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Research Article

Evaluation of the variations in the physicochemical and microbiological properties of tarhana enriched with a black carrot during the production process

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ABSTRACT

Anthocyanins are natural pigments in various fruits and vegetables, including black carrots. These pigments give the black carrot its dark purple color and have gained attention in the food industry due to their potential health benefits and functional properties. In this study, black carrot concentrate (BCC) was added to the tarhana formulation to improve the nutritional value and technological properties of tarhana, and its effects on the physicochemical, microbiological, and techno-functional properties of tarhana throughout the process were focused on. Fermentation increased the tarhana samples' total acidity, moisture, ash, and protein contents. After drying, BCC was observed in the tarhana formulation markedly increased the ash (2.57–2.14%) and anthocyanin content (27.53–1.06 mg/100g) compared to traditional tarhana. The microbial composition (LAB, yeast, and TMAB) was similar before fermentation, but microbial growth was higher in tarhana without BCC after fermentation. It was found that the time taken to reach approximately 10% moisture value in tarhana samples was 420 min at 60°C. BCC reduced fermentation loss (12.47-8.41%) and viscosity (267.08–214.05 (267.08-214.05 mPa.s). Drying and fermentation did not significantly affect the total color change. While the emulsification activity of the samples increased (40.31–55.05%), the foaming stability (7.62–3.16) decreased. BCC was not effective on the foaming capacity, water absorption capacity, or oil absorption capacity. Tarhana with 5% BCC was similar to traditional tarhana in taste, odor, color, grittiness, cohesiveness, and overall acceptability.

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INTRODUCTION

Carrot (*Daucus carota*), which belongs to the Apiaceae family, is one of the most consumed root vegetables worldwide and has many colors, including white, yellow, orange, red, and purple or black, due to its bioactive pigments. Although orange carrots are widely consumed today, black carrots have become a commercially valuable agricultural product due to their rich nutritional content and several functional health benefits. Black carrot, scientifically known as *Daucus carota* ssp. *sativus* var. *atrorubens* Alef, is cultivated in the eastern parts of the world, especially in countries such as Turkey, Pakistan, Afghanistan, Egypt, and India [1]. It is a good source of vitamins (A, thiamine, riboflavin, niacin, B6, biotin, and C), minerals (iron, phosphorus, calcium, magnesium, potassium, sodium, and zinc), and dietary fiber (cellulose, hemicellulose, lignin, and pectin). It also contains polyphenolic compounds, which give it its characteristic purple color. Anthocyanins are the most abundant water-soluble pigments in black carrots, known as a group of flavonoids, and have become increasingly important in the food industry due to their natural coloring properties. These bioactive components have emerged as promising agents with their role in preventing various metabolic disorders like diabetes, cholesterol, obesity, blood pressure, degenerative and inflammatory diseases, and their high antioxidant capacity [2–4].

Tarhana is a cereal-based traditional fermented food that has an important position in the Middle East, Anatolia, and the Balkans and is mostly consumed as a soup, but recently its consumption as chips has become widespread [5]. Tarhana is produced both at home and industrially, with increasing demands [6]. Although it varies from region to region, in the production of Tarhana dough, wheat flour, yogurt, various vegetables such as pepper, tomato, onion, and a few spices such as salt and pepper are generally used and dried after a period of fermentation. Lactic acid bacteria and yeasts play a role in the fermentation of tarhana and contribute to the characteristic acidic-sour taste and aroma formation of the fermentation products they produce, such as lactic acid, ethanol, CO_2, acetaldehyde, and diacetyl. These organic acids and some drying processes have a bacteriostatic effect on foodborne pathogens such as *Escherichia coli* O157:H7 and *Staphylococcus aureus* [7,8].

Fermented foods are among the functional products that positively affect human health. Fermentation increases the taste, flavor, nutritional value, bioavailability, digestibility, and shelf life of the product [9]. Tarhana is also considered a nutritious food product because it contains carbohydrates, free essential amino acids (particularly lysine and threonine), vitamins (B1, B2), and minerals (calcium, iron, sodium, potassium, magnesium, and zinc) from both plant and animal sources, as well as being fermented [10,11]. The amount and type of ingredients used in tarhana production can affect its nutritional value. There have been several studies on enriching the nutritional content of tarhana, but these studies have generally focused on searching for wheat flour substitutes [12–21]. In this study, black carrot concentrate (BCC) was used to enrich the nutritional value and physicochemical properties of tarhana. For this purpose, different amounts of BCC (5–10%) were added to tarhana dough, and the changes in the chemical, microbiological, and functional properties of tarhana throughout the process were examined and its drying properties were determined.

MATERIALS AND METHODS

Materials

The ingredients used in tarhana production were purchased from local markets in Istanbul, Turkey. Black carrot concentrate was obtained from Endemix Natural Ingredents Inc. in Istanbul, Turkey. The sourdough used was supplied by Istanbul Halk Ekmek (IHE) Inc. in Istanbul, Turkey. The materials were stored in the refrigerator at 4°C until production. All chemicals used in this study were obtained from Merck (Darmstadt, Germany).

Tarhana Production and Fermentation

Traditional tarhana was produced according to the method described by Bilgiçli et al. [22]with some modifications (Table 1). The ingredients (wheat flour, yogurt, tomato sauce, sourdough, grated onion, capia pepper, chili pepper, and table salt) were kneaded using an Arzum mixer (Arzum, Ar1069, Turkey) until exactly homogenized. To prepare tarhana enriched with (BCC), tomato sauce in traditional tarhana formulation was replaced with 5% and 10% BCC. The prepared tarhana dough was fermented at 25°C for 48 hours and dried at 60°C until it reached about 10% moisture using a cabinet dryer (APV Pasilac Ltd., London, UK). Dried samples were ground in a grinder (Karmatte, Turkey) and stored in polyethylene bags.

Chemical Analysis

The moisture, ash, and protein content of tarhana samples were determined using the standard methods of The American Association of Cereal Chemists [23]. The total acidity of tarhana samples was analyzed as previously described [24]. The total acidity values of the samples were given as % lactic acid. The water activity of the samples was performed using a water activity meter (Novasina, LabTouch-aw, Switzerland). All analyses were repeated 3 times in tarhana dough before and after fermentation and dried tarhana after drying.

Microbiological Analysis

To evaluate the microbial composition of tarhana samples before, after fermentation, and after drying, *Lactobacillus* spp. (LAB), yeast and total mesophilic aerobic bacteria counts (TMAB) were performed on Man Rogosa and Sharpe Agar (MRS), Potato Dextrose Agar (PDA), and Plate Count Agar (PCA), respectively. For this purpose, the tarhana sample (10 g) was weighed and homogenized

Table 1. Formulation of tarhana dough

Ingredients	BC0 (g)	BC5 (g)	BC10 (g)
Wheat flour	1000	1000	1000
Yogurt	400	400	400
Sourdough	150	150	150
Tomato sauce	200	105	10
Onion	50	50	50
Capia pepper	50	50	50
Chili pepper	20	20	20
Table salt	10	10	10
Black carrot concentrate	-	95	190

BC0: Traditional tarhana (control); BC5: Tarhana with 5% BCC; BC10: Tarhana with 10% BCC.

with a physiological saline solution (90 mL). Appropriately dilutions were inoculated into the relevant medium by the spread plate method. Then, the petri dishes were incubated at 30°C for 48 hours and the counting results were expressed as colony-forming units per gram logarithmically (log cfu/g).

Drying Characteristic Analyses

The data derived from drying tarhana was used to determine the drying characteristics of the samples. The moisture contents of tarhana samples were determined in certain periods according to Eq. 1 [25]:

$$M = (W_i - W_d)/W_d \quad (1)$$

where M is the moisture content (kg water/kg dry matter), W_i and W_d are, respectively, the weight of the sample (kg) and the dry matter content of the sample (kg).

The drying rate of tarhana samples was calculated using Eq. 2 [25]:

$$DR = (M_{t1} - M_{t2})/t_2 - t_1 \quad (2)$$

where DR is the drying rate (kg water/kg dry matter. min), and M_{t1} and M_{t2} are the moisture content (kg water/kg dry matter) at times t_1 and t_2 (min).

Fermentation loss was determined considering the weight of tarhana dough (dry matter basis) before and after drying [18].

Total Anthocyanin Contents

Total anthocyanin content was performed according to the pH differential method [26]. The pH of the appropriately diluted samples was adjusted to pH 1.0 (0.025 M potassium chloride adjusted to pH=1 with HCl) and 4.5 (0.4 M sodium acetate adjusted to pH=4.5 with HCl) with buffer solutions. The absorbance of the samples was measured at 510 and 700 nm using a UV-Vis spectrophotometer (Shimadzu, UV-1800, Kyoto, Japan). The total anthocyanin content was determined as mg of cyanidin-3-glucoside (Cy-3-glu) equivalents per 100 g of the sample.

Determination of Color

The colors of tarhana samples were measured using a chroma meter (Konica Minolta CR-400, NJ, USA) during fermentation and after drying. The color values of the samples were expressed as L^*, a^*, and b^*, which express whiteness/darkness, greenness/redness, and yellowness/blueness, respectively. Hue angle (h) and saturation index (SI) were calculated using a^* and b^* values with the following Eq. 3 and 4:

$$\text{Hue: } \arctan(b^*/a^*) \quad (3)$$

$$SI = \sqrt{(a^*)^2 + (b^*)^2} \quad (4)$$

To examine the effect of fermentation and drying on the color change of the samples, the total color difference index (ΔE) was calculated with Eq. 5:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (5)$$

Determination of Functional Properties

A rheometer (Anton Paar, MCR-302, Austria) was used to measure the viscosity of tarhana at 100 rpm and 60 °C. For this, the tarhana solution (10%) was prepared in distilled water and cooked on a hotplate until boiling [24].

For water and oil absorption capacities, 5 g of tarhana powder was homogenized in 25 mL of distilled water/sunflower oil by mixing for 60 min and then centrifuged at 4000 rpm for 20 min. Water and oil absorption capacity was expressed as ml water or oil/g tarhana [9].

For foam capacity and foam stability, after 10 g of tarhana powder was dispersed in distilled water, the mixture was centrifuged at 4000 x g for 20 min. The supernatant was whipped with a blender for 2 min and the volume of the foam was recorded after 10 s. The volume of gas added per ml of solution was used to calculate the foaming capacity. The time passed (min) until half of the original foam volume disappears representing the foaming stability [9].

For the emulsifying activity, after centrifuging 10 g of tarhana in distilled water, the supernatant and sunflower oil (1:1) were mixed. The mixture was mixed in a blender for 5 min. The ratio of the volume of the emulsified layer to the total volume of the mixture was used to express the emulsifying activity (%) [9].

Sensory Analysis

Tarhana preparation according to the method of Çağlar et al. [12] was used for sensory analysis with slight modifications. Tarhana powder (100 g) was mixed with tap water (1000 mL) and table salt (10 g) and cooked on medium heat until boiling. After boiling, butter (40 g) was added and cooked on low heat for 2 min. All samples were prepared in the same way. Tarhana soup was served in bowls and evaluated by 10 panelists who had tasted this soup before. All of the tarhana soups were evaluated in random orders by the panelists. Panelists evaluated the taste, odor, color, grittiness, cohesiveness, mouthfeel, and overall acceptability of tarhana soup using a 5-point scale.

Statistical Analysis

Statistical evaluation was performed with one-way ANOVA at a significance level of p=0.05 using the JMP ver. 6 software (SAS Institute, Inc., Cary, USA). Two different productions were performed and all measurements were studied in three parallels. The values were expressed as mean ± standard deviation.

RESULTS AND DISCUSSION

Chemical Characteristics

The chemical composition of tarhana enriched with BCC at different substitution levels (5 and 10%) is shown in Table 2. The increase in total acidity after fermentation was associated with lactic acid fermentation and there was no significant difference between the samples (p>0.05). The total acidity value obtained in this study was higher than in other enriched tarhana studies [10,27] and it increased with BCC in dried tarhana (p<0.05). The increase in the acidity of tarhana containing BCC can be attributed to the high carbohydrate content of these samples. BCC reduced the moisture content of tarhana from 43.95 to 39.25%, and with the loss of fermentation, the moisture content of the samples increased significantly after fermentation (p<0.05). On the other hand, as seen in Figure 2, the moisture level of the samples was approximately 10% at the end of the drying process applied for an equal period at constant temperature (p>0.05). According to the Turkish Standards Institute, the maximum moisture content in tarhana should not be more than 10%. Water activity is important in maintaining the shelf life and chemical stability of food. The water activity values of tarhana samples ranged between 0.86 and 0.87 after fermentation and 0.46 and 0.49 after drying (p > 0.05). Çolak et al. [28] examined a total of 138 traditional tarhana samples collected from different parts of Istanbul and found the minimum moisture content and water activity of the samples to be 10.35 and 0.658, respectively. Göncü

Table 2. Effect of black carrot concentrate on the chemical composition of tarhana

Characteristics	Tarhana samples	Before fermentation	Post fermentation	Dried tarhana
Total acidity (%)	BC0	$0.33±0.03^{b}$	$0.73±0.16^{a}$	$1.69±0.12^{b}$
	BC5	$0.52±0.00^{b}$	$1.00±0.06^{a}$	$2.13±0.00^{b}$
	BC10	$0.89±0.12^{a}$	$1.06±0.03^{a}$	$2.77±0.22^{a}$
Moisture (w/w %)	BC0	$43.95±0.40^{a}$	$47.82±0.59^{a}$	$10.29±1.44^{a}$
	BC5	$41.06±0.90^{b}$	$44.57±0.46^{b}$	$10.29±0.52^{a}$
	BC10	$39.25±0.05^{c}$	$41.67±0.01^{c}$	$10.71±1.94^{a}$
Water activity (aw)	BC0	$0.87±0.01^{a}$	$0.87±0.01^{a}$	$0.46±0.04^{a}$
	BC5	$0.86±0.01^{b}$	$0.86±0.01^{a}$	$0.47±0.01^{a}$
	BC10	$0.85±0.00^{b}$	$0.86±0.01^{a}$	$0.49±0.08^{a}$
Ash (w/w %)	BC0	$1.37±0.03^{b}$	$1.49±0.06^{b}$	$2.14±0.12^{b}$
	BC5	$1.50±0.02^{a, b}$	$2.01±0.09^{a}$	$2.45±0.06^{a}$
	BC10	$1.76±0.14^{a}$	$2.23±0.17^{a}$	$2.57±0.09^{a}$
Protein (w/w %)	BC0	$7.24±0.44^{a}$	$7.52±0.56^{a}$	$13.81±0.07^{a}$
	BC5	$7.28±0.57^{a}$	$7.45±0.52^{a}$	$13.67±0.78^{a, b}$
	BC10	$7.28±0.43^{a}$	$7.36±0.48^{a}$	$12.61±0.61^{b}$
Total anthocyanin (mg/100 g)	BC0	$10.02±1.80^{c}$	$8.66±1.50^{c}$	$1.06±0.17^{c}$
	BC5	$44.46±1.97^{b}$	$39.87±2.09^{b}$	$10.23±2.20^{b}$
	BC10	$84.62±0.32^{a}$	$82.95±1.31^{a}$	$27.53±2.46^{a}$

BC0: Traditional tarhana (control), BC5: Tarhana with 5% BCC, BC10: Tarhana with 10% BCC.

[29] also added the sour cherry puree to the tarhana and the aw did not change. The ash content increased from 1.49 to 2.23% after fermentation, and from 2.14 to 2.57% in dried tarhana. While BCC significantly increased the amount of ash ($p<0.05$), there was no difference between BC5 and BC10 ($p>0.05$). The amount of protein did not change before and after fermentation ($p>0.05$), but decreased from 13.81 to 12.61% with increasing BCC in dried samples ($p<0.05$). In other studies, the protein amount for traditional tarhana was 13.7, 14,67, and 14,84 % [29–31].

The total anthocyanin content of the black carrot concentrate used in the study was 1352.26 mg/100g. As seen in Table 2, adding black carrot concentrate to the tarhana formulation significantly increased the total anthocyanin content ($p<0.05$). Initially, the total anthocyanin content of tarhana dough ranged from 10.02 to 84.62 mg/100 g. Similarly, Pandey et al. [32] developed fortified dairy products by adding black carrot concentrate and found the total anthocyanin content of ice cream, yogurt, and butter enriched with 7.5% BCC, ranging from 24.52 to 113.27 mg/100 g. After fermentation, a slight decrease in anthocyanin was observed in the samples, which was attributed to the decomposition of anthocyanin by microorganisms [33]. Degradation of black carrot anthocyanins as a result of heat treatment caused a decrease in the anthocyanin content of the samples, the anthocyanin content of dried tarhana samples was between 1.06 and 27.53 mg/100 g. The results obtained from different studies showed that anthocyanins in black carrot juice and concentrates increased with increasing solid content, pH, and temperature during both heating and storage [34,35].

Different lowercase superscripts in the same column indicate a significant difference ($p\leq0.05$).

Microbiological Characteristics

Tarhana is a fermented cereal food produced as a result of lactic acid fermentation, in which lactic acid bacteria and yeast play an active role. The changes in the microbial composition of tarhana samples during the process are indicated in Figure 1. At the beginning of fermentation, the numbers of LAB, yeast, and TMAB were significantly different in all samples ($p>0.05$). The low acid content and fermentation conditions of tarhana dough further encouraged the growth of LAB in traditional tarhana. After fermentation, the number of LAB was 8.05 log cfu/g in the BC10 sample and went up to 9.81 log cfu/g in BC0. TMAB and yeast count increased at the end of fermentation, but there was no significant difference between samples ($p>0.05$). Our results were in agreement with Arslan-Tontul et al. [36], who reported that the yeast count increased from 7.51 to 7.91 log cfu/g and the TMAB count increased from 7.49 to 7.92 log cfu/g in the first 2 days of fermentation. Similarly, Kumral [37] reported that the LAB and yeast counts of tarhana samples increased, but the number of microorganisms tended to decrease as the fermentation time ascended. Moreover, Kıvanç and Funda [38], the number of LAB, yeast, and TMAB increased rapidly within 3 days after fermentation. LAB, yeast, and TMAB count in dried tarhana samples ranged from 4.56 to 3.00, 3.34 to 2.08, and 3.45 to 2.65, respectively ($p<0.05$). In addition, mold was not detected during the whole process. Looking at the results, it was seen that the enrichment of tarhana dough with BCC partially negatively affected microbial growth. Gulbandilar et al. [39] analyzed homemade and commercially dried tarhana samples and found an average TMAB count of 3.10 log cfu/g. Aktaş and Akın [40]reported that in tarhana samples enriched with rice and corn bran, the mean TMAB count was 5.71 log cfu/g, while LAB was 6.39 log cfu/g.

Drying Characteristics

The drying characteristics of tarhana samples dried in the cabinet dryer were investigated at a constant temperature. The drying curves of tarhana samples are presented in Figure 2. In all samples, the drying process was performed until the final moisture content of the resulting tarhana powder reached approximately 10% (w/w). The time to reach the desired moisture content was 420 min at 60°C. As expected, the moisture content of the samples declined continuously with time and the moisture content at the end of the drying period was approximately 10%.

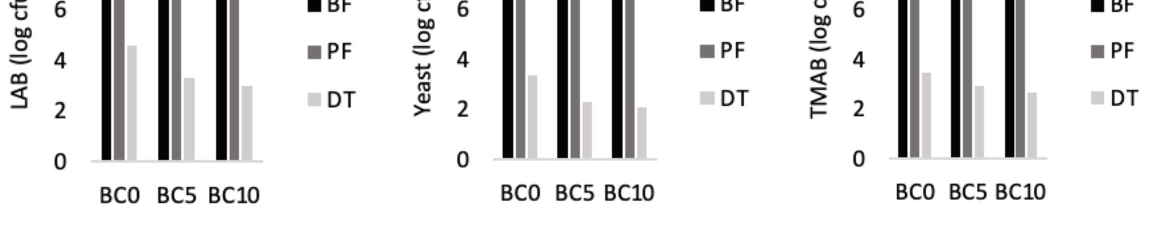

Figure 1. Microbial changes during tarhana production: LAB, yeast, and TMAB counts.

BC0: Traditional tarhana (control); BC5: Tarhana with 5% BCC; BC10: Tarhana with 10% BCC; BF: Before fermentation; PF: Post-fermentation; DT: Dried tarhana.

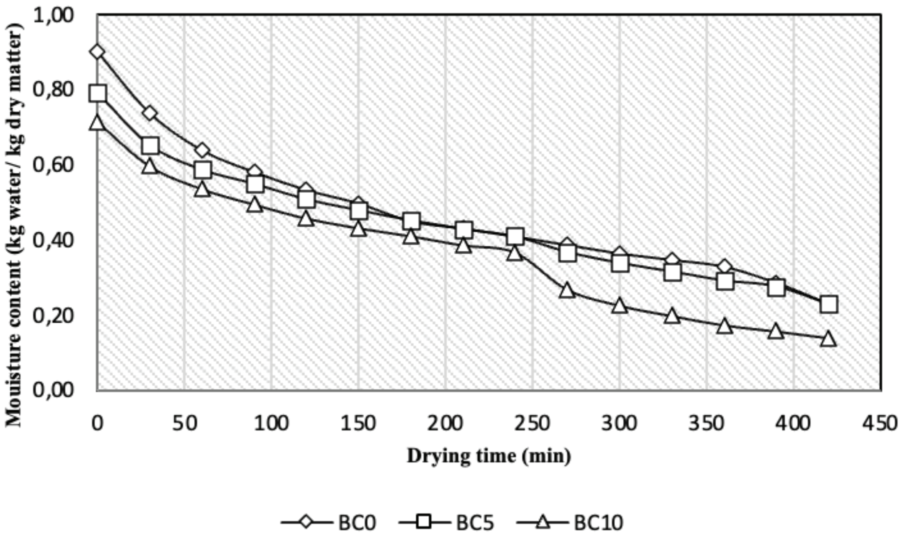

Figure 2. Drying curves of tarhana samples at 60°C

BC0: Traditional tarhana (control); BC5: Tarhana with 5% BCC; BC10: Tarhana with 10% BCC.

The changes in drying rate depending on time are shown in Figure 3. As can be seen, the drying rate was the fastest at the beginning of the drying process in all samples, and the rate mostly diminished with time. The sample with the highest initial drying rate was the control (BC0) with the highest initial moisture content. A constant drying period was not observed in the drying curves of tarhana samples. Similar results were also reported in previous studies for tarhana [41,42]. BCC additive caused a decrease in the moisture content of the product and accordingly, the drying rate was decreased, which may be related to the use of BCC as a tomato sauce substitute.

Color Values of Tarhana

Color plays an important role in consumer preference when considering the sensory properties of foods. Color values of the tarhana samples are shown in Table 3. The effect of BCC addition on L^*, a^*, and b^* values was significant ($p<0.05$), and BCC fortification decreased L^* (lightness), and b^* (yellowness) but increased a* (redness). This shows the effect of the natural BCC bluish-purple color

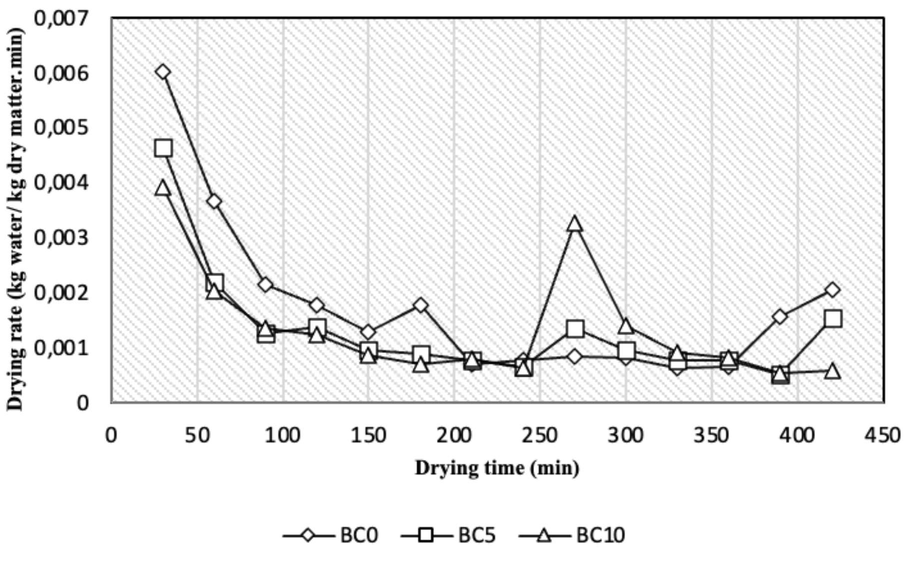

Figure 3. Drying rate curves of tarhana samples at 60°C

BC0: Traditional tarhana (control); BC5: Tarhana with 5% BCC; BC10: Tarhana with 10% BCC;

with high levels of anthocyanins [43]. However, L^*, a^*, and b^* values decreased during the fermentation process, while the L^* value of dried tarhana increased in all samples. The higher L^* values of the dried samples suggest that they had a brighter color as compared to the fresh samples. The changes in a^* value after drying might be due to temperature-induced decomposition in anthocyanin pigments from black carrots [35,44]. SI values showed a decrease during the drying and fermentation process, but the difference was significant only in the drying process ($p<0.05$). The hue angle of the dried and fresh tarhana samples was between 0° and 90°, representing a color in the red/yellow region (Fig. 4). According to Table 3, h values were different compared to control at all determined stages ($p<0.05$) and were highest in control (close to yellow). ΔE value was highest in BCC-added samples after drying, but there was no significant difference between samples ($p>0.05$). While the total color change was not significant after the fermentation and drying process, the color parameters (L^*, a^*, and b^*) showed different trends ($p<0.05$). The results showed that the effect of the drying process on the total color change was greater than the fermentation process, likewise in samples with BCC added.

Functional Characteristics of Tarhana

Fermentation loss is substantial from the point of functional and sensory properties of tarhana. In addition, long fermentation time causes losses in dry matter, which means economic loss [13]. When the tarhana samples with BCC were compared with BC0, the fermentation loss ranged between 8.41% and 12.47% and was different from each other ($p<0.05$). These results showed that the fermentation loss decreased as the amount of BCC added to the tarhana increased (Table 4), which may be due to lower microbial activity (Fig. 1). This situation was also associated with less dry matter loss in BCC added samples (Table 2). Ismail et al. [17] determined the fermentation loss between 7.12-12.61% for tarhana samples made with wheat flour, whole wheat flour, oatmeal flour, and whole barley flour.

Different lowercase superscripts in the same column indicate a significant difference ($p\leq0.05$).

On the other hand, some functional properties of tarhana samples are summarized in Table 4. Among the samples enriched with black carrots, the highest viscosity value (267.08 mPa·s) was revealed in tarhana without BCC (Table 4). The addition of BCC significantly reduced viscosity ($p<0.05$), which may be related to dietary fibers in

Table 3. Color values of tarhana samples

Characteristics	Tarhana Samples	Before Fermentation	Post Fermentation	Dried Tarhana
L^*	BC0	66.42 ± 5.65^a	68.87 ± 3.88^a	73.58 ± 1.26^a
	BC5	52.14 ± 3.41^b	49.58 ± 1.24^b	61.80 ± 0.16^b
	BC10	44.20 ± 0.49^c	43.82 ± 1.23^c	54.98 ± 0.99^c
a^*	BC0	10.09 ± 1.41^c	10.47 ± 0.63^c	8.43 ± 0.63^c
	BC5	22.37 ± 0.07^b	18.11 ± 1.12^b	14.26 ± 0.64^b
	BC10	27.38 ± 0.31^a	23.26 ± 4.44^a	18.1 ± 0.91^a
b^*	BC0	26.52 ± 0.39^a	25.23 ± 7.07^a	25.09 ± 0.08^a
	BC5	13.25 ± 0.32^b	$10.88\pm1.53^{b,a}$	14.02 ± 0.63^b
	BC10	8.87 ± 1.10^c	7.23 ± 1.42^b	8.59 ± 1.15^c
SI	BC0	28.39 ± 0.87^a	27.36 ± 6.76^a	26.47 ± 0.28^a
	BC5	26.00 ± 0.10^b	21.13 ± 1.74^a	20.00 ± 0.90^b
	BC10	28.79 ± 0.04^a	24.36 ± 4.66^a	20.04 ± 1.31^b
h	BC0	81.72 ± 2.03^a	79.39 ± 4.50^a	83.54 ± 0.92^a
	BC5	19.29 ± 0.72^b	19.77 ± 2.87^b	44.13 ± 0.00^b
	BC10	6.28 ± 1.61^c	5.71 ± 0.00^c	12.68 ± 1.93^c
ΔE	BC0	-	6.08 ± 2.17^a	7.90 ± 2.61^a
	BC5	-	5.89 ± 0.56^a	13.34 ± 1.29^a
	BC10	-	4.55 ± 4.70^a	13.15 ± 0.05^a

L^*: lightness; a^*(+/-): red/green; b^*(+/-): yellow/blue; SI: saturation index; h: hue angle; ΔE: the total color difference index. BC0: Traditional tarhana (control); BC5: Tarhana with 5% BCC; BC10: Tarhana with 10% BCC. Different lowercase superscripts in the same column indicate a significant difference ($p\leq0.05$).

Figure 4. Color characteristics of tarhana samples during production (A) Traditional tarhana (BC0); (B) Tarhana with 5% BCC; (C) Tarhana with 10% BCC; BF: Before fermentation; PF: Post-fermentation; DT: Dried tarhana.

Table 4. Fermentation loss and some functional characteristics of tarhana samples

Samples	Fermentation loss (%)	Viscosity (mPa.s)	Foaming capacity (mL/mL)	Foaming stability (min)	Water absorption capacity (mL/g)	Oil absorption capacity (mL/g)	Emulsifying activity (%)
BC0	12.47±0,48[a]	267.08±1.03[a]	0.08±0.03[a]	7.62±1.97[a]	0.78±0.32[a]	1.13±0.11[a]	40.31±2.21[b]
BC5	10.86±0.02[b]	242.30±2.33[b]	0.10±0.01[a]	3.37±1.75[b]	0.85±0.00[a]	1.20±0.07[a]	44.72±0.39[b]
BC10	8.41±0.04[c]	214.05±5.66[c]	0.16±0.15[a]	3.16±1.07[b]	0.75±0.00[a]	1.10±0.00[a]	55.05±0.71[a]

BC0: Traditional tarhana (control); BC5: Tarhana with 5% BCC; BC10: Tarhana with 10% BCC.

tomato sauce which tend to increase consistency due to the reduced amount of tomato sauce [45]. Abou El Samh et al. [46] also determined the viscosimetric properties of black carrot-added probiotic yogurt using a Brookfield viscometer and reported a significant decrease in the viscosities of their products. Foaming is associated with fermentation, the breakdown of proteins during fermentation increases foam stability [47]. The addition of BCC did not affect the foaming capacity of tarhana ($p>0.05$) but its foaming stability ($p<0.05$) (Table 4). The highest foaming capacity and the lowest foaming stability were found at BC10. Caglar et al. [12] also added carob flour to tarhana and the foaming capacity increased from 0.78 to 0.91 ml/ml. In gluten-free tarhana formulations developed by Köten [47], it increased from 0.12 to 0.34 ml/ml. Tarakçı et al. [10] added cherry laurel to tarhana and, like our study, foam stability decreased from 10 to 7.49 min. The water absorption capacity is an important factor in providing the desired viscosity in products such as soup, confectionery, and bakery products. The oil absorption capacity also indicates the degree of hydrophobicity of the food, substantial for overall consumer acceptability [48]. No significant differences were found in the water and oil absorption capacities of the tarhana samples (p> 0.05). Ertaş et al. [49] found the water and oil absorption capacity of tarhana enriched with whey concentrate to be 0.73-0.41ml/g and 0.93-0.76 ml/g, respectively. The emulsifying activity is a result of the interaction of fat and protein. Proteins provide emulsification by forming a film around the oil droplets, thus preventing phase separation within the food system [50]. The emulsifying activities of the samples ranged from 40.31% to 55.05%. The highest emulsifying activity was observed in the tarhana sample containing BC10. The results were consistent with the values (35-43.75%) reported by Tangular and Tatlısoy [51] .

Sensory Characteristics

The sensory characteristics of tarhana soups prepared with BC0, BC5, and BC10 were presented in Figure 5. The results showed good acceptability with the highest score of tarhana soup without BCC added for all attributes tested (p<0.05). The highest level of BCC addition (10%) was found to affect the sensory characteristics of the resulting tarhana soup, where significantly lower scores were obtained for all attributes tested compared to the BC0. With the addition of 5% and 10% BCC, there was no statistical difference in grittiness and cohesiveness values (p>0.05), but taste, odor, color, overall acceptability, and mouthfeel were different (p<0.05). These sensory results indicated that the addition of 5% BCC in tarhana soup was sufficient to be acceptable.

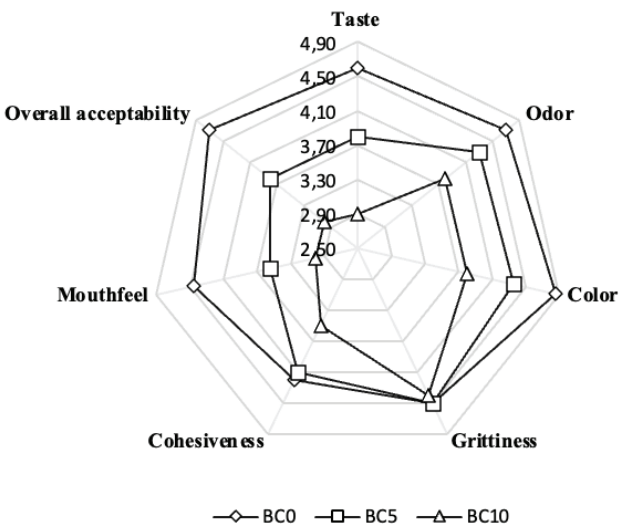

Figure 5. Sensory characteristics of tarhana samples.

BC0: Traditional tarhana (control); BC5: Tarhana with 5% BCC; BC10: Tarhana with 10% BCC.

CONCLUSION

In our research, the effect of BCC on the physicochemical, microbiological, functional, sensory, and drying properties of tarhana was investigated during the tarhana production process. BCC affected the properties of tarhana depending on the concentration. Our findings revealed that fortifying tarhana with black carrot markedly improved its chemical properties due to increased ash and total anthocyanin content. BCC caused a decrease in the moisture content of the product, and accordingly, the drying rate decreased over time. The fermentation and drying process did not have a substantial effect on the overall color change, but the color parameters (L^*, a^*, and b^*), especially a^*, showed different trends. The addition of black carrot concentrate significantly reduced fermentation loss and viscosity without greatly affecting the functional properties of tarhana. The results also showed that BCC could be used to develop generally acceptable tarhana. Therefore, a new more functional tarhana can be developed with BCC.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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