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Utilization of carob flour for mitigating oil separation issue in traditional Turkish tahini halva

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Abstract

Tahini halva, a popular confectionery product, often encounters challenges such as oil separation and oxidation. This study investigates the potential of utilizing carob flour as a substitute for cocoa to address these issues and enhance the quality of tahini halva, especially in terms of bioactive properties and dietary fiber. Carob, abundant in the Mediterranean region, offers high nutritional value and functional benefits, making it a promising alternative. A comparative analysis was conducted to evaluate the effects of carob flour on the physicochemical, antioxidant, and sensory characteristics of tahini halva in comparison to cocoa. Results revealed that the incorporation of carob flour effectively mitigated oil release, imparted superior antioxidant activity, and influenced the color attributes of tahini halva. Furthermore, sensory evaluation indicated comparable acceptability with control samples, with the optimal concentration of 5% carob flour yielding the most favorable outcomes. This research highlights the potential of carob flour as a functional ingredient to enhance the nutritional profile and sensory appeal of tahini halva, offering opportunities for product innovation and diversification in the confectionery industry.



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INTRODUCTION

Tahini halva refers to a solid, homogeneously fine fibrous product prepared according to the appropriate technique by cooking a sugar syrup obtained from sugar, drinking water, and citric acid or tartaric acid, with the addition of edible glucose syrup when necessary, then thickening and whitening the sugar syrup with soapwort extract (*Radix saponariae Albae sive L.*) and/or modified proteins, and mixing and kneading it with tahini, and optionally adding flavorings according to the technique (1). According to the relevant codex, plain tahini halva must contain at least 26% sesame oil, 52% tahini, 10% protein, and at most 47% sugar, 3% moisture, and 2% ash. In Turkey, plain, cocoa, and pistachio tahini halva production is commonly carried out.

Tahini halva, which is important in terms of nutritional value, the problems of oil separation and rancidity (the bitterness of taste due to the formation of free fatty acids) during storage negatively affect the edibility and marketing of the product. The reason for oil separation in halva is filling the gaps between the protein and sugar particles precipitated with soapwort extract by sesame oil without emulsifying (2). Furthermore, rancidity occurs during storage due to oil separation (3).

The carob tree (*Ceratonia siliqua L.*), cultivated in many countries around the Mediterranean basin since ancient times, holds significant economic and environmental importance. In Turkey, it grows along the coastal strip extending from Urla in Izmir to Samandağ district in Hatay. The carob fruit contains 62-67% total sugars, 4-6% protein, and 23-27% dietary fiber. 100 grams of seedless carob provide 293 kcal of energy. Carob flour is obtained by drying and grinding the separated carob seeds and is used as a substitute for cocoa in various food products in the food industry (4). Compared to cocoa, carob flour has several advantages, such as being caffeine-free, more cost-effective, having protective properties against free radicals, containing less fat, increasing dietary fiber intake, and having a high content of phenolic compounds. Additionally, it possesses a color and taste reminiscent of cocoa, making it a popular cocoa substitute in food

industry applications including baked goods, desserts, pasta, and beverages (5).

The aim of this study is to enhance the nutritional value of tahini halva, a traditional Turkish food, by utilizing carob fruit powder, which is abundantly cultivated in Turkey but underutilized. Additionally, the study aims to address the issues of oil separation during storage and subsequent deterioration of quality due to oil oxidation in halva. Tounsi et al. (6) investigated the use of carob powder in halva production, but their research was limited to an optimization study aimed at finding a suitable formulation for halva production. The properties of halvas produced with the optimum formulation were not examined, and the results regarding the oil separation problem were not observed. Some research has been conducted to address the major problem encountered in halva, which is emulsion stability. In these studies, various approaches have been made, including the use of natural waxes (7), emulsifiers such as soy lecithin and distilled monoglycerides (8), stabilizers like gum arabic (9), and fibers such as defatted sesame seed coats and date fiber concentrate (10), to prevent oil separation. The current study represents the first study for the use of carob flour in order to prevent oil separation and oxidation in tahini halva.

It is believed that the high levels of polysaccharides and polyphenolic compounds found in carob fruit structure may provide a solution to the problems of oil separation and rancidity in tahini halva. Additionally, cocoa, which is used in tahini halva production, is not farmed in Turkey and is imported. Carob flour can be used as a substitute for cocoa. Substituting carob flour and its products for cocoa is evaluated to increase carob fruit cultivation and enhance its added value in various products.

MATERIAL AND METHOD

Materials

Granulated sugar, soapwort extract, citric acid, tahini, sunflower oil, cocoa, and carob flour (0.7% fat, 54.6% carbohydrate, 25.8% fiber, and 4.2% protein) were procured from local markets in Mersin. The production was conducted at

Toros University Food Chemistry Laboratory.

METHODS

Tahini Halva Production

The production method of tahini halva is depicted in Figure 1, while the formulations used in the production of the samples are shown in Table 1. Within this scope, citric acid was added to a mixture of powdered sugar and water, and then boiled at 130-135°C for 40-45 minutes. Subsequently, heat treatment was terminated, and while the syrup was still hot, soapwort extract was added and stirred for 25-30 minutes. Tahini and sunflower oil were added to the prepared sugary mixture and initially mixed with a spatula, then kneaded by hand while the mixture was still hot. The samples were molded in round bowls with a diameter of 10 cm. After

left at room conditions for 12 hours, they were removed from the molds and packaged using the vacuum packaging method. The produced samples were stored at 2-10°C till analysis.

Physicochemical Analysis

Titratable acidity

The titratable acidity values of the samples were determined by the alkaline titration method, and the results were expressed as % oleic acid (11).

Moisture content

Samples of halva are brought to room temperature by cooling in a desiccator after being equilibrated to a constant weighing mass, and their masses are recorded. Sample containers, approximately 1 g ± 0.1 in weight, are weighed and subjected to drying in an oven (Nüve EN400, Turkey)

Figure 1. Tahini Halva Production Flow Chart

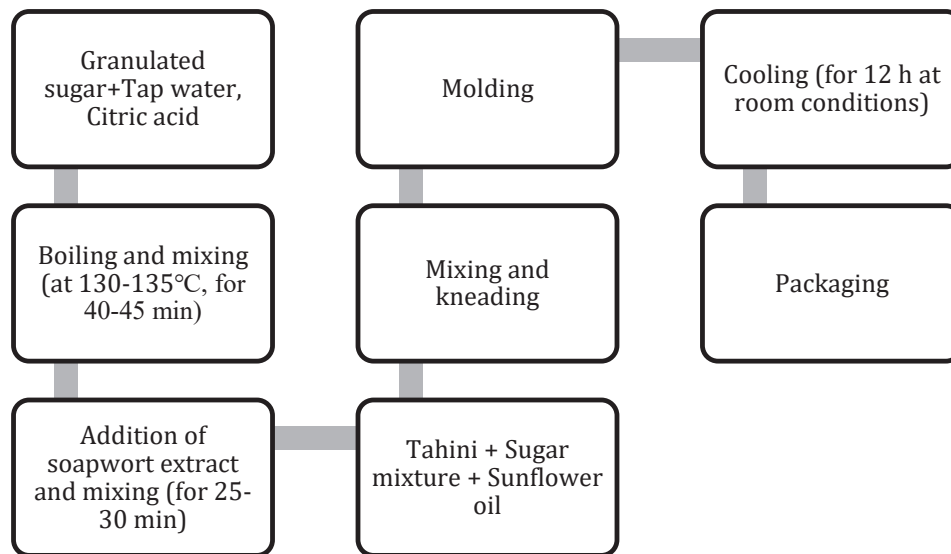


Table 1. Formulations Of Tahini Halva With Added Carob Flour (G)

Ingredients	Control	T1	T2	T3
Granulated sugar	40.00	40.00	40.00	40.00
Soapwort extract	1.00	1.00	1.00	1.00
Citric acid	0.05	0.05	0.05	0.05
Tahini	52.00	54.00	52.00	50.00
Cacao	3.00	-	-	-
Sunflower oil	3.95	3.95	3.95	3.95
Carob flour	-	1.00	3.00	5.00

until a constant mass is obtained at 105°C. The weight loss occurring after the drying process is calculated, and the moisture content is expressed as a percentage (11).

Ash content

The ash content of the halva samples was determined using the burning method in a muffle furnace (Nevo, Turkey) at 550-600°C. Approximately 5 g of halva samples, with a sensitivity of 0.1 mg, are weighed into pre-weighed crucibles and subjected to preliminary incineration before the ashing process. Subsequently, the samples are incinerated in the muffle furnace with a gradual temperature increase until ashed (11).

Total sugar content

The total sugar content was determined according to the phenol-sulfuric acid method reported by DuBois et al. (12). To prepare the blank solution, 1 mL of distilled water and 5 mL of concentrated H₂SO₄ was mixed with 1 mL of 5% phenol. Standard solutions used for calibration curve construction were prepared by dissolving glucose solutions in different concentrations. After dissolving 10 mg of the sample in 100 mL of distilled water, 1 mL of the solution was taken, to which 1 mL of 5% phenol solution and 5 mL of concentrated H₂SO₄ was added. The mixture was kept at room temperature for 10 minutes, and the absorbance was measured at 488 nm using a UV-VIS spectrophotometer.

Oil Separation Analysis

Samples of tahini halva produced from all formulations were transferred to 50 mL centrifuge tubes, with 20 g of each sample taken. Subsequently, the samples were heated to 35, 45, 50, and 55 °C in a hot water bath and centrifuged at 2000 rpm for 5 minutes. After centrifugation, the separated oil from the samples was collected using a Pasteur pipette and transferred to an Erlenmeyer flask, and the total released oil Percentage In The Halva Was Calculated (10).

Antioxidant Activity

Antioxidant activity was assessed following the method outlined by Brand-Williams et al.

(13). To do this, 5 g of sample was mixed with an 80% methanol solution for 30 minutes using a magnetic stirrer (Digitmex, Hong Kong). Following filtration, the mixture was centrifuged at 4500 rpm for 15 minutes. Subsequently, 100 µL of the resulting extract was pipetted into a cuvette, followed by the addition of 3900 µL of DPPH solution (1,1-diphenyl-2-picrylhydrazil radical) (3.94 mg/100 mL methanol). This mixture was then incubated in darkness for 30 minutes, after which the absorbance was measured at 515 nm using a UV-VIS spectrophotometer (UV-1601, Rayleigh, BFRL, China). The antioxidant activity, indicative of free radical scavenging activity, was determined using Trolox calibration and expressed as µmol Trolox equivalents per gram (µmol TE/g).

Color

Color assessment was conducted utilizing a colorimeter (Hunter Lab., Hunter Assoc. Laboratory, Reston, VA, USA). Prior to measurements, the colorimeter underwent calibration using a reference white. Findings were interpreted based on the L*, a*, and b* parameters (14)

Sensory Analysis

Sensory analysis was conducted by a total of 10 academic staff experienced in sensory evaluation within the framework of Toros University, along with 5 personnel experienced in halva production. A 5-point hedonic test was utilized for the evaluation of the color, texture, hardness, aroma, taste, and overall acceptability characteristics of the halva samples (10).

Statistical Analysis

The production of samples was conducted in two replicates, and analyses were performed in at least two parallels. The obtained results regarding physicochemical, oil separation, antioxidant activity, color, and sensory properties were subjected to analysis of variance using the SPSS statistical package program (IBM SPSS Statistics Version 23). In cases where there was a significant difference among the samples, the Duncan Multiple Comparison Test was employed at a 95% confidence interval to

determine the differences between the means (15).

RESULTS AND DISCUSSION

Physicochemical Properties

The titratable acidity, moisture, ash, and total sugar content values of tahini halvas produced using carob flour are shown in Table 2. The titratable acidity values of tahini halvas ranged from 1.30% to 2.09% in terms of oleic acid. According to the Turkish Food Codex Tahini Halva Regulation (1), the acidity in terms of oleic acid extracted from tahini halvas should not exceed 2%. It can be said that the acidity values of the samples in this study comply with the codex. It was found that as the amount of carob flour used increased, the acidity of the halvas also increased ($p < 0.05$). Herken and Aydın (16) used carob flour in tarhana production and determined that the acidity increased with the increasing level of carob flour usage. The researchers linked this increase to the high level of total soluble sugar content in carob flour. It has been emphasized that a higher content of sugar may also result in a more easily digestible substrate for microorganisms.

The moisture content of tahini halvas with added carob flour ranged from 1.78% to 1.86%. It was observed that the moisture content of halvas with added carob flour did not differ significantly from the control sample ($p > 0.05$). According to the Turkish Food Codex Tahini Halva Regulation (1), the moisture content in tahini halvas should not exceed 3%. In this study, it was determined

that the moisture content of all halva samples were below 3%, in compliance with the codex.

The Turkish Food Codex Tahini Halva Regulation (1) stipulates that the ash content of halva should not exceed 2%, and it was found that the values in this study were compliant with the codex. As the concentration of carob flour increased, the ash content of tahini halvas also significantly increased ($p < 0.05$). While the ash content of the control sample and the T3 sample with 5% added carob flour were statistically equivalent ($p > 0.05$), the ash content of the T1 and T2 samples with 1% and 3% carob flour, respectively, was significantly lower ($p < 0.05$). It is known that the ash content reflects the total mineral content of food (17). Carob flour has an average ash content of 2.8% and is particularly rich in minerals such as calcium (308.6 mg/100 g), potassium (1473.2 mg/100 g), and phosphorus (198.2 mg/100 g) (18). On the other hand, cocoa powder has a higher ash and mineral content compared to carob flour, but it was reported that both are dominated by minerals such as calcium, potassium, and phosphorus (6). Elyıldırım (19) reported that the ash content of walnut and cocoa tahini halvas varied between 1.03% and 1.07% over a 120-day storage period.

When examining the total carbohydrate content of the halvas, it was observed that the addition of carob flour significantly increased the carbohydrate content of the halvas ($p < 0.05$). Carob powder was a sweet product since it contained approximately 23% of soluble sugars, whereas cocoa powder is a bitter product due to

Table 2. Physicochemical Properties Of Tahini Halva Samples With Added Carob Flour (n=3)

Sample code	Titratable acidity (Oleic acid %)	Moisture (%)	Ash (%)	Total carbohydrate (glucose %)
Control	1.30±0.08 ^c	1.77±0.07 ^a	1.07±0.03 ^a	52.36±0.14 ^c
T1	1.30±0.05 ^c	1.83±0.03 ^a	0.77±0.06 ^c	53.44±0.19 ^b
T2	1.58±0.16 ^b	1.78±0.08 ^a	0.92±0.03 ^b	53.62±0.24 ^b
T3	2.09±0.07 ^a	1.86±0.01 ^a	1.01±0.02 ^a	55.27±0.15 ^a

Control: Tahini halva without carob flour, T1: Tahini halva containing 1% carob flour, T2: Tahini halva containing 3% carob flour, T3: Tahini halva containing 5% carob flour; ^{a, b, c}: Values indicated with different superscript letters in the same column are significantly different from each other at the $p < 0.05$ level.

its significantly low sugar level (approximately 0.20%) (6). Petkova et al. (20) reported that the total carbohydrate content of carob flour is 85.5%, with 57.44% being total soluble carbohydrate, 8.6% reducing sugar, 3.25% glucose, 4.16% fructose, and 34.13% sucrose. It is known that the dietary fiber content of carob flour is 30.35% (21). Consequently, the addition of carob flour enriches tahini halvas both with sugar and dietary fiber.

Oil Separation

The oil separation percentages of tahini halvas with added carob flour at different temperatures are presented in Table 3. Upon examination of the results, it was observed that as the temperature increased, the amount of oil separated increased in all samples. It was found that the cocoa used in the control sample, at a rate of 3%, exhibited greater oil retention properties compared to the 1% and 3% carob flour used in samples T1 and T2, respectively ($p<0.05$). The highest oil separation was observed in sample T1 ($p<0.05$), followed by T2. However, when carob flour was used at a rate of 5%, the oil separation percentages were lower than in the control sample, indicating significant preservation of emulsion stability ($p<0.05$). In fact, no oil separation was observed in sample T3 at 35°C. Thus, it was determined that the use of carob flour at a rate of 5% was more effective in preventing oil separation than cocoa. The ability of a substance to retain oil is primarily determined by its dietary fiber content, which can absorb and retain both water and oil (2). Numerous studies have explored not only the high fiber content of carob powder, but also its chemical composition and physical

structure, which varies depending on the processing method used to produce the powder. Carob powder contains a significant proportion of dietary fibers, comprising approximately 50% of its composition. As a result, carob powder can be regarded as a functional ingredient due to its abundant dietary fiber and polyphenol content (22). The higher dietary fiber content of carob flour (approx. 30-40%), compared to cocoa (up to 15%), explains its greater oil retention capacity (23).

Antioxidant Activity

The graph illustrating the antioxidant activities of tahini halvas is presented in Figure 2. Accordingly, it was determined that the antioxidant activities of tahini halvas with added carob flour were significantly higher than those with added cocoa ($p<0.05$), and as the concentration of carob flour used increased, the antioxidant activity also increased. The most abundant phenolic compound found in carob, which is rich in phenolic compounds, is gallic acid. Gallic acid, a natural phenolic compound found in plants, is an effective antioxidant, particularly effective in slowing down the oxidation of oils (24). By enhancing the antioxidant activity in tahini halvas, oxidation following oil separation can be prevented. There are studies indicating usage of carob flour in pasta (25), tarhana (18), and yogurt (26) productions, and it has been reported in these studies that carob flour increases the antioxidant properties in all products.

Table 3. Oil Release In Tahini Halvas With Added Carob Flour (%) (n=3)

Sample code	35°C	45°C	50°C	55°C
Control	3.48±1.13 ^b	3.78±1.02 ^c	4.60±0.88 ^c	5.15±0.76 ^c
T1	7.15±0.83 ^a	10.85±0.66 ^a	10.08±1.14 ^a	11.6±1.32 ^a
T2	7.08±0.20 ^a	7.45±0.94 ^b	7.45±0.86 ^b	8.58±0.52 ^b
T3	0.00±0.00 ^c	0.13±0.01 ^d	2.20±0.05 ^d	2.8±0.06 ^d

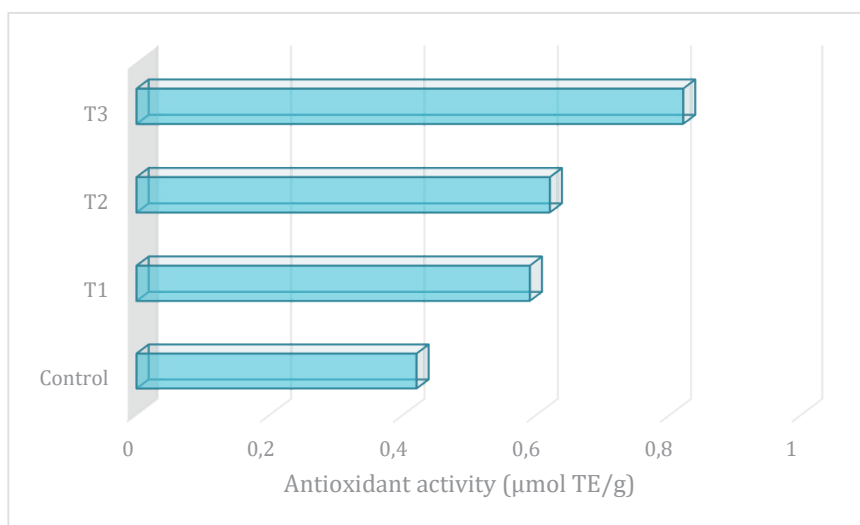
Control: Tahini halva without carob flour, T1: Tahini halva containing 1% carob flour, T2: Tahini halva containing 3% carob flour, T3: Tahini halva containing 5% carob flour; ^{a, b, c, d}: Values indicated with different superscript letters in the same column are significantly different from each other at the $p<0.05$ level.

Color Characteristics

The L^* , a^* , and b^* color parameters of tahini halvas are presented in Table 4. The L^* component represents lightness or brightness component and ranges from 0 to 100 (27). It was found that the sample T1, prepared with 1% carob flour, had the lightest color, and this lightness value was statistically different from the other samples ($p<0.05$). The control, T2, and T3 samples were generally darker in color, and there was no statistical difference in lightness among these three samples ($p>0.05$). The parameters a^* (from green to red) and b^* (from blue to yellow) are two chromatic components, and positive values indicate the presence of red and yellow tones in the food (27). It was observed that the addition of carob flour increased the redness of the tahini

halvas. While there was no statistical difference in the a^* values between the cocoa control sample and samples T1 and T2 ($p>0.05$), sample T3 had significantly more redness than all other samples ($p<0.05$). The samples with added carob flour had significantly higher yellowness levels than the control sample ($p<0.05$). The different concentrations of carob flour did not have any effect on the b^* value ($p>0.05$). Elyıldırım (19) reported the L^* , a^* , and b^* color values of cocoa sesame halvas as 31.86, 6.84, and 9.80, respectively, which are consistent with the color parameters in the current study, and it was also reported that the color values of cocoa tahini halvas were affected by different temperatures and storage periods.

Figure 2. Antioxidant Activities Of Tahini Halva Samples With Added Carob Flour (n=3)



Control: Tahini halva without carob flour, T1: Tahini halva containing 1% carob flour, T2: Tahini halva containing 3% carob flour, T3: Tahini halva containing 5% carob flour

Table 4. Color Characteristics Of Tahini Halva Samples With Added Carob Flour (n=3)

Sample code	L^*	a^*	b^*
Control	27.97±1.19 ^b	6.47±0.37 ^b	12.22±1.22 ^b
T1	34.60±2.65 ^a	7.17±1.20 ^b	16.87±1.14 ^a
T2	24.86±3.92 ^b	7.34±0.85 ^b	16.87±3.37 ^a
T3	23.11±2.53 ^b	9.24±0.72 ^a	19.45±2.55 ^a

Control: Tahini halva without carob flour, T1: Tahini halva containing 1% carob flour, T2: Tahini halva containing 3% carob flour, T3: Tahini halva containing 5% carob flour; ^{a, b}: Values indicated with different superscript letters in the same column are significantly different from each other at the $p<0.05$ level.

The color pigments in carob powder, especially those in brown tones, are typically polyphenolic compounds. Among these polyphenols, the most important ones are flavonols, which belong to the flavonoids class and give carob its dark brown color. Flavonols are the decisive polyphenolic compounds in the color of carob, usually associated with dark brown and reddish tones. Yellowish tones are likely derived from carotenoids (22, 28). The darker and more reddish and yellowish tones observed in tahini halvas with added carob flour indicate that carob flour contains more flavonols and carotenoids compared to cocoa powder. Myricetin and quercetin are flavonols found in carob fruit, present in carob flour at levels of 0.05 mg/g and 0.04 mg/g, respectively (29). The amount of quercetin in cocoa powder is reported to be in the range of 3.20-5.99 $\mu\text{g/g}$ (30).

Sensory Properties

The sensory properties of tahini halvas with added carob flour were determined based on parameters of color, texture, hardness, odor, taste, and overall acceptability, and the results are shown in Figure 3. When evaluating the color properties of the halvas, it was found that the sample T3 with 5% carob flour addition was equally liked as the control sample ($p>0.05$), but

lighter color caused by lower concentrations of carob flour was less preferred by the panelists ($p<0.05$). Additionally, no statistical difference was observed between the L^* values of the T3 sample and the control ($p>0.05$). Visual representations of the color and texture of the tahini halvas are presented in Figure 4. The non-roasted carob powder has a lighter color than cocoa powder because cocoa is sensitive to Maillard reactions and caramelization (31). Therefore, the use of carob flour at lower concentrations resulted in a lighter color.

All halvas received similar scores in terms of texture properties and hardness ($p>0.05$). The use of carob flour at any concentration had a positive effect on odor and taste, with all samples containing carob flour being found equivalent to the control sample in terms of taste and odor ($p<0.05$). When examining the scores for overall acceptability, it was determined that the panelists found all samples acceptable ($p<0.05$). Based on the sensory analysis, it was found that the use of carob flour in tahini halva was acceptable in terms of sensory properties, but when carob flour was used at higher concentrations to approach the familiar cocoa color, the halva was more liked. Similar results were specified by Tounsi et al. (6), where tahini halvas with 5% carob flour addition were reported as the most preferred sample in

Figure 3. Sensory Properties Of Tahini Halva Samples With Added Carob Flour



Control: Tahini halva without carob flour, T1: Tahini halva containing 1% carob flour, T2: Tahini halva containing 3% carob flour, T3: Tahini halva containing 5% carob flour

terms of hardness and overall acceptability.

CONCLUSION

Carob, a fruit abundant in the Mediterranean region, can be successfully used as a raw material in a variety of food products due to its high nutritional value and various functional effects. In this study, where carob flour was used to address one of the major issues in tahini halva, which is oil separation, and to prevent oxidation, the following key results were obtained. All samples of tahini halva met the criteria set by the Turkish Food Codex Tahini Halva Regulation for acidity, moisture, and ash content. Carob flour significantly increased the total carbohydrate content of tahini halva due to its total sugar and dietary fiber content. The use of 5% carob flour inhibited oil release in tahini halva more than cocoa. The addition of carob flour provided higher antioxidant activity in halva compared to cocoa, and as the amount of carob flour increased, antioxidant activity also increased. Tahini halva with carob flour had darker, redder, and more yellow coloration. This is attributed to the fact that carob flour is richer in flavonols than cocoa. Except for color, all sensory parameters were equally liked compared to the control sample. Tahini halva with low concentrations of carob flour was less preferred by panelists due to its light color, whereas the use of 5% carob flour resulted in a color similar to the control. Overall, the analysis indicated that the use of 5% carob flour provided the least oil release, highest antioxidant properties, best color characteristics, and most preferred sensory qualities.

Author Contributions

Study design: ÇÖ, BÖ, YÖ; Data acquisition: ÇÖ, BÖ; Data analysis: ÇÖ, BÖ, YÖ; Drafting the manuscript: ÇÖ, BÖ Critical review for content: YÖ and Final approval of the article: ÇÖ, BÖ, YÖ

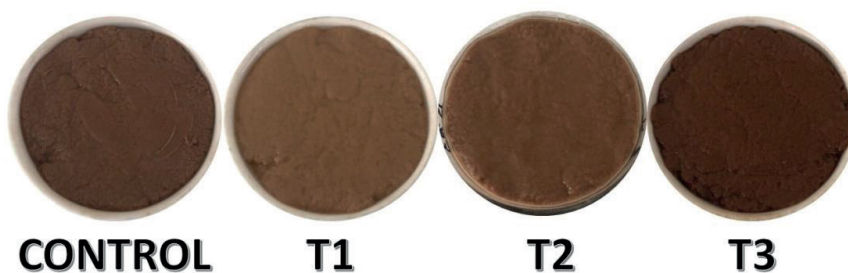
Conflict of Interest

All authors declared that they have no conflict of interest.

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Figure 4. Colors And Appearances Of Tahini Halva Samples With Added Carob Flour



Control: Tahini halva without carob flour, T1: Tahini halva containing 1% carob flour, T2: Tahini halva containing 3% carob flour, T3: Tahini halva containing 5% carob flour

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