild rosehip fruits. For this reason, different color parameters have been reported for the same species in various studies [59,60]. In their study, [61] determined the color parameters of *Rosa canina* L. and *Rosa rubiginosa* L. fruits and stated that *Rosa canina* L. powder has yellow color characteristics similar to the RC powder in this study.

Potassium (K), the first mineral evaluated in the mineral analysis of RC and RS powders, is the most abundant macroelement in all rosehip varieties. The potassium values of RC and RS powders in this study were 11417.18 mg/kg and 15018.37 mg/kg, respectively. It has also been reported that potassium levels vary between 8292.83 mg/kg and 13221.55 mg/kg among different rosehip species, but in some species, this mineral ranges from 23095.4 to 24459.9 mg/kg [62]. Potassium levels in rosehip species from different genotypes in the Erzincan region were found to be between 11152 mg/kg and 45405 mg/kg [63]. The potassium values of RC and RS powders in this study fall within the range determined for genotypes in the Erzincan region. The potassium values of rosehip samples in studies by [64] and [65] were lower, at 890.5–1023.9 mg/kg and 5316.8 mg/kg, respectively. In contrast, the potassium values of RC and RS powders were higher than the potassium level of wild *Rosa canina* L. species (6258.3 mg/kg) reported by [66] Furthermore, the potassium values of the RC and RS powders used in this study were higher than those of some rosehip samples from the Van region of Turkey (2251.50 mg/kg) [67]. Another macro element found in rosehip species and varieties is Ca (calcium). The calcium values of RC and RS powders were 802.51 mg/kg and 602.93 mg/kg, respectively. One study reported that the calcium content in rosehip samples from different experimental areas ranged from 654.9 mg/kg to 8169.94 mg/kg [68]. In the study by [65], the calcium levels of rosehip samples were 3479.3±3445.40 mg/kg, and compared to these values, the calcium values of RC and RS powders were lower. In contrast, the calcium values of rosehip samples from Kastamonu province were between 133.3 mg/kg and 146.7 mg/kg, and compared to this study, the calcium values of RC and RS powders were higher [64]. When the magnesium (Mg) values of RC and RS powders were examined, magnesium was found to be the second most abundant element after potassium. The magnesium values of RC and RS powders were quite high, at 2056.80±60.93 mg/kg and 1739.93±60.93 mg/kg, respectively. Previous studies have reported that the magnesium content of rosehip samples from different regions or genotypes ranged from 990 mg/kg to 1254 mg/kg [69]. However, in some regions, these values ranged from 1301.50 mg/kg to 1435.00 mg/kg or from 2134 mg/kg to 5504 mg/kg [63,66]. The iron (Fe), zinc (Zn), and copper (Cu) mineral values of the fruit powders were as follows for RC: 25315.39±840.94 µg/kg, 10902.61±649.06 µg/kg, and 5705.27±1194.40 µg/kg, respectively, for SPF 1; and 34635.78±840.94 µg/kg, 8751.70±649.06 µg/kg, and 3495.37±1194.40 µg/kg, respectively, for RS 1. These data show that the iron values of rosehip (*Rosa canina* L.) samples collected from Konya and Kastamonu provinces are lower (72.90 mg/kg and 59.40 mg/kg, respectively), but higher than the iron values of powder samples obtained only from rosehip seeds in the Erzurum region (8.49–17.57 mg/kg) [64,69].

3.2. pH

Acidity is an important parameter for product quality control and for determining microbial safety in foods. Each food has specific pH values (Aksoy, 2021). The pH value of the Control group in the cake treatments was 7.18±0.20, while the pH range of the cake treatments with added RC and RS powders was 5.96±0.20–6.68±0.20 and 6.58±0.20–6.90±0.20, respectively (Table 3.). In this study, a gradual decrease in pH values was observed with increasing proportions of RC and RS powders in the treatments. Similarly, [50] observed that the pH value in the product gradually decreased as the proportion of rosehip powder (*Rosa canina* L.) added to the waffle cone increased. In general, similar results have been reported in other studies [70], showing that the acidity level in functional products with plant-based flours added as substitutes increased compared to the control group.

Table 3. Mean pH Values of Dough and Cake Treatments

Treatment	pH-dough	pH-cake
K	6.63±0.11[f]	7.18±0.20[g]
RC5	6.46±0.11[cd]	6.68±0.20[d]
RC10	6.24±0.11[b]	6.28±0.20[b]
RC15	6.17±0.11[a]	5.96±0.20[a]
RS5	6.59±0.11[e]	6.90±0.20[f]
RS10	6.48±0.11[d]	6.80±0.20[e]
RS15	6.44±0.11[c]	6.58±0.20[c]
Mean	6.43±0.043	6.62±0.104

** Means indicated by different letters in the same column have statistically significant differences (pH-dough p<0.001; pH-cake p<0.001)*

3.3. Ash, Moisture, Protein, and Fat

When we examined the physicochemical properties of the treatments, we observed an increase in moisture and ash values in parallel with the addition of fruit powder to the product, while no change could be observed in protein and fat values in parallel with the amount of fruit powder added (Table 4.).

Table 4. Mean Values of Some Physicochemical Properties of the Treatments

Treatment	**Moisture** (%)	**Ash** (%)	**Protein** (%)	**Fat** (%)
K	18.90±0.47[a]	1.05±0.03[a]	5.83±0.03[c]	14.02±0.11[c]
RC5	21.11±0.47[b]	1.05±0.03[a]	5.51±0.03[b]	13.37±0.11[b]
RC10	21.77±0.47[bc]	1.16±0.03[ab]	5.30±0.03[a]	14.18±0.11[c]
RC15	22.04±0.47[bc]	1.22±0.03[b]	5.60±0.03[b]	13.97±0.11[c]
RS5	21.14±0.47[b]	1.14±0.03[ab]	5.55±0.03[b]	12.21±0.11[a]
RS10	21.65±0.47[b]	1.21±0.03[b]	5.59±0.03[b]	14.71±0.11[d]
RS15	23.39±0.47[c]	1.22±0.03[b]	5.61±0.03[b]	14.57±0.11[d]
Mean	21.43±0.37	1.15±0.02	5.57±0.04	13.86±0.22

** Means indicated by different letters in the same column have statistically significant differences. Statistical significance levels: Moisture (p<0.01), ash (p<0.05), protein (p<0.001), and fat (p<0.001)*

Moisture content, one of the most important parameters for assessing the microbial and chemical safety of a product, is a key factor affecting the product's storage process. Products with high moisture content are more susceptible to bacteria and molds than those with low moisture content [48]. In this context, when the moisture contents of the treatments were examined, the lowest value was measured in the K group (18.90±0.47%) and the highest in the RS15 group (23.39±0.47%). Except for the control group, the moisture content measured in the other treatments was slightly higher than that of other commercially sold fruit (19.6%) and cocoa (16.3%) cakes [71]. While there is no accepted standard for the general moisture content of cakes, industrial studies to determine shelf life may be necessary to assess product durability. When the moisture contents of the treatments were examined, it was found that the treatments with added RC and RS powders were more humid compared to the control group. In another similar study, bread was produced using 0.5–2.5% rosehip powder instead of wheat flour, and the bread with added fruit powder had a higher moisture content compared to the control [72]. Research suggests that plant-based flours added as substitutes for wheat flour increase the fiber concentration in the product, which leads to an increase in the water-holding capacity of the product [73-75]. When the ash values of the treatments in this study were examined, the lowest values were found in the K and RC5 groups (1.05±0.03%), and the highest values were found in the RC15 and RS15 groups (1.22±0.03%). In the study by [72] the ash value in bread was also higher in the groups with added fruit powder. In this study, the ash value was higher in the treatments with added RC and RS powders compared to the control (Table 4.). As the mineral content of the product increases, its ash content also increases. General data have shown that plant-based fruit powders increase the ash content in the product due to the minerals they contain [50]. On the other hand, the lower protein content of RC (5.98±0.01%) and RS (5.59±0.02%) powders compared to wheat flour (11%) resulted in the highest protein ratio being found in the K group (5.83±0.03%) among the treatments. Among the treatments with added fruit powder, protein values ranged from 5.30±0.03% to 5.61±0.03%, which were lower than the control. In the study conducted by Vartolomei and Turtoi [72], protein values were also lower in the groups with added rosehip powder compared to the control. Similar results were obtained in other studies evaluating plant-based powders [75,76]. When the fat content of the cake samples was examined, the average fat value of the treatments ranged from 12.21±0.11% to 14.71±0.11%, and significant differences were detected; however, these results did not show consistent variability with the addition of RC and RS powders.

3.4. Weight, Volume, and Specific Volume

In the treatments, the highest volume was measured in the control group at 120±2.63 mL, while in the groups with added RC and RS powders, the volume ranged from 82.5±2.63 to 100.5±2.63 mL. The highest specific volume was observed in the K group at 2.71±0.05 mL/g, while in the groups with added RC and RS powders, it ranged from 1.84±0.05 to 2.24±0.05 mL/g (Table 5.).

Table 5. Mean Values of Weight, Volume and Specific Volume of Transactions

	Weight (g)	Volume (mL)	S. Volume (mL/g)
K	44.33±0.82	120±2.63^{e}	2.71±0.05^{e}
RC5	44.87±0.82	100.5±2.63^{d}	2.24±0.05^{d}
RC10	44.82±0.82	93±2.63^{bcd}	2.08±0.05^{cd}
RC15	45.63±0.82	84±2.63^{ab}	1.84±0.05^{a}
RS5	44.80±0.82	100±2.63^{cd}	2.24±0.05^{d}
RS10	44.47±0.82	91±2.63^{abc}	2.05±0.05^{bc}
RS15	43.35±0.82	82.5±2.63^{a}	1.90±0.05^{ab}
Mean	44.61±0.31	95.86±1.00	2.15±0.18

** Means indicated by different letters in the same column have statistically significant differences. Statistical significance levels: Weight ($p>0.05$), volume, and Standard Volume ($p<0.001$)*

As the proportion of RC and RS powders added to the treatments increased, both the volume and specific volume levels gradually decreased. This reduction is primarily due to the dilution of gluten-forming proteins in wheat flour when non-gluten plant powders are incorporated into the formulation. As the substitution level increases, the relative amount of gluten proteins responsible for forming the viscoelastic network decreases, weakening the dough structure and limiting its ability to retain fermentation gases during baking. In one study, functional bread was produced using rosehip powder at 5%, 10%, and 15% as a substitute for wheat flour. Similarly, the addition of fruit powder led to decreases in the volume and height values of the breads [77]. Additionally, rosehip powders are rich in dietary fiber, which has a high water-binding capacity. This may lead to competition for water between fiber components and gluten proteins, restricting gluten hydration and hindering optimal gluten network development. In another study on bread produced by adding rosehip seeds, fruit powder substitution reduced the degree of softening and extensibility of the dough texture, while increasing the stability and tensile strength of the dough [78]. Such changes indicate a shift in the rheological behavior of the dough, where increased fiber content promotes a more rigid but less extensible structure. One reason suggested in the literature for this is that adding fibrous plant powder causes the protein reticular structure to develop weakly and prevents optimal gluten network formation. Consequently, the weakened gluten matrix reduces the dough's gas-holding capacity, resulting in lower cake volume and specific volume. Another reason is that increased mineral density strengthens the bonds within the gluten, thus reducing its elasticity under the pressure of the gases formed [72,79-81].

3.5. Mineral Content

Minerals are involved in many physiological, structural, hormonal, and enzymatic processes in the body and are among the most important nutrients due to their numerous regulatory functions in human health [82]. Studies have shown that rosehip fruit and seed powders are sources of both macro (P, K, Ca, Mg) and micro (Fe, Cu, Mn, Zn) minerals [83]. In this study, detailed mineral analysis of the treatments revealed that the levels of Ca (calcium), K (potassium), Mg (magnesium), and Mn (manganese) were significantly higher in the treatments with added RC and RS powders compared to the K group (p<0.001). However, there was no significant difference in the levels of Na (sodium), Fe (iron), and Zn (zinc) (p>0.05) (Table 6).

Table 6. Mean Values of Mineral Substance Analyses for the Treatments

Treatment	Ca (mg/kg)	Fe (µg/kg)	Mg (mg/kg)	Zn (µg/kg)	Na (mg/kg)	K (mg/kg)	Mn (µg/kg)	Cu (µg/kg)
K	37.44±2.98^{a}	10146.21±1485.28	186.85±13.44^{a}	6813.48±380.37	1869.79±90.72	1350.63±84.95^{a}	3534.00±29851^{a}	109168.55±1266.71^{b}
RC5	48.78±2.98^{b}	6565.07±1485.28	209.23±13.44^{ab}	6481.26±380.37	1826.92±90.72	1514.59±84.95^{ab}	3819.19±298.51^{ab}	776.06±1266.71^{a}
RC10	65.47±2.98^{c}	5399.10±1485.28	240.64±13.44^{b}	5829.60±380.37	1859.58±90.72	1695.49±84.95^{bc}	4541.12±298.51^{bc}	803.65±1266.71^{a}
RC15	80.42±2.98^{d}	6440.30±1485.28	288.07±13.44^{c}	6333.66±380.37	1851.11±90.72	1830.53±84.95^{c}	5223.25±298.51^{c}	859.02±1266.71^{a}
RS5	45.74±2.98^{ab}	10453.41±1485.28	203.30±13.44^{ab}	6447.82±380.37	1833.72±90.72	1531.06±84.95^{ab}	4299.69±298.51^{abc}	761.82±1266.71^{a}
RS10	52.77±2.98^{b}	9855.65±1485.28	212.49±13.44^{ab}	6260.72±380.37	1791.07±90.72	1688.33±84.95^{bc}	5119.57±298.51^{c}	756.71±1266.71^{a}
RS15	73.17±2.98^{cd}	9209.66±1485.28	294.50±13.44^{c}	6863.80±380.37	2137.40±90.72	2271.90±84.95^{d}	7348.53±298.51^{d}	961.19±1266.71^{a}
Mean	57.68±1.13	8295.63±561.38	233.58±5.08	6432.91±143.77	1881.37±34.29	1697.50±32.11	4840.77±112.83	16298.14±478.77

** Means indicated by different letters in the same column have statistically significant differences. Statistical significance levels: Fe, Zn and Na (p>0.05), Ca, Mg, K, Mn and Cu* (p<0.001)

Potassium and magnesium values in the K group were 1350.63±84.95 mg/kg and 186.85±13.44 mg/kg, respectively, while in the RS15 group, these values were 2271.90±84.95 mg/kg and 294.50±13.44 mg/kg, respectively. When calcium values were examined, a higher value was found in the RC15 group (80.42±2.98 mg/kg) compared to the K group (37.44±2.98 mg/kg). For manganese, the lowest value was found in the K group at 3534.00±298.51 µg/kg, while the highest was in the RC15 group at 7348.53±298.51 µg/kg. An increase in mineral levels was observed in parallel with the ratio of RC and RS powders. Similarly, in another study, wheat bread was produced with rosehip flour and chestnut flour at 5% and 10% concentrations, and the mineral content of the product was evaluated. The data showed that the content of all minerals (except sodium) in the bread increased in parallel with the fruit powder ratio [84]. In another study, different rosehip seeds were used in bread production. The results showed that the enriched bread contained higher levels of macro elements, especially Ca and K, and that the presence of microelements Zn, Fe, and Mn was significant [85]. All the data indicated that adding fruit powder to food enriched the product with minerals that increased its biological activity [82,86]. In this study, RC and RS powders increased the nutritional value of the treatments and demonstrated a remarkable nutritional profile.

3.6. Total Phenolic Compound, Total Flavonoids, DPPH and Reducing Power Activity (RPA)

In this study, based on the DPPH, total phenolic content, and total flavonoid content values, the groups supplemented with RC and RS powders exhibited higher antioxidant potential than the control group. The DPPH, total phenolic content, and total flavonoid content values for the control group were 2128.73±4.29 µg mL^{-1}, 6.79±0.13 mg GAE g^{-1}, and 2.29±0.76 mg QE g^{-1}, respectively, while the values for the RS15 group were 438.35±2.13 µg mL^{-1}, 11.75±1.22 mg GAE g^{-1}, and 3.24±0.87 mg QE g^{-1}, respectively. When RC and RS powders were used as flour substitutes, the highest RPA values among the treatments were observed in the RS15 group (35.35±1.57 mg TE g^{-1}) compared to the control group (24.33±1.13 mg TE g^{-1}) (Table 7).

Table 7. Average Values of Total Phenolic Compounds, Total Flavonoids, DPPH, and RPA Analyses of the Treatments

Treatment	DPPH IC_{50} (µg mL^{-1})	Total Phenolic Compounds (mg GAE g^{-1})	Total Flavonoids (mg QE g^{-1})	RPA mg TE g^{-1}
K	2128.73±4.29^{d}	6.79±0.13^{a}	2.29±0.76^{a}	24.33±1.13^{a}
RC5	1994.25±1.85^{d}	7.16±0.22^{ab}	2.48±1.15^{b}	25.57±1.89^{ab}
RC10	1064.18±3.05^{c}	7.45±0.34^{b}	2.57±0.76^{bc}	26.72±2.60^{b}
RC15	616.02±1.90^{b}	7.90±0.13^{bc}	3.24±0.66^{c}	28.38±1.62^{c}
RS5	963.60±1.29^{c}	9.08±1.03^{c}	2.29±0.99^{a}	27.70±2.57^{bc}
RS10	585.40±1.81^{b}	10.12±0.34^{d}	2.48±0.59^{b}	32.69±1.00^{d}
RS15	438.35±2.13^{a}	11.75±1.22^{e}	3.24±0.87^{c}	35.35±1.57^{e}
Mean	1112.93±258.2	8.61±0.68	2.65±0.16	28.68±1.50

** Means indicated by different letters in the same column are statistically significantly different. Statistical significance levels apply to DPPH, total phenolic compounds, total flavonoids, and RPA* ($p<0.001$)

In a similar study, cereal crackers enriched with wild fruits such as hawthorn, aronia, sea buckthorn, and rosehip powder were produced, and both the antioxidant potential and sensory properties of the product were evaluated. The data confirmed the high antioxidant activity of wild plants and their potential for developing functional foods [87]. In another study, 15% rosehip powder and 25% hibiscus powder were used as substitutes for wheat flour in cookie production. Analyses showed that the antioxidant capacity of the cookies increased due to the higher total phenolic content [88]. Additionally, rosehip by-products have been evaluated in cereal products such as noodles. In this study, by-products such as grape, rosehip, and pomegranate seeds were powdered and used as substitutes for wheat flour. The results showed that adding 10% fruit seeds to the noodles increased the RPA value by 8 times for grape seeds, 5.7 times for rosehip seeds, and 4 times for pomegranate seeds compared to control samples [19]. All these data demonstrate that rosehip fruit has a unique bioactive compound profile that is promising for nutritional use.

3.7. Color

Significant color differences were observed between the groups, depending on the ratio of RC and RS powders added to the treatments (Table 8).

Table 8. Mean Values of Crust and Crumbs Color (L*, a* and b*) Analyses of Treatments

	Crust			Crumbs		
Treatment	L*	a*	b*	L*	a*	b*
K	61.86±0.05^{g}	11.81±0.01^{c}	42.26±0.22^{f}	77.08±0.10^{g}	1.86±001^{a}	24.26±0.03^{d}
RC5	49.83±0.05^{f}	19.05±0.01^{e}	39.05±0.22^{e}	64.40±0.10^{f}	10.17±0.01^{d}	30.01±0.03^{e}
RC10	46.48±0.05^{e}	19.24±0.01^{f}	36.06±0.22^{d}	58.49±0.10^{e}	13.81±0.01^{f}	34.61±0.03^{f}
RC15	40.99±0.05^{d}	22.59±0.01^{g}	43.09±0.22^{g}	55.61±0.10^{d}	14.76±0.01^{g}	35.50±0.03^{g}
RS5	32.63±0.05^{c}	12.76±0.01^{d}	16.11±0.22^{c}	48.27±0.10^{c}	8.24±0.01^{b}	14.14±0.03^{c}
RS10	28.34±0.05^{b}	11.13±0.01^{b}	11.03±0.22^{b}	39.36±0.10^{b}	10.13±0.01^{c}	11.94±0.03^{b}
RS15	24.88±0.05^{a}	8.07±0.01^{a}	5.41±0.22^{a}	34.02±0.10^{a}	10.82±0.01^{e}	10.90±0.03^{a}
Mean	40.71±3.37	14.95±1.37	27.57±4.14	53.89±3.79	9.97±1.09	23.05±2.75

* *Means indicated by different letters in the same column have statistically significant differences. Statistical significance levels Crust and Crumbs Color L*, a* and b** ($p<0.001$)

Treatments with added RC powder have lighter and more yellow tones compared to those with added RS powder. As the amount of fruit powder increased, the internal a* and b* values of RC-added treatments gradually increased, while the L* (lightness) values gradually decreased. Similarly, in another study, whole wheat bread was produced with a combination of 2.5% rosehip fruit and various plant-derived materials, and a decrease in L* (lightness) values and an increase in a* and b* values were observed as the fruit powder ratio increased ([70]. In the study by [77], bread was produced by substituting wheat flour with rosehip (*Rosa canina* L) flour at rates of 5%, 10%, and 15%, and it was reported that the enriched samples had a darker color, consistent with previous studies. In RS powders, treatments showed an appearance similar to cocoa products due to the fruit's naturally dark color, and a decrease in L* (lightness) values was observed depending on the powder ratio (Figure 4. and Figure 5.). Similar results were found in the study by [77]. As the RS powder ratio increased in the treatments, the shell a* value gradually decreased, while the inner a* values gradually increased. Conversely, as the RS powder ratio increased, a gradual decrease was observed in both the shell and inner b* values.

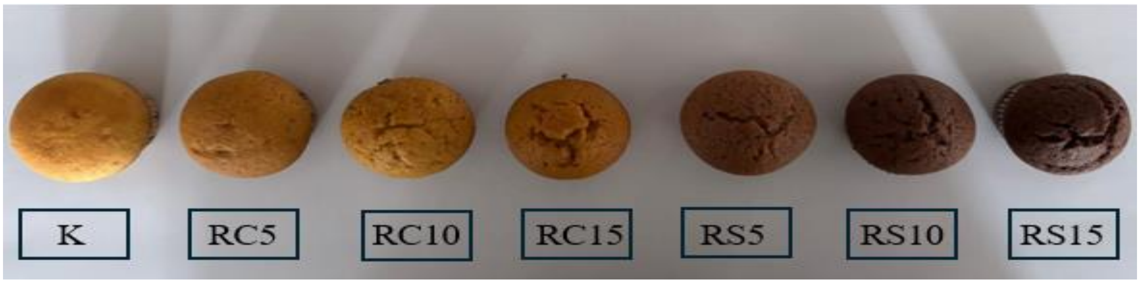

Figure 4. Images of Crust Colors (L*, a*, and b*) Related to the Treatments

Figure 5. Images of Crumbs Colors (L*, a*, and b*) Related to the Treatments

5. Conclusion

The results of this study showed that using Rosa canina (RC) and Rosa spinosissima (RS) powders as partial substitutes for wheat flour significantly affected the physicochemical and antioxidant properties of cakes. RS powder had higher pH, moisture, Fe, K, and Mn content, as well as more bioactive components, compared to RC powder. The addition of both powders decreased the pH and specific volume of the cakes, while increasing ash, moisture, total phenolic content, flavonoid content, and antioxidant activity.

Phenolic compounds and antioxidant capacity were particularly higher in cakes containing RS powder. Furthermore, the use of RC and RS powders affected the colour properties of the cakes, resulting in darker shades compared to the control group. When all formulations were evaluated, the cake containing 15% RS (RS15) was found to be the most suitable and effective in terms of physicochemical and antioxidant properties. Overall, the findings indicate that RS powder, especially at the 15% level, can be used as a functional component in cake production and can contribute to the development of value-added bakery products with improved nutritional and antioxidant properties.

Ethics in Publishing

There are no ethical issues regarding the publication of this study.

Author Contributions

The thesis study was conducted by the student, and the advisor provided academic guidance throughout all stages of the study.

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