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Use of Carob Flour in the Production of Tarhana

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In this study, the effect of carob flour incorporation on some physical, chemical, technological, sensory and functional properties of tarhana was investigated. Carob flour was replaced with wheat flour at 0, 5, 10, 15 and 20% levels in tarhana dough. Dietary fibre, raw fibre, ash, Ca, K, Cu, total phenolic compound contents and total antioxidant capacity of dry tarhana samples as well as the acidity values during fermentation of the wet tarhana samples increased with carob flour substitution. Samples with supplementation had lower lightness and higher Hunter *a* and *b* values. Carob flour addition decreased the viscosity and yield stress of tarhana soup samples. The results showed that carob flour addition affected all the parameters measured to various extents including sensory properties. Overall acceptability scores were most highly correlated with taste. According to the sensory analysis results, carob flour can be used successfully up to the amount of 15%.

INTRODUCTION

Carob fruit (carob pod), which is the fruit of the carob tree (*Ceratonia siliqua* L. Fabaceae), is naturally grown in Turkey. Carob products have been gaining importance because their functional properties contribute to human diet especially in the Mediterranean areas of Europe and Turkey [Ayaz *et al*., 2009; Yousif & Alghzawi, 2000]. Carob pods, after roasting and milling, can be directly used in the form of flour for a range of products mainly as cocoa substitute; or generally modified into other products, mostly to pekmez (thick syrup). The average proximate composition of raw carob pods is 8–10% moisture, 90–91% carbohydrate (total sugars of sucrose (34–46%), glucose (2–5%) and fructose (2–5%)), 30–36 % dietary fibre, 3–4% protein, 3% polyphenols with gallic acid being the most abundant phenolic acid, 0.5–0.9% fat and 2–3% ash rich in Ca, P and K [Ayaz *et al*., 2007; Iipumbu, 2008].

Tarhana, an important traditional food consumed widely in the Turkish diet, is mainly prepared by mixing yogurt, wheat flour, yeast and a variety of vegetables and spices followed by fermentation for one to seven days [Ibanoğlu *et al*., 1995]. Both lactic bacteria and yeast fermentations occur simultaneously during tarhana production and, partial digestion of nutrients results in a product with improved digestive properties [Turker & Elgün, 1995]. After fermentation, the mixture is sun dried and kept generally as a dried powder for almost a year. Owing to its low pH (3.8–4.2) and moisture content (6–9%), tarhana is a naturally safe product with a long shelf-life [Ibanoglu & Ibanoglu, 1997]. Tarhana has been fortified or supplemented before to increase its biological value [Turker & Elgün, 1995; Tarakci *et al*., 2004; Erkan *et al*., 2006; Bilgicli *et al*., 2006; Lar *et al*., 2013].

Although many functional and nutritional properties of carob fruit are limited to such products as carob pekmez, carob flour has a potential to be used in tarhana. Thus, this study was designed to understand the effect of carob flour (CF) on some important properties of tarhana.

MATERIALS AND METHODS

Raw materials

The wheat flour used was a commercial variety, Type 550 (Efsane Wheat Flour, Turkey) and yoghurt was full fat commercial brand (BIM Co., Turkey) made from cow's milk. The other ingredients, tomato paste (32°Brix), compressed baker's yeast, fresh onion bulbs (peeled, washed and chopped), dry hot red pepper, dry mint and table salt were obtained from local markets in Denizli. CF is obtained from a national carob products producer in Mersin (Atışeri Ltd.).

Tarhana production

Five different tarhana formulations including 0, 5, 10, 15, 20% CF on wheat flour basis were prepared with two replicates. Based on 1000 g wheat flour, 500 g yoghurt, 120 g tomato paste, 120 g onion, 20 g dry red pepper, 30 g water, 20 g baker's yeast, 15 g salt and 2 g dry mint were used as raw materials. After blending the onions for 30 s (Model A516, Kenwood Limited, New Lane, Havant), tomato paste, dry red pepper and dry mint were added and blended for further 30 s. Wheat flour, carob flour, salt, yoghurt, tap water and baker's

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yeast were added to the mixture. The dough was covered and fermented at 30°C for 4 days in an incubator with intermittent kneading. Sampling was made once every 24 h over the fermentation period. After fermentation, the mixture was dried in an air oven in stainless steel trays (Status, Sainsbury Way, Hessle) at 50°C for 48 h and finely ground (Lionhill Mill 14920, Copenhagen, Denmark) to a particle size smaller than 1 mm for further analyses. Dried samples were kept at 4°C for a month.

Preparation of tarhana soups

Dry tarhana (100 g) was well mixed with 1000 g water, 40 g sunflower oil and 10 g salt. After boiling for 5 min with continuous stirring, soups were cooled to 70°C for sensory analysis and to 60°C for viscosity measurements.

Colour

A colorimeter (Minolta Chroma meter CR-300, Osaka, Japan) was used to determine the Hunter lab colors of whiteness (*L*-), red/greenness (*a*-), and yellow/blueness (*b*-) values of the dried tarhana samples with the light source D and standard viewer 65°.

Chemical analysis

Dried and ground tarhana samples were analysed for moisture, ash and protein by standard methods [AOAC, 2005]. The conversion factor of 6.25 was used for the crude protein content. Acid concentration of dried and ground samples (10 g) was determined according to Turkish Tarhana Standard [Anon., 1981]. Acidity number is defined as the quantity of 0.1 mol/L NaOH used to neutralise the acidity of 10 g tarhana sample dissolved in 67% ethyl alcohol. The pH was measured by a digital pH meter (HI 2210, Hanna Instruments, Michigan, USA) after mixing 10 g of sample with 100 mL of distilled water during and at the end of the fermentation process (0, 24, 48, 72 and 96 h).

The analysis of the mineral content of the samples was made using a PerkinElmer® Optima™ 2100 DV ICP-OES (PerkinElmer Life and Analytical Sciences, Shelton, CT, USA).

Total dietary fibre and crude fibre were analysed in the laboratories of The Scientific and Technical Research Council of Turkey, TUBITAK-Marmara Research Centre-Food Institute according to the enzymatic-gravimetric method (AOAC 991.43) [AOAC, 2005] and FiberTech Instruction Manual, respectively. Amino acid and fatty acid composition were analysed in the laboratories of TUBITAK by using a UFLC (Ultra Fast Liquid Chromatography) instrument and a Perkin Elmer Autosystem XL Gas Chromatograph (IUPAC II.D.19 method), respectively.

Determination of *in vitro* protein digestibility (IVPD)

The IVPD of the samples was determined by the modified methods of Hsu *et al*. [1977] and Dahlin & Lorenz [1993] as expressed by Herken & Con [2014].

Rheological measurements

The rheological characteristics of tarhana soup samples were studied using a Brookfield Viscometer DVII+ (Brookfield Eng. Labs. Inc., Stoughton, MA, USA) provided by a circulating water bath maintained at 60°C. The viscometer was operated between 0–180 rpm by gradually increasing the velocity at each 30 s collecting 12 different values (spindle number SC4–21, sample chamber SC4–13R). Each result was recorded in mPa s after 30 s rotation. Data were fitted using the Bingham Plastic Model which can be expressed as follows and the flow curve parameters determined.

$$\tau = \tau^{\circ} + \eta \cdot \gamma$$

where τ is the shear stress (D/cm^2), τ° is the yield stress (D/cm^2), η is the plastic viscosity (cp) and γ is the shear rate (s^{-1}).

Total phenol (TP) content and total antioxidant capacity (TAC) determination

Total phenol contents of the samples were determined using Folin–Ciocalteu reagent described by Skerget *et al*. [2005]. For this purpose, 9 mL of a working solution (methanol/water:1/1) and 1 g sample were kept at 4°C for 24 h by shaking periodically, then centrifuged for 5 min at 5000 rpm. The supernatant (2 mL) was taken into a tube and mixed with 10 mL of 10-fold diluted Folin–Ciocalteu reagent. Sodium bicarbonate solution (8 mL, 20% w/w) was added to the mixture

TABLE 1. Some chemical and mineral composition of WF and CF with their IVPD values and the same values of the tarhana samples as affected by the supplementation (on dry base).

Sample*	Dry matter (%)	Ash (%)	Protein (%)	Fat (%)	IVPD	Ca (mg/100 g)	K (mg/100 g)	Cu (ppm)	Total dietary fibre (%)	Raw fibre (%)
WF	90.3±0.2	0.52±0.03	10.41±0.15	3.05±0.05	78.7±0.9	24.4±0.1	151.1±0.1	2.2±0.1	3.1±0.1	1.13±0.05
CF	93.6±0.1	2.89±0.01	3.98±0.13	1.63±0.01	74.1±0.8	291.6±0.4	1028.0±3.4	4.8±0.1	35.2±0.0	5.06±0.01
C	94.6±0.1	3.35±0.02[e]	12.02±0.11[a]	4.17±0.15[a]	81.2±0.1[a]	121.8±1.2[e]	517.8±0.4[e]	3.3±0.1[e]	5.2±0.0[e]	1.03±0.01[e]
T5	94.1±0.3	3.41±0.01[d]	11.98±0.67[a]	4.32±0.11[a]	80.4±0.9[a]	132.4±0.3[d]	560.8±0.8[d]	3.7±0.0[d]	7.3±0.1[d]	1.21±0.02[d]
T10	94.8±0.2	3.54±0.01[c]	11.90±0.43[a]	4.08±0.25[a]	80.1±0.1[a]	141.0±1.4[c]	582.8±1.2[c]	3.8±0.0[c]	9.4±0.0[c]	1.38±0.03[c]
T15	94.7±0.2	3.59±0.02[b]	12.04±0.12[a]	4.25±0.18[a]	81.1±0.8[a]	154.2±0.5[b]	643.5±3.4[b]	3.9±0.0[b]	11.4±0.1[b]	1.69±0.04[b]
T20	93.8±0.3	3.77±0.02[a]	12.06±0.13[a]	4.12±0.22[a]	81.0±0.1[a]	180.7±2.4[a]	742.5±2.5[a]	4.2±0.1[a]	13.5±0.0[a]	2.01±0.04[a]

*WF: wheat flour, CF: carob flour, C: control tarhana, T5: 5% carob flour supplemented tarhana, T10: 10% carob flour supplemented tarhana, T15: 15% carob flour supplemented tarhana, T20: 20% carob flour supplemented tarhana, IVPD: *In vitro* protein digestibility. Different letters designate statistical differences ($p \leq 0.05$).

and incubated at room temperature for 2 h; then absorbance was read at 760 nm in a spectrophotometer (Shimadzu UV-1601, Shimadzu Scientific Instruments, Inc., Tokyo, Japan) against the blank. Gallic acid (Aldrich Chem. Co., Milwaukee, WI) was used in the standard preparation. Results were expressed as mmol/L gallic acid equivalent (GAE)/g. Total antioxidant capacity (TAC) of the samples was determined according to a method described by Erel [2004] by using commercially available kits (Relassay, Turkey). Results were expressed as mmol/L Trolox equivalent (TE)/g.

Sensory analysis

Sensory evaluations were performed by using twenty panelists who consume and are accustomed to tarhana soup in their diet. A 5-point hedonic scale ranging from 1 (dislike extremely) to 5 (like extremely) was used to evaluate product attributes of colour, odour, taste, consistency, and general acceptability. The coded samples were served to the panelists at random to guard against any bias.

Statistical analysis

Results are presented as mean values. Data are tested using SPSS for Windows Release 17 (SPSS Inc.). Statistical analysis of the results is based on one-way analysis of variance (ANOVA) and Tukey's multiple range analyses. Statistically significant differences are considered at the level of p≤0.05 unless otherwise given.

RESULTS AND DISCUSSION

Chemical composition, IVPD and fibre content

According to the results (Table 1), the ash content of wheat flour (maximum ash content of 0.55%) confirms the labelled content of the flour used in this study. The ash content of the samples increased up to 3.77% when 20% of CF substitution is applied. Protein contents of the samples were very close to the lowest limit value of 12% given in the Tarhana Standard [Anon., 1981] and they did not differ significantly, because the other raw materials, especially yoghurt also contain protein and, the substitution level was not high enough to see the difference. CF addition did not have a significant effect on IVPD parameters with respect to the control group. Protein digestibility values were observed to be above 80% confirming the studies of Bilgicli *et al*. [2007] and Herken & Çon [2014]. Fermentation has previously been reported [Herken & Çon, 2014; Sindhu & Khetarpaul, 2001] to have a positive effect on protein digestibility values. This can be attributed to the modification of proteins and decrease of antinutritional factors during fermentation as protein digestibility is reported to be affected by various antinutrients [Parihar *et al*., 1993]. Carob flour has a low protein content whereas wheat flour is also deficient in lysine. Amino acid results (Table 2) were affected by the other raw materials such as yoghurt and vegetables and some amino acid values such as alanine, glysine, valine, serine, proline, tryptophan, aspartic acid, Cis-4-hydroxy-D-Proline Hyp, lysine and histidine did not change with the rate of substitution. However, the substituted samples had approximately 10% lower amino acid values for glutamic acid, methionine, leucine, threonine,

TABLE 2. Amino acid and fatty acid composition of carob flour and tarhana samples†.

	CF	C	T5	T10	T15	T20
Amino acids (mg/100 g)						
Alanine (Ala)	441.8	540.8	533.4	525.0	510.1	500.2
Glycine (Gly)	145.0	553.1	530.5	515.2	505.3	501.0
Valine (Val)	263.7	688.5	676.5	660.3	637.1	610.2
Leucine (Leu)	283.4	1038.6	1010.4	975.2	933.4	907.7
Isoleucine (Ile)	173.6	604.1	589.6	566.3	546.6	518.1
Threonine (Thr)	328.3	514.3	511.3	510.3	478.6	459.9
Serine (Ser)	71.5	703.9	645.5	611.9	660.6	678.8
Proline (Pro)	576.0	2977.54	3005.7	3035.3	2978.5	2946.7
Arginine (Arg)	69.5	407.64	422.2	442.1	436.5	448.1
Tryptophan (Trp)	26.7	173.99	162.1	151.8	155.4	158.2
Aspartic acid (Asp)	305.3	589.14	576.5	566.8	555.2	546.4
Methionine (Met)	n.d.	129.2	104.2	92.9	77.7	58.3
Cis-4-hydroxy-D-Proline (Hyp)	231.0	1479.1	1454.3	1436.2	1430.1	1420.3
Glutamic acid (Glu)	383.5	4499.2	4244.6	4030.4	3686.8	3288.3
Phenylalanine (Phe)	150.5	761.0	734.6	694.7	672.1	652.3
Lysine (Lys)	123.1	731.3	701.2	696.3	689.1	692.8
Histidine (His)	62.2	455.2	450.2	431.3	446.6	458.8
Tyrosine (Tyr)	44.7	374.1	345.9	319.2	289.1	263.3
Σ Protein*	3.8	10.8	10.6	10.4	10.3	10.2
Fatty acids (%)						
C15:0	n.d.	0.73	0.75	0.76	0.75	0.73
C16:0	21.7	26.9	26.6	26.9	26.7	25.9
C16:1	n.d.	1.26	1.25	1.28	1.27	1.28
C17:0	n.d.	0.42	0.42	0.43	0.42	0.41
C18:0	4.73	6.99	7.11	7.31	7.20	7.06
C18:1n9c	46.46	20.30	20.41	20.50	19.97	19.61
C18:2n6c, Omega-6	23.79	23.68	22.80	22.46	21.08	19.98
C18:3n6	2.22	1.54	1.48	1.41	1.33	1.23
C20:0	n.d.	0.18	0.18	0.17	0.18	0.18
C20:1n9c	n.d.	0.75	0.71	0.69	0.70	0.72
C6:0	n.d.	0.90	0.82	0.80	0.79	0.93
C8:0	n.d.	0.57	0.55	0.55	0.57	0.60
C10:0	n.d.	1.34	1.35	1.39	1.38	1.40
C12:0	n.d.	1.72	1.73	1.80	1.77	1.80
C14:0	n.d.	6.78	6.87	7.09	6.98	6.99
C14:1	n.d.	1.07	1.11	1.13	1.14	1.11
Σ total fat*	0.29	3.62	3.59	3.57	3.56	3.54

*Σ protein is the sum of the individual amino acids, Σ total fat is the sum of the individual fatty acids. † n.d.:not detected (p≤0.05). CF: carob flour, C: control tarhana, T5: 5% carob flour supplemented tarhana, T10: 10% carob flour supplemented tarhana, T15: 15% carob flour supplemented tarhana, T20: 20% carob flour supplemented tarhana.

TABLE 3. Hunter colour values of the raw materials and tarhana samples as affected by the supplementation*.

	WF	CF	C	T5	T10	T15	T20
L	70.1±0.1	39.4±0.0	57.6±0.3[a]	49.3±0.0[b]	45.4±0.2[c]	44.7±0.0[d]	44.5±0.0[d]
a	0.1±0.0	5.5±0.04	5.5±0.1[c]	6.2±0.0[b]	6.5±0.1[a]	6.6±0.1[a]	6.7±0.0[a]
b	9.4±0.0	11.6±0.1	17.8±0.1[a]	14.7±0.1[b]	13.6±0.0[c]	12.8±0.0[d]	12.8±0.0[d]

*Values with different letters in the same row are statistically different (p≤0.05). WF: wheat flour, CF: carob flour, C: control tarhana, T5: 5% carob flour supplemented tarhana, T10: 10% carob flour supplemented tarhana, T15: 15% carob flour supplemented tarhana, T20: 20% carob flour supplemented tarhana. Different letters designate statistical differences (p≤0.05).

phenylalanine and tyrosine (p≤0.05). The same is valid for fatty acid compositions (Table 2); because fat content of tarhana samples did not differ significantly (p≤0.05) by substitution. But, the oleic acid and linoleic acid contents of carob flour were remarkable.

Total dietary fibre and raw fibre contents of the samples were observed to rise from 5.2 to 13.5% and from 1.03 to 2.01%, respectively by supplementation. Total dietary fibre of carob flour was observed to be 35.2% in this study which is consistent with the previous results [Iıpumbu, 2008] of 30–36% obtained by the same method. High dietary fibre content of CF was previously reported to exhibit valuable health-promoting attributes such as blood cholesterol lowering, antioxidant properties and the reduced risk of gastrointestinal cancer [Zunft *et al*., 2003].

Mineral composition

Carob flour was investigated to have 10280 ppm K, 2916 ppm Ca, 922 ppm P, 441 ppm Mg, 11.7 ppm Zn, 9.9 ppm Fe, 8.6 ppm Mn, 4.8 ppm Cu, 1.8 ppm Cr and 0.4 ppm Se. The mineral contents showed no significantly different values in the control and supplemented tarhana samples except for potassium, calcium and copper which have significantly higher amounts (Table 1). Based on the current recommended dietary allowances (RDAs) for some minerals [Anon., 2006] and accepted food labelling regulation [Anon., 2002], CF may be considered to have a high amount of Ca and, based on the Dietary Reference Intakes Reports [Anon., 2012], it is a source of K, Cu, Mn, Cr and Se.

Colour results

According to the colour results (Table 3), CF has lower *L* and higher *a* and *b* values than wheat flour. It was reported [Yousif & Alghzawi, 2000] that roasted carob flour had very close results with cocoa. All the samples had positive values of *a* and *b* confirming that the yellow and red tones were dominating over green and blue. However, CF supplementation increased redness with lower yellowness. There was also a significant decrease in lightness values of the samples with higher amount of CF in the formulation. Colour is an important parameter affecting also the sensory properties of the soup, because the typical colour of tarhana soup changed depending on the supplementation rate.

pH and acidity

pH of tarhana is important for sensory properties. Changes in pH and acidity values of tarhana dough during fermentation are shown in Figures 1 and 2. CF affected acidity values and higher values were observed with higher rates of supplementation at all the stages of the fermentation. This rise can be explained by the high level of total soluble sugar content of CF resulting in a higher amount of easily digestible substrate for microorganisms. Our acidity values were in the range declared in the Tarhana Stan-

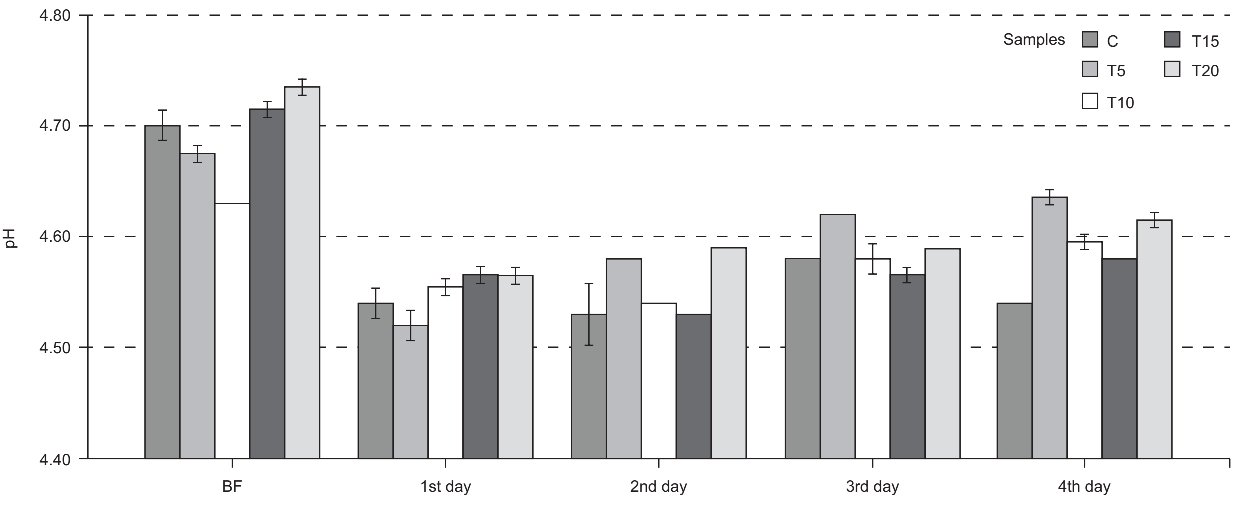

FIGURE 1. pH values of the wet tarhana samples during fermentation (p≤0.05).

BF: Before fermentation, C: control tarhana, T5: 5% carob flour supplemented tarhana, T10: 10% carob flour supplemented tarhana, T15: 15% carob flour supplemented tarhana, T20: 20% carob flour supplemented tarhana.

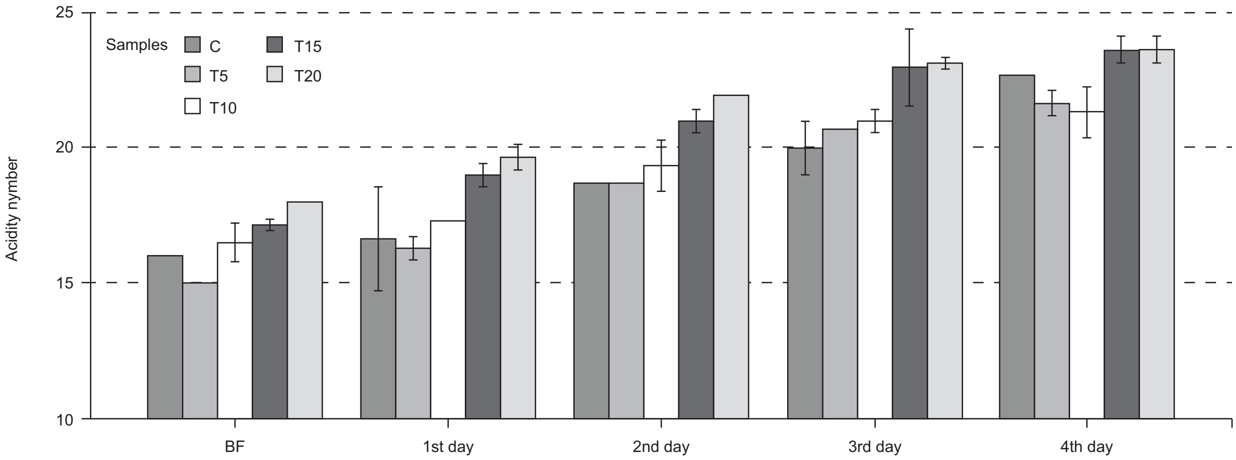

FIGURE 2. Acidity numbers of the wet tarhana samples during fermentation ($p \leq 0.05$).

BF: Before fermentation, C: control tarhana, T5: 5% carob flour supplemented tarhana, T10: 10% carob flour supplemented tarhana, T15: 15% carob flour supplemented tarhana, T20: 20% carob flour supplemented tarhana.

dard [Anon., 1981] according to which the degree of acidity in tarhana should be between 15 and 40 g/10 g tarhana. The pH of all the samples decreased dramatically at the initial stages of the fermentation. pH values varied in different samples between 4.7 and 4.5 confirming a knowledge that the typical pH range for tarhana-like products is said to be 4–5 [Hesseltine, 1979]. There was not a high correlation ($r \leq 0.82$, p:0.05) between the pH and acidity values of the samples for all stages of fermentation in this study and this was also the case in previous studies [Bilgicli *et al*., 2007; Herken & Çon, 2014]. Higher acidity values do not always lead to lower pH values, which can possibly be explained by partly dissociated compounds during analysis giving high pH values.

Fermentation loss

Fermentation loss, expressed as the matter loss of tarhana during the process was shown in Figure 3. Despite an increased fermentation rate at the initial stages of fermentation by supplementation, total weight losses of the samples (18.6, 18.7, 18.7, 18.2 and 18.5% for C, T5, T10, T15 and T20, respectively) were not significantly different ($p > 0.05$).

TAC and TP content

Total antioxidant capacity and total phenolic contents of tarhana increased significantly ($p < 0.05$) by CF addition (Figure 4). TAC increased from 7.70 to 23.10 mmol/L TE/g while TP content increased from 8.90 to 13.30 mmol/L GAE/g by supplementation. Many studies have investigated the relationship between TAC and TP values of food. The correlation coefficient between the mean TP and TAC values of each sample, which is found by using the Pearson correlation test in SPSS, is 0.974 ($p < 0.05$) in our study. Considering CF to contain high amount of phenolic substance which was previously reported to be 1.3–20 g/100 g, and high antioxidant capacity [Kumazawa *et al*., 2002], these results are expected. Generally, all phenolic compounds respond to Folin-Ciocalteu reagent, so, this reagent is generally accepted as being the colorimetric assay of phenolic and polyphenolic content and measuring the total reducing capacity of a sample in most cases since phenolics are the most abundant antioxidants in majority of plants. The reagent can also react with some nitrogen-containing compounds, vitamins and inorganic compounds and these compounds can also have or help the reducing capacity [Everette *et al.,* 2010]. Carob is observed to have more efficient antioxidant capacity than some of the popular sources such as red wines, and the reducing power of its extracts was also reported to be higher than four-fold that of many antioxidants such as gallic acid, caffeic acid and catechin [Makris & Kefalas, 2004]. In recent human studies, carob fibre was shown to have a positive effect on human cholesterol levels, especially, reducing LDL (low-density-lipoprotein) cholesterol levels, also improving the LDL/HDL (high-density-lipoprotein, good cholesterol) ratio [Zunft *et al*., 2001, 2003]. Different from other dietary fibres, carob fibre was reported to contain both water-soluble and water-insoluble polyphenols exhibiting considerable natural antioxidative activity and contributing to a more favourable balance between oxidants and antioxidants [Zunft *et al*., 2001]. Our data suggest that

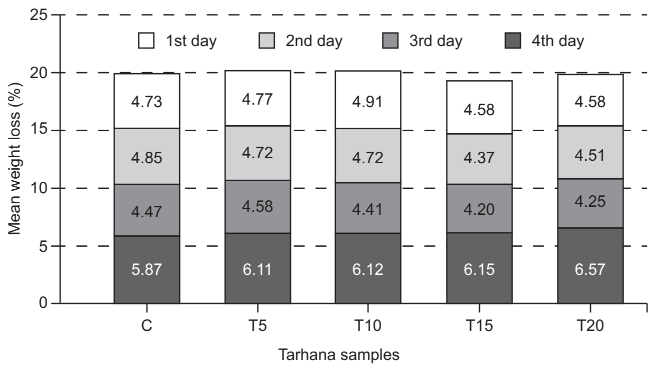

FIGURE 3. Weight loss of the wet tarhana samples during fermentation ($p \leq 0.05$).

BF: Before fermentation, C: control tarhana, T5: 5% carob flour supplemented tarhana, T10: 10% carob flour supplemented tarhana, T15: 15% carob flour supplemented tarhana, T20: 20% carob flour supplemented tarhana.

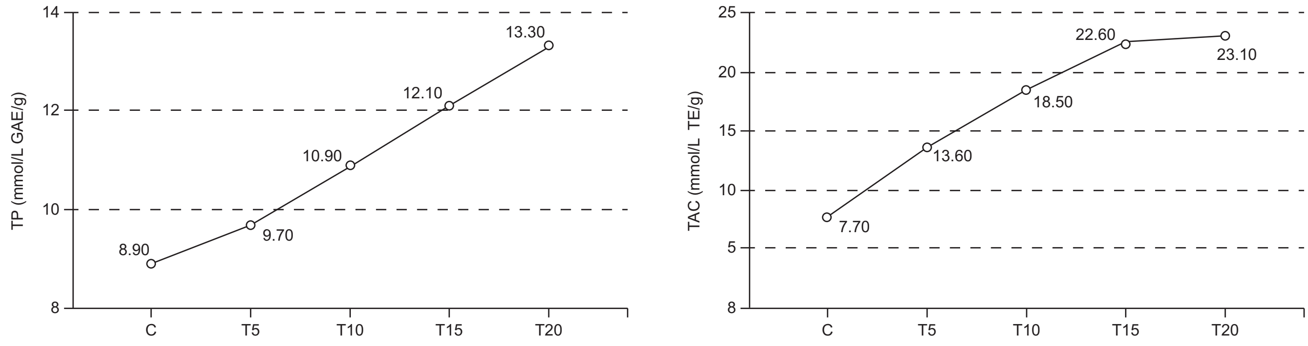

FIGURE 4. Effect of CF substitution on total phenolics (TP) contents and of total antioxidant capacity (TAC) of the tarhana samples (p≤0.05).

C: control tarhana, T5: 5% carob flour supplemented tarhana, T10: 10% carob flour supplemented tarhana, T15: 15% carob flour supplemented tarhana, T20: 20% carob flour supplemented tarhana.

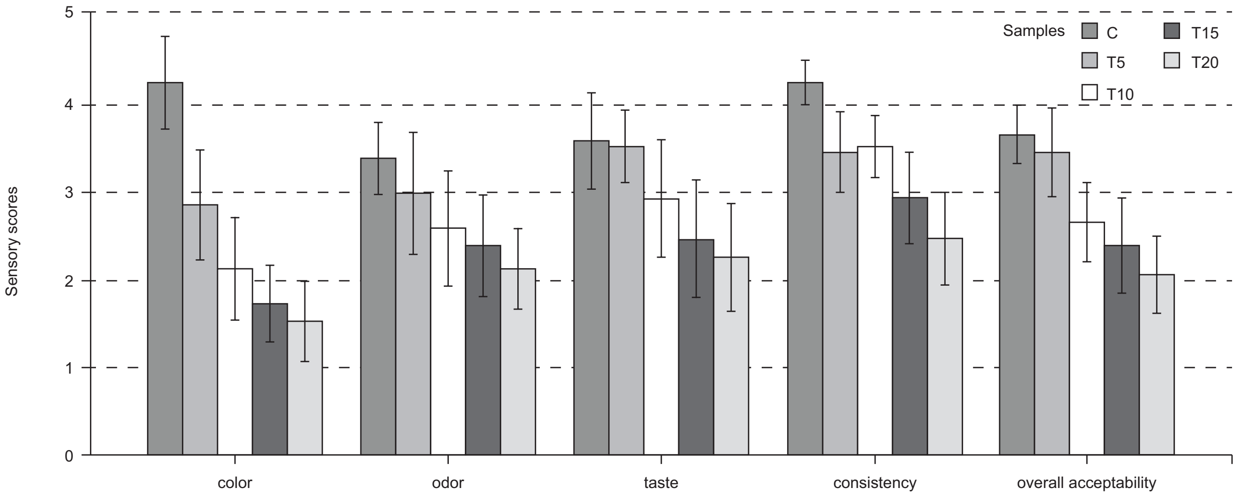

FIGURE 5. Sensory results of the tarhana soup samples (p≤0.05).

C: control tarhana, T5: 5% carob flour supplemented tarhana, T10: 10% carob flour supplemented tarhana, T15: 15% carob flour supplemented tarhana, T20: 20% carob flour supplemented tarhana.

CF supplementation to tarhana can supply higher phenolic compounds and also antioxidant capacity.

Rheological properties

In relation to the viscosity measurements, CF was observed to reduce the viscosity of tarhana soups giving lower yield stress values. Viscosity data clearly indicate that the soup samples obey the Bingham equation with confidence of fit values between 99.0–99.3 at a determined range of shear rate and temperature (Table 4). The plastic viscosity, a measure of the internal resistance to fluid flow of a Bingham plastic, expressed as the tangential shear stress in excess of the yield stress divided by the resulting rate of shear [Steffe, 1996], yield stress which is the minimum stress needed to cause a Bingham plastic to flow [Steffe, 1996], and; shear stress and viscosity values calculated for the shear rate of 50 rpm are shown in Table 4. Results demonstrate that the soup samples exhibit a linear shear stress, shear-rate behaviour after an initial shear stress threshold has been reached and, carob flour addition decreased the viscosity and yield stress of tarhana soup samples.

Sensory properties

According to the sensory results, panelists gave lower scores for the samples with higher CF percentages (Figure 5). Overall acceptability scores were found to be correlated at higher rates with taste scores (r:0.802 at 0.05 level) than the other parameters that are colour, odour and consistency.

TABLE 4. Viscosity results of tarhana soup samples.

Sample	Plastic viscosity (mPa.s)	Yield stress (Pa)	Cof† (%)	Shear Stress* (Pa.s)	Viscosity* (mPa.s)
C	103.1±8.0^{a}	17.8±1.4^{a}	99.0±0.4	23.0±1.5^{a}	485±37^{a}
T5	89.5±9.4^{b}	17.5±0.2^{a}	99.2±0.1	22.0±1.2^{a}	465±30^{a}
T10	79.2±5.3^{b}	12.7±0.7^{b}	99.2±0.1	16.6±0.7^{b}	348±14^{b}
T15	82.0±1.7^{b}	13.0±0.8^{b}	99.3±0.1	17.1±0.7^{b}	359±15^{b}
T20	3.4±8.0^{b}	13.7±1.8^{b}	99.1±0.2	17.8±1.5^{b}	373±34^{b}

*Values calculated for the shear rate of 50 rpm; † Confidence of fit. C: control tarhana, T5: 5% carob flour supplemented tarhana, T10: 10% carob flour supplemented tarhana, T15: 15% carob flour supplemented tarhana, T20: 20% carob flour supplemented tarhana. Different letters designate statistical differences (p≤0.05).

Due to the overall acceptability results, samples supplemented up to 15% CF did not have significantly different scores than those of the control. Higher rates were expressed in taste which was not typical for the flavour of tarhana.

CONCLUSION

Carob flour supplementation had positive effects on chemical and functional properties of tarhana by increasing the mineral composition - namely Ca, K and Cu-, dietary fibre content, antioxidant capacity and phenol content while affecting the sensory results negatively. It was observed from the sensory results, the supplementation can be carried out up to a 15% level successfully. This research deserves attention as carob fruits are highly nutritious and functional, and their pods have a limited use despite the fact they are abundantly and naturally grown in our region. In the health food market, carob fruit is used for a limited number of products. To benefit from such foods, their incorporation to the well-known and highly consumed food products is the most possible and easy way as it is done in this study.

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