Food Science and Technology
ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.1590/fst.21020

Physicochemical, sensory properties and *in-vitro* bioaccessibility of phenolics and antioxidant capacity of traditional noodles enriched with carob (*Ceratonia siliqua* L.) flour

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Abstract

In this study, the use of carob flour (CF) was investigated to improve the nutritional, antioxidative, and sensory properties of the noodles produced by the traditional method. In traditional noodle production, carob flour was used as a substitute to wheat flour at six different ratios (0% -control: Cmilk, Cwater, 10-40%, CF; w/w). In the noodle samples, L* and b* decreased whereas a* value increased as the CF substitution ratio increased. Regarding the CF substitution, which was found to be a natural antioxidant source rich in phenolic compounds added to the noodle formulation, the antioxidant capacity, total phenol content, and their bioaccessibility values increased. Bioaccessibility of total phenolic content (%) values (22.43-30.07%) of CF-added noodle samples were significantly higher than those of the control samples ($p < 0.05$). According to the bioaccessibility results of antioxidant capacities, FRAP (50.17%) showed the highest value in the 40% CF noodle sample. As a result, the use of 10% and 20% carob flour in the noodle formulation were determined as the optimum values in terms of sensory properties. In developing new food formulations with high functional properties, it has been recommended to use carob flour as a functional food ingredient.

Keywords: traditional noodle; carob flour; antioxidant capacity; *in vitro* bioaccessibility; functional food additive.

Practical Application: Improving the *in vitro* bioaccessibility, antioxidative and sensory properties of noodles.

1 Introduction

In recent years, the importance of functional products in nutrition has increased and scientific studies have intensified in this direction as consumers have focused on nutrition and health issues (Mark et al., 2019; Kebouchi et al., 2020). Cereals and cereal products are among the foods that are widely consumed both in Turkey and in the world. Cereal and cereal products contain low amounts of micronutrients and some of them are lost during the processing of foods (Cheng & Hardy, 2003). Due to the fine particle size of the flour, different fruit and vegetable flour additives can be added and food formulations with functional properties can be developed (Nystrom et al., 2003).

Noodle is described as the most consumed pasta-like product with different varieties, which can be produced using flour, water/milk, salt and/or eggs, whey, or other additives (Khouryieh et al., 2006; Lee et al., 2002; Demir, 2008). The importance of noodles is increasing day by day. It is also a popular product in countries other than those in Asia and it is consumed in countries such as Japan, China, Korea, and the United States (Fu, 2008; Raungrusmee et al., 2020). Noodle is a food product that has a simple preparation process for noodles, low cost, appropriate sensory properties, and long shelf life and, therefore, it is suitable for enrichment studies (Eyidemir, 2006; Ge et al., 2001). It has been reported that unshelled barley flour (Hatcher et al., 2005), rice flour (Zhu et al., 2019; Geng et al., 2019), coconut flour (Gunathilake & Abeyrathne, 2008), starches from beans, kidney beans and chickpeas (Sung & Stone, 2004), potato and rice starch (Sandhu et al., 2010), peas (Wee et al., 2019), oat flour (Zhang et al., 2018), buckwheat flour (Sun et al., 2018), lupine flour (Jayasena et al., 2010) is used and legume (soy and chickpeas) were used in noodle products enriched with bioactive compounds, cereal-like products (quinoa and amaranth) and cereal (rice and corn) flours were used in the production of gluten-free noodles (Bilgiçli, 2013), and legume flours were used in the production of enriched corn noodles for celiac patients as substitute functional components.

Studies on developing foods with high antioxidant activity have also gained importance in recent years (Esposito et al., 2005; Marnett, 2000). Antioxidants play an important role in health, especially in protecting cells from the potentially harmful effects of reactive oxygen or free radicals (Mirończuk-Chodakowska et al., 2018; Yu et al., 2002). Carob (*Ceratonia siliqua L.*) is a perennial plant belonging to the *Ceasalpinaceae* subfamily of the *Leguminosae* family (Dakia et al., 2007). It is grown in Mediterranean countries including Spain, Portugal, Italy, Morocco, Greece, Turkey, Algeria, Syria and Palestine (Yousif & Alghzawi, 2000; Durazzo et al., 2014). Ground flour form of carob can be used instead of cocoa in ice cream, cake, cake, and sugar foods (Pekmezci et al., 2008). Carob flour has an important nutritional value due to its high amounts of dietary fiber and phenolic compounds (Ortega et al., 2011). Also, recently, fruits and vegetables are of interest as sources with biological activity due to their anticarcinogenic, antimutagenic, and antioxidant properties

Received 08 May, 2020
Accepted 18 June, 2020
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(Dillard & German, 2000; Reddy et al., 2005). There are studies investigating the effect of carob flour added to products such as tarhana, biscuits, pasta, bread, gluten-free products, and milk-based beverages in functional product development (Iipumbu, 2008; Ortega et al., 2011; Bengoechea et al., 2008; Kumazawa et al., 2002; Herken & Aydin, 2015; Çağ Lar et al., 2013; Aydın, 2012; Šebečić et al., 2007; Sęczyk et al., 2016; Tsatsaragkou et al., 2012; Durazzo et al., 2014). However, not much information is available on the usefulness of carob flour in noodle production.

This study aimed to add 10%, 20, 30 and 40 carob flour to wheat flour in different substitution ratios to the noodles produced by the traditional method. Physicochemical (moisture, ash, pH, acidity, color), sensory properties and the total phenolic compound, antioxidant capacity and their bioaccessibility of traditional noodles supplemented with various levels of carob flour were determined.

2 Materials and methods

2.1 Materials

As the raw material to be used in the formulation of traditional noodle, wheat flour which contains 14.8% water content, 1.15% dw ash, 13.9% dw protein was provided from Bandırma Has Un (Toru Un) Co. Ground natural carob flour used in trials (*Ceratonia siliqua* L.) was supplied by a local brand and kept in a cool and isolated place until use. Refined kitchen salt, drinking milk, and eggs to be used in noodle production were purchased from local markets.

2.2 Methods

Traditional noodle production

The noodles produced in the research were produced in Kocaeli/Kartepe Ketenciler Village based on the traditional home type noodle (erişte) production method (Tutar Arzu, personal meeting, November 2018/Kartepe). Wheat flour, water/milk, salt, and eggs were used in the production of noodles by the traditional method. Noodle production trials were carried out by the addition of carob flour to wheat flour in six different ratios (%0-control: Cmilk, Cwater, 10-40%, CF; w/w) (Table 1).

In the traditional noodle production stages shown in Figure 1, the noodle ingredients are kneaded for 10 minutes. The dough obtained after kneading was divided into equal pieces and wrapped with a damp fabric to prevent the surface from drying and rested for 20 minutes. The rest of the round dough pieces were opened with a rolling pin and subjected to pre-thinning. The thinned doughs are cooked on a tin plate of a stone oven until the front and back sides were properly cooked and the excess moisture is removed from the doughs, thus preventing adhesions that may occur during cutting, and for a better maturation of the gluten structure. At this stage, pre-drying is applied to the noodles. After the hot noodle doughs resting on the fabric have cooled down, they were put on top of the dough rolling table with the help of a knife and size reduction and strip-cutting stages were carried out. The noodles that have been pre-dried were placed on the fabrics so that they do not stick together and left to dry in the shade for some time. After the noodles with reduced moisture content were completely dry, they were kept in handmade fabric noodle bags at room temperature. When necessary, dried samples were milled in the mill for use in analysis and stored at room temperature until use.

Table 1. Traditional noodles (erişte) formulation*.

Ingredients[a]	Ratio (%)
Wheat Flour[b]	100, 90, 80, 70, 60 (%)
Carob flour	0, 10, 20, 30, 40 (%)
Water[1]/Milk	Variable (60-64 mL/100 mL)
Egg and Salt	13 g/100 g; 2.8 g/100g

*Control sample including no carob flour was also prepared; [1]One control sample was prepared to water instead of milk. other samples prepared with milk; [a]Ingredients at 21 ± 1 °C; [b]4% moisture basis.

Physico-chemical analysis of traditional noodle

Moisture (method no: 925.40), ash (method no: 950.49), acidity (Total) (method no: 935.57), and pH (Method No: 981.12) contents of the traditional noodle samples were assessed according to the standard methods of Association of Official Analytical Chemists (2000). The color measurement of traditional noodle samples was carried out by Minolta Spectrophotometer CM-139 3600d (Osaka, Japan) based on CIE L^*, a^*, b^* color system. The tests were performed at least in triplicate and mean values were reported.

Extraction of extractable, hydrolyzable, and bioaccessible phenols

Three different extraction methods were applied for extractable (20 mL of HCl (conc)/methanol/water (1:80:10, v/v) mixture at room temperature), hydrolyzable (hydrolyzable phenols: combined with 20 mL of methanol/H_2SO_4conc (10:1) and placed in a water bath at 85 °C for 20 h) and bioaccessible phenols. These methods were modified from those originally proposed by Vitali Čepo et al. (2009) and were used in the analyses of antioxidant capacity and total phenolic content. For the determination of bioaccessible phenols, investigated samples were processed by an *in vitro* digestive enzymatic extraction that mimics the conditions in the gastrointestinal tract according to the procedure of Vitali Čepo et al. (2009) with slight modifications. The whole procedure was carried out in triplicate and all supernatants were stored at 20 °C until used.

Determination of Total Phenolic Contents (TPC)

The extractable, hydrolyzable, and bioaccessible phenols of traditional noodle samples were determined at 760 nm by using Shimadzu UV-1280 UV-VIS spectrophotometer according to the Folin-Ciocalteu method (Naczk & Shahidi, 2004). Gallic acid was used as standard and the results were expressed as mg GAE/g dw. The total phenolic content was calculated as the sum of extractable and hydrolyzable fractions and bioaccessibility was calculated as the percentage of total phenolic content. The procedure was carried out three times for each extract.

Figure 1. Production of traditional noodle.

Determination of Antioxidant Capacity (AC)

Antioxidant capacities of the extractable and hydrolyzable and bioaccessible phenolics of the traditional noodle samples were determined using radical cation decolorization assay (2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) (Apak et al., 2008), cupric ion reducing antioxidant capacity assay (CUPRAC) (Apak et al., 2004), ferric reducing antioxidant power assay (FRAP) (Benzie & Strain, 1996), with slight modifications. All assays were repeated three times for each extract collected from the samples and absorbance of samples was measured by using a spectrophotometer (Shimadzu UV-1280). A calibration curve was prepared, using Trolox (6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid) and the results were expressed as μmol TE/g dw for each method.

Sensory evaluation

The sensory properties of control and CF-added noodle samples were evaluated by 62 panelists comprising students and lecturer of the Department of Gastronomy and Culinary Arts, Kocaeli University (30 male, 32 female, aged 18-45 years). Noodle samples were allowed to cook in water up to optimum cooking time (10-13 min), allowed to infuse until they absorb water and rested for two minutes, and then analyzed. All sensory evaluations were made using the modified sensory evaluation form (Yalçın, 2005; Rekha et al., 2013) containing the sensory quality criteria in the noodles, on the 1-9 hedonic scale *(9-point hedonic scale with 9-like extremely and 1-dislike extremely)*. Cooked noodles were evaluated by scoring 7 sensory properties: color, taste/flavor, odor, appearance, stickiness, mouthfeel, general taste.

2.3 Statistical analysis

Data obtained from the analyses were statistically evaluated with a computer-based program JMP IN 7.0.0 (Statistical Discovery from SAS Institute Inc. (2007), the LSD (Least Significant Difference) test was performed to determine the significant difference between the mean values at the $p \leq 0.05$ level.

3 Results and discussion

3.1 Physicochemical properties and color values of noodles

The results of moisture, ash, pH, titratable acidity, and color analysis of the noodle (CF noodles) samples produced by the traditional method with carob flour (CF) are given in Table 2. The average moisture content of carob flour was 7.11%, ash content was 3.03%, pH value was5 .10, and titratable acidity was 0.06%. Similar to the present study, it has been reported that the addition of 3%, 5%, and 8% carob flour to tarhana did not

Table 2. Some chemical compositions of samples*.

Samples	CF*** Level (%)	Moisture (%)	Ash (%)	pH	Titratable acidity (%)	L*	a*	b*
Cmilk[1]	0	10.24 ± 0.01[a]	1.97 ± 009[c]	6.25 ± 0.04[a]	0.18 ± 0.00[e]	76.88 ± 1.68[a]	-0.89 ± 0.45[c]	17.11 ± 0.46[a]
Cwater[1]	0	10.63 ± 0.01[a]	2.02 ± 0.02[c]	6.27 ± 0.03[a]	0.18 ± 0.00[e]	75.29 ± 0.80[a]	-0.76 ± 0.19[c]	17.42 ± 0.56[a]
CF Noodles**	10	10.14 ± 0.17[a]	2.11 ± 0.03[bc]	6.05 ± 0.08[b]	0.30 ± 0.00[d]	47.47 ± 2.11[b]	3.00 ± 0.06[b]	9.28 ± 2.41[b]
	20	9.96 ± 0.07[a]	2.24 ± 0.04[bc]	5.83 ± 0.06[c]	0.42 ± 0.00[c]	42.45 ± 2.48[c]	3.04 ± 0.02[b]	8.21 ± 0.54[bc]
	30	10.40 ± 0.20[a]	2.35 ± 0.27[b]	5.58 ± 0.03[d]	0.66 ± 0.00[b]	42.68 ± 0.13[c]	3.12 ± 0.04[b]	7.00 ± 0.09[cd]
	40	10.04 ± 1.45[a]	3.06 ± 0.27[a]	5.41 ± 0.04[e]	0.72 ± 0.00[a]	39.30 ± 0.44[d]	5.60 ± 0.06[a]	6.31 ± 0.17[d]
CF***		7.11 ± 0.39	3.03 ± 0.15	5.10 ± 0.08	0.06 ± 0.00	43.47 ± 0.76	5.57 ± 0.08	10.46 ± 0.42

*Means with different superscripts in columns indicate significant difference ($p \leq 0.05$). Data are expressed as means ± standard deviations. *L** (lightness), ± *a** redness/greenness, ± *b** (yellowness/blueness). [1]Control: Cmilk, Cwater ** CF Noodles: CF-%10, 20, 30, 40: noodle supplemented with carob flour; ***CF: carob flour

change the amount of water in the samples and carob flour had 5.1% moisture and 2.8% ash content (Işık Erol, 2010). Yousif & Alghzawi (2000), in roasted carob powder (CF) samples, have reported pH 4.81, 9.03% moisture, and 2.48% ash content. Tsatsaragkou et al. (2014) have reported a 9.35% moisture content in carob flour. Differences in chemical properties can be associated with the roasting temperature and time applied in carob flour (CF) production. The average moisture content of carob flour-added noodle samples was 9.96-10.40%, ash content was 2.11-3.06%, pH value was 5.41-6.05, and the titratable acidity was in the range of 0.30-0.72%. There were no significant differences ($p < 0.05$) between the control noodles (Table 2). No statistically significant difference was observed in terms of physicochemical properties ($p < 0.05$) except for ash, pH, and titratable acidity value of the noodle samples. Vitali Čepo et al. (2009) have reported that biscuits with 25% carob had low protein values and high ash content compared to the control biscuits. Similarly, as the carob flour addition increased in the present study, the ash content of the noodles increased compared to the control sample ($p < 0.05$). In a study in which 8.96%, 10.3, and 11.6% of CF were added to bread, it has been reported that 10.3% CF added bread samples could be successful more than 90% of the markets (Iipumbu, 2008).

CIE L*, a*, and b* color values of carob flour (CF) are given in Table 2. In control noodles, the preparation with milk or water had no statistically significant effect at $p < 0.05$ level in terms of color values. Mean color values in CF-added noodle samples were L*: 39.30-47.47 a*: 3.00-5.60 and b*: 6.31-9.28. With the addition of CF, the L* (brightness) and b* (jaundice) values of the noodles decreased significantly ($p < 0.05$) whereas the a* (redness) values increased significantly ($p < 0.05$) compared to the control noodles. Similar results have been reported for tarhana by Işık Erol (2010), for biscuit by Aydın (2012) and pasta by Hallaç & Dulger Altıner (2016) regarding a decrease in L and b values and an increase in a value as the CF ratio increased. Yousif & Alghzawi (2000) have reported that the color values of roasted carob flour and cocoa were close to each other. Since carob flour is brown, when added to the samples, a decrease in brightness was observed and the unique color of the noodles changed. This was due to the fact that these products are sensitive to Maillard reactions and caramelization (Yousif & Alghzawi, 2000; Mohamed et al., 2010; Balasubramanian et al., 2014).

3.2 Total phenolic contents, antioxidant capacities and their in vitro bioaccessibilities of noodles

Total phenol contents and bioaccessibility results of CF and CF-added noodle samples are given in Table 3. In the carob flour (CF) sample, TPC was 51.04 mg/g GAE and the bioaccessibility of phenols was determined to be 59%. Durazzo et al. (2014) have reported, similar to our study, TPC value in carob flour as 71.03 mg/100 g GAE. Custódio et al. (2011) have reported that the rich phenolic acid content in carob flour (carob tree (*Ceratonia siliqua* L.) germ flour) increased the antioxidant and cytotoxic capacity. Ortega et al. (2011) examined the carob flour and washed carob flour (excluding soluble nutrient fraction) by the *in vitro* digestion method. The soluble nutritional fraction has been reported to increase the stability of the phenolic components during the duodenal digestive phase.

Extractable and hydrolyzable phenols are important fractions in determining antioxidant properties (Pérez-Jiménez et al., 2008). As the ratio of CF increased, the total phenolic contents of the extractable and hydrolyzable of the noodles showed a significant increase ($p < 0.05$) compared to the control. Compared to the control samples (52.88-58.15 mg/g GAE), the total phenolic content (TPC) (61.08-82.59 mg/g GAE) values in traditional noodles enriched with CF were found to be significantly ($p < 0.05$) higher. As the ratio of CF addition increased, a significant increase ($p < 0.05$) was observed in the total phenolic contents of all the fractions of the noodles compared to the control. In a study on biscuits, carob flour was found to give the highest values by increasing the total phenol content by 304% and total dietary fiber content by 42% (Šebečić et al., 2007). Vitali Čepo et al. (2009) have reported a total phenol content of 1395 mg ferulic acid equivalents/100 g dry matter, and 20.4% phenolic bioaccessibility. Similarly, in the present study, the bioaccessibility values of the total phenol content in the noodles with 10-40% CF varied changed in the range of 22.43-30.07%. According to the results, with its high CF additive phenol content, it can also be recommended in the processing of different foods as a functional additive.

The results showing the effect of carob flour additive on the antioxidant capacity of the noodle are given in Table 4. In the carob flour (CF) example, the highest values in antioxidant capacity were determined as extractable 106.70 μmol TE/g (CUPRAC), hydrolysable 94.33 μmol TE/g (CUPRAC), and bioaccessible phenolics 104.96 μmol TE/g (CUPRAC). The bioaccessibility

Table 3. Total phenolic contents of noodle samples*.

Sample	CF*** Level (%)	Extractable Phenolics	Hydrolyzable Phenolics	TPC[a]	Bioaccessible Phenolics[b]
		(mg/g GAE dw)			
Cmilk[1]	0	6.06 ± 0.00[e]	52.09 ± 0.85[d]	58.15 ± 0.85[cd]	10.70 ± 0.78[e]
Cwater[1]	0	5.74 ± 0.13[e]	47.14 ± 0.90[cd]	52.88 ± 0.77d	11.96 ± 0.42[de]
CF Noodles**	10	6.62 ± 0.03[d]	54.46 ± 5.51[bc]	61.08 ± 5.54[cd]	13.70 ± 0.22[d]
	20	8.52 ± 0.06[c]	60.28 ± 2.32[ab]	68.80 ± 2.26[b]	17.17 ± 0.66[c]
	30	12.47 ± 0.48[b]	64.67 ± 1.81[a]	77.15 ± 2.29[a]	21.79 ± 0.68[b]
	40	15.97 ± 0.06[a]	66.62 ± 2.21[a]	82.59 ± 2.27[a]	24.83 ± 2.46[a]
CF***		17.31 ± 0.54	33.73 ± 0.12	51.04 ± 0.42	30.62 ± 0.30

*Mean values represented by the same letters within the same column are not significantly different at $p \leq 0.05$. Data are expressed as means ± standard deviations (n = 3). [1]Control: Cmilk, Cwater; ** CF Noodles: CF-%10, 20, 30, 40: noodle supplemented with carob flour; ***CF: carob flour; [a]Total phenol content (TPC) was calculated as the sum of extractable and hydrolizable phenols; [b]Bioaccessibility was calculated as the percentage of total phenolic content.

Table 4. Antioxidant capacities of noodle samples*.

Sample	CF*** Level (%)	Extractable (µmol TE/g dw)			Hydrolyzable (µmol TE/g dw)			Bioaccessible (µmol TE/g dw)		
		ABTS[2]	CUPRAC[2]	FRAP[2]	ABTS[2]	CUPRAC[2]	FRAP[2]	ABTS[2]	CUPRAC[2]	FRAP[2]
Cmilk[1]	0	0.23 ± 0.01[c]	4.07 ± 0.12[e]	5.54 ± 0.05[e]	14.55 ± 1.28[d]	23.52 ± 0.78[e]	18.81 ± 0.27[f]	4.22 ± 0.08[e]	3.62 ± 0.51[d]	1.61 ± 0.02[e]
Cwater[1]	0	0.20 ± 0.01[c]	3.37 ± 0.07[e]	4.87 ± 0.02[f]	14.88 ± 0.01[d]	14.70 ± 3.39[f]	23.29 ± 0.70[e]	4.17 ± 0.03[e]	3.18 ± 0.20[d]	1.37 ± 0.02[e]
CF Noodles**	10	0.92 ± 0.09[c]	6.96 ± 0.93[d]	9.40 ± 0.06[d]	18.12 ± 1.31[c]	34.71 ± 2.79[d]	31.51 ± 0.52[d]	6.13 ± 0.24[d]	12.59 ± 1.45[c]	18.69 ± 1.38[d]
	20	2.80 ± 0.05[c]	11.20 ± 0.31[c]	10.33 ± 0.03[c]	25.27 ± 0.06[b]	47.38 ± 2.13[c]	41.22 ± 0.34[c]	9.98 ± 0.29[c]	17.74 ± 0.94[bc]	23.96 ± 0.78[c]
	30	7.87 ± 4.11[b]	18.70 ± 0.10[b]	17.58 ± 0.61[b]	26.91 ± 0.47[b]	55.91 ± 3.12[b]	48.00 ± 0.96[b]	13.06 ± 0.63[b]	22.71 ± 2.58[b]	30.88 ± 1.56[b]
	40	14.93 ± 0.13[a]	23.30 ± 0.19[a]	25.44 ± 0.07[a]	39.22 ± 0.27[a]	69.95 ± 0.66[a]	51.90 ± 1.94[a]	21.64 ± 0.41[a]	40.72 ± 4.87[a]	38.78 ± 0.71[a]
CF***		93.14 ± 3.34	106.70 ± 0.45	28.35 ± 0.77	61.30 ± 0.15	94.33 ± 2.58	69.81 ± 3.03	85.29 ± 2.05	104.96 ± 5,65	51.49 ± 1.95

*Mean values ± standard deviation with different superscript in the same row are significantly different ($p \leq 0.05$). **CF Noodles: CF-%10, 20, 30, 40: noodle supplemented with carob flour; ***CF: carob flour; [1]Control: Cmilk, Cwater; [2]Antioxidant capacity methods: ABTS: radical scavenging assay, CUPRAC: cupric ion reducing power assay, FRAP: ferric reducing antioxidant power assay.

values of the CF addition were determined by the ABTS, CUPRAC, and FRAP method, respectively to be 52.22%, 52.20%, 52.49%, and showed similar results. Durazzo et al. (2014) have reported 11.62 ± 1.26 µmol/g d.w extractable and 3.78 ± 1.44 µmol/g d.w. non-extractable polyphenols content in the additive obtained from carob seeds, also known as E410, by the FRAP method. Şahin et al. (2009) reported that as the roasting temperature and duration applied to CF increased, total phenol content and antioxidant capacity in CF increased, therefore there were differences in carob flours used in the studies.

Antioxidant capacity results also showed the same trend as in the total phenol content. CF-added noodle samples had a high antioxidant capacity compared to control samples ($p < 0.05$). In all methods, the antioxidant capacities of the hydrolyzable phenolics gave higher results than those extracted. The *in-vitro* bioaccessibility of antioxidants of the noodle samples is given in Figure 2. Bioaccessibility values increased from 28.63%, 27.64% (Control-Cmilk, Cwater) to 39.96% in the ABTS method, from 13.17%, 18.02% (Control-Cmilk, Cwater) to 43.69% in the CUPRAC method and from 6.61%, 4.86% (Control-Cmilk, Cwater) to 50.17% in the FRAP method. According to the bioaccessibility results, it can be said that the FRAP method gives the highest bioaccessibility value, shows similar results in other methods, and all three methods used for noodle samples are suitable. The high phenol content of CF addition caused an increase in the antioxidant content of enriched noodle samples. The differences between the methods were thought to be due to the inability to extract some phenolic compounds and to have different sensitivity and selectivity for hydrophilic and lipophilic substances.

As expected, the total phenolic content and antioxidant capacity values of the noodles increased with the increase in CF addition. No study was found in the literature to enrich the noodles with carob flour. Similar to the present study, there are studies in which the increase in additives used in food enrichment in noodles and pasta samples showed positive correlations with the increase in TPC and TAC values (Boroski et al., 2011; Khan et al., 2013; Sęczyk et al., 2016; Khare et al., 2014; Li et al., 2015; Zhu & Li, 2019; Li et al., 2014; Choo & Aziz, 2010). Sęczyk et al. (2016) have reported that in the pasta enriched with carob flour, the increase in the addition of carob flour (1% to 5% (w/w)) showed a positive correlation with the total phenolic content and antioxidant capacity in pasta. Vitali Čepo et al. (2009), when carob was added to the biscuit by 24.5%, have reported an increase of 149.63% in the total phenol content of biscuits and 94.6% in the antioxidant content. Šebečić et al. (2007) have reported the total phenol content (TPC) (1.10 g/kg) in biscuits prepared with wheat flour as 5.53 g/kg in biscuits containing 25% CF. In the present study, a 41.96% increase in TPC content and a 237% increase was determined in total antioxidant content according to the CUPRAC method. The different percentages of increase reported in studies were associated with the carob

Table 5. Sensory analyses of noodle samples*.

Sample	CF*** Level (%)	Color	Flavor/Taste	Smell	Apperance	Stickiness	Mouthfeel	Overal acceptibility
Cmilk[1]	0	7.06 ± 1.60^{a}	7.10 ± 1.46^{a}	7.00 ± 1.53^{a}	6.52 ± 1.77^{a}	6.61 ± 1.79^{a}	6.94 ± 1.54^{a}	7.06 ± 1.46^{a}
Cwater[1]	0	6.95 ± 1.41^{a}	7.00 ± 1.41^{a}	6.97 ± 1.50^{a}	6.35 ± 1.58^{ab}	6.40 ± 1.84^{ab}	6.77 ± 1.50^{ab}	6.90 ± 1.43^{ab}
CF Noodles**	10	6.24 ± 1.88^{b}	6.50 ± 1.86^{ab}	6.13 ± 1.82^{b}	5.87 ± 1.94^{abc}	6.10 ± 1.80^{abc}	6.23 ± 2.09^{bc}	6.47 ± 1.84^{abc}
	20	5.59 ± 1.85^{b}	6.03 ± 1.77^{b}	5.55 ± 1.72^{bc}	5.42 ± 2.00^{c}	5.77 ± 1.87^{bc}	5.94 ± 1.86^{c}	6.00 ± 1.69^{bcd}
	30	5.92 ± 2.32^{b}	5.06 ± 2.54^{c}	5.00 ± 2.37^{c}	5.32 ± 2.39^{c}	5.68 ± 2.07^{c}	4.77 ± 2.33^{d}	5.56 ± 2.36^{cd}
	40	6.18 ± 2.13^{b}	5.23 ± 1.81^{c}	5.16 ± 1.97^{c}	5.76 ± 2.22^{bc}	6.15 ± 1.60^{abc}	5.10 ± 2.12^{d}	5.24 ± 1.99^{d}

*Mean values represented by the same letters within the same column are not significantly different at $p \leq 0.05$. All values are mean ± SD, $n = 62$. [1]Control: Cmilk, Cwater; ** CF Noodles: CF-%10, 20, 30, 40: noodle supplemented with carob flour; ***CF: carob flour.

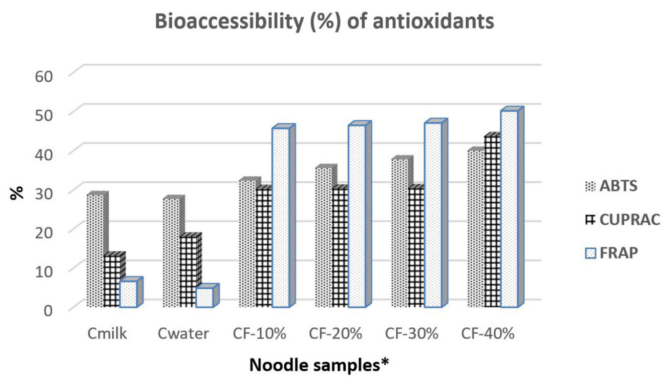

Figure 2. Bioaccessibility (%) of antioxidant capacities[1] of noodles. *Noodle samples: Control: Cmilk, Cwater, CF: carob flour, CF-%10, 20, 30, 40: noodle supplemented with carob flour. [1]Antioxidant capacity methods: ABTS: radical scavenging assay, CUPRAC: cupric ion reducing power assay, FRAP: ferric reducing antioxidant power assay.

type, carob flour, Maillard reaction products formed during the roasting, the type of grain, the processing of foods and the antioxidant properties of phenolic compounds in foods (Ragaee et al., 2006; Vitali Čepo et al., 2014; Borrelli et al., 2003; Zieliński & Kozłowska, 2000; Adom & Liu, 2002). Also, the potential antioxidant capacity of food products enriched with different additives, interactions between food matrix components, bioactive components (phenolics) and free of process methods had an effect (Swieca et al., 2014; Fares et al., 2010; Gawlik-Dziki et al., 2012; Gong et al., 2017; Wu et al., 2004).

3.3 Sensory analyses

In addition to the nutritional value of food, good sensory properties are also an important factor for consumers (Yousif & Alghzawi, 2000). It was understood from the data in Table 5 that the noodle samples produced by adding carob flour were well appreciated by the panelists in the sensory evaluation. In the sensory analysis of the noodles, the control noodles had the highest scores in terms of color, taste/aroma, odor, appearance, stickiness, mouthfeel, and general acceptability, and the closest values to the control noodle were the formulations containing 10% and 20 carob flour, respectively ($p < 0.05$). Although formulations containing 30% and 40% carob flour scored lower others, the scores of all noodles, in general, received 5 or higher scores on a 9-point scale and were generally accepted by the panelists.

In terms of color scores, CF-added noodles were found to be different than the control ($p < 0.05$). As the substitution ratio increased, the image resembling cocoa color was liked by the panelists. The odor scores of the noodles produced with CF substitutes ranged between 5.00-6.13, the highest score was given to 10% CF substituted noodles whereas the lowest score was given to 30% CF substituted noodles. CF substitution reduced the odor score and received scores lower than the control. According the analysis results, when the samples were compared in terms of aroma/taste, the lowest value was 5.23 in 30% CF substituted noodles, followed by 40% CF substituted noodles (5.23) where there was statistically no difference between them. The decrease in taste with the increase in CF addition can be associated with the high levels of tannins and astringent phenolic components found in carob (Avallone et al., 1997; Kumazawa et al., 2002; Drewnowski & Gomez-Carneros, 2000). In terms of appearance, the reason that noodle samples with 30-40% CF addition received low appearance values was that undesirable disintegration was observed during the cutting process due to hard kneading of the dough as the addition ratio increased. Apart from the control samples (7-moderately pleasant), the scores of 10% and 20% CF noodles (6- slightly pleasant) were significantly higher than those in other groups ($p < 0.05$). It can be argued that in high sensory properties scores, the carob's dark color, the soft structure it creates, and its distinctive taste adds a different appearance, taste, aroma, and color to the traditional noodles. The panelists emphasized that the products were interesting and affordable when sold commercially. According to the general evaluation, the acceptability scores of the noodles produced with CF substitution ranged between 5.24 and 6.47 and it was observed that they had acceptable qualities since they received 5 or higher points.

Similar to the present study, there are studies in which carob flour (CF) was used in other cereal products. In sensory evaluations on CF-added pasta (Sęczyk et al., 2016), carob fiber-added pasta (Biernacka et al., 2017), CF-added gluten-free cake (Abd Rabou & Al-Sadek, 2018), and CF-added biscuit (Aydın, 2012), CF-added formulations were accepted by panelists.

4 Conclusion

Noodles containing carob flour showed high phenolic content, antioxidant capacity, and *in vitro* bioaccessibility compared to those in control samples. CF-added noodles received high sensory scores. Therefore, carob flour can be used as a functional ingredient in enriching noodles and similar cereal products. Since improving the nutritional properties of the noodles produced by the traditional method and enriching them with antioxidants will provide more functional and healthy noodles to the consumer, the present study was thought to contribute to the development of the product portfolio in the functional food market.

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