Use of coffee silverskin to improve the functional properties of cookies

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Abstract The purpose of this study was to determine the suitability of coffee silverskin (CSS) supplementation to enhance phenolic content and antioxidant capacity of cookies. Cookie samples were prepared with partial replacement of wheat flour by CSS (2.5, 5.0, and 7.5%). Spread ratios were found lower in all cookies with CSS than in control. Cookies became darker with increasing levels of CSS. This is due to the fact that CSS has a dark color like cocoa. CSS supplementation had improved functional quality of cookies by increasing phenolic contents, antioxidant capacities, and in vitro bioaccessibilities of them. According to the sensory evaluation, all samples with CSS received 6 and above scores (6: like slightly, 7: like moderately) for all attributes from the panelists. The results demonstrated that CSS supplementation have a good potential for developing functional and acceptable cookies and similar bakery products.

Keywords Cookie · Coffee silverskin · Antioxidant · Phenolic · In vitro bioaccessibility

Introduction

In recent years, the demand for functional food, which has positive effects on human health, has been increasing with the change in nutritional habits and increase in nutritional awareness. Especially the development of food products with high antioxidant activity and high dietary fiber is very

important for healthy nutrition. In this context, a number of studies have been carried out to enrich the bakery products.

Coffee silverskin (CSS) is the thin tegument of the outer layer of green coffee beans and is a major by-product of the roasting process (Borrelli et al. 2004). During the roasting processes the residual CSS is completely removed (Esquivel and Jiménez 2012). CSS is an industrial waste that can easily be obtained in large quantities, and is likely to have a high added value. Nevertheless, it could not be recognized in the past and has been almost exclusively used as combustible or fertilizer (Saenger et al. 2001).

In recent years, consumption of coffee has increased; consequently, tons of coffee silverskin, which is the most important by-product derived from the roasting process of coffee beans, are produced every year (Kaplinsky 2004). This by-product is a very valuable economic resource rich in phenolic compounds, although once it seems like waste. It has a great potential in industrial applications as food additives or supplements of high nutritional value (Murthy and Naidu 2012a; Martínez-Pinilla et al. 2015).

The demand for coffee by-products such as coffee silverskin (bean testa, epidermis) is growing rapidly. Coffee silverskin is a natural source of a number of compounds that are likely to be beneficial to health (Borrelli et al. 2004; Napolitano et al. 2007; Murthy and Naidu 2012b; Martinez-Saez et al. 2014). Since it is not known that it has antioxidative and prebiotic effects as physiological functions, most CSS are discarded as industrial waste (Borrelli et al. 2004).

Antioxidant properties of coffee are associated to coffee silverskin fibre and this is attributed to the presence of chlorogenic acid (CGA) adhering to the dietary fiber matrix formed by a complex carbohydrate structure. For this reason, the dietary fiber in coffee silverskin is classified as antioxidant dietary fiber (Napolitano et al. 2007; Murthy

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and Naidu 2012b). In addition to these compounds, it contains inhibitor of hyaluronidase enzyme (Furosawa et al. 2011). CSS can be used to increase the antioxidant capacity of foods because of its phenolic composition and healthful and beneficial content, and can be considered as a low-cost, innovative functional ingredient (Bresciani et al. 2014). However, no studies regarding the impact of coffee silverskin addition on phenolic contents and in vitro bioaccessibilities of phenolic compounds, antioxidant capacities and in vitro bioaccessibilities of antioxidants from cookie samples are available.

The objective of this study was to investigate the possibility of using coffee silverskin for production of nutritionally enriched cookies with respect to phenolic compounds, and antioxidant activity. Quality characteristics, and functional properties such as phenolic content, antioxidant activity, and in vitro bioaccessibilities of antioxidants and phenolic compounds from cookie samples supplemented with various levels of CSS were determined.

Materials and methods

Materials

Coffee silverskin (*Coffea arabica*, grown in Colombia) containing 14.9% protein (db), and 60.20% total dietary fiber was supplied by a local coffee brand, Antalya-TURKEY. Soft wheat flour containing 13.5% moisture (db), 0.55% ash (db), and 9.0% protein (db) was used and purchased from local market Bursa, Turkey. All of other ingredients were supplied from local markets in Bursa-TURKEY.

Methods

Cookie production

Cookie samples were prepared according to The American Association of Cereal Chemists International method 10–54.01 (AACCI 1999). Coffee silverskin (CSS) was ground in a blender (Philips, China) and sieved through 60 mm sieve to obtain CSS powder. Cookie formulations were prepared by replacing wheat flour with CSS at 2.5, 5.0 and 7.5% (w/w) levels, and control sample without CSS was also prepared (Table 1). Cookies were baked in a convection oven (Inoksan FKE 006, TR) at 180 ± 2 °C for 8 min. The baked cookies were left to cool for 30 min and then they were wrapped in aluminum foil and allowed to stand at room temperature prior to analyzes.

Baking performances of cookies

Moisture and ash contents of cookies were determined according to AACCI Method No:44.01 and 08.01, respectively (AACCI 1990). The tests were performed at least in triplicate and mean values were reported. The physical parameters [diameter (D), thickness (T)] of the cookies were evaluated after cooling for 30 min. The diameter and thickness values were measured via caliper and spread ratio was calculated from the ratio of diameter and thickness values. The color of the cookies (L^* , a^* and b^*) was measured with a Minolta CM-3600d model (Osaka, Japan). Standard white plate was used for the calibration of the colorimeter.

The texture of the samples 24 h after baking was evaluated using a texture analyzer (TA-Xt PLUS, Stable Microsystems, UK), equipped with a 50 kg load cell. The test was made using a ‘measure force in compression’ test with 3-point bending jig and heavy duty platform (HDP/90) and each test was made three times and results were expressed as mean $\pm$ S.D values. The maximum peak force (Newton) required to break the cookies was used as the hardness of the cookies.

Functional properties of cookies

Determination of phenolic contents

Phenolic substances were extracted according to the method made by Vitali et al. (2009), with some modifications. 2 g of ground sample extracted with 20 mL of HCl conc/methanol/water (1:80:10 v/v) solution at 20 °C in a laboratory rotary shaker (JB50-D; Shanghai, China) at 250 rpm for 2 h. At the end of this time, extract was centrifuged at 3500 rpm for 10 min at 20 °C (Sigma 3 K 30, Germany) and the supernatant was used as *extractable phenolics*. Residue was mixed with 20 mL of methanol/H₂SO₄-conc (10:1) solution and shaken with a laboratory rotary shaker 250 rpm for 20 h at 85 °C, then it was cooled to room temperature. After that, it was centrifuged at 3500 rpm for 10 min at 4 °C and supernatant was used as *hydrolysable phenolics*.

Phenolic contents were determined according to Apak et al. (2008). The absorbance was measured at 750 nm using a spectrophotometer (Jenway, 6405 UV/Vis) and results were given as mg gallic acid equivalents (GAE)/g. Each sample was analysed three times. *Total phenolic contents* were calculated as the sum of extractable and hydrolysable phenolics of each sample.

Table 1 Cookie formulations

Ingredients ^a	Control	CSS*-2.5	CSS*-5.0	CSS*-7.5
Flour (g)	100	97.5	95	92.5
Coffee silverskin powder (g)	0	2.5	5.0	7.5
Sugar (g)	42	42	42	42
High fructose corn syrup(g)	1.5	1.5	1.5	1.5
Shortening (g)	40	40	40	40
Sodium bicarbonate (g)	1.0	1.0	1.0	1.0
Ammonium bicarbonate (g)	0.5	0.5	0.5	0.5
Salt (g)	1.25	1.25	1.25	1.25
Skim milk powder (g)	1.0	1.0	1.0	1.0
Water (mL)	19.03	27.12	28.11	30.80

^aDry basis

*CSS coffee silverskin powder

Evaluation of antioxidant capacity

Cupric ion reducing antioxidant activity (CUPRAC) assay and 2,2-azinobis-[3-ethylbenzothiazoline-6-sulphonocacid] (ABTS) radical cation assay (Apak et al. 2008) and ferric reducing antioxidant power assay (FRAP) (Benzie and Strain 1996) were used to determine antioxidant capacity of the extracts (extractable and hydrolysable). The results were given as μ mole Trolox equivalent (TE)/g sample. Each experiment was replicated three times.

In vitro bioaccessibilities of phenolics and antioxidants from cookie samples

In vitro enzymatic digestion system build by method of Bouayed et al. (2012) was used for the analyzes of bioaccessible phenolics and antioxidants. Pepsin enzyme (40 mg/mL in 0.1 M HCl) was added to each sample and digested at pH 2–2.5 at 37 °C for 1 h (shaken in water bath at 100 rpm), then intestinal digestion with porcine pancreatin enzyme (2 mg/mL) and porcine bile mixture (12 mg/mL) at pH 7.2–7.5 at 37 °C for 2.5 h (shaken in water bath at 100 rpm) was made. After that, the mixture was centrifuged at 3500 rpm/10 min at 15 °C and supernatant was stored at – 18 °C until analyzing. Bioaccessible phenolic content of each supernatant was determined according to a modified Folin–Ciocalteu colorimetric spectrophotometric method by Apak et al. (2008). Bioaccessible antioxidant capacity of them was analyzed by CUPRAC and ABTS radical cation assays (Apak et al. 2008) and FRAP assay (Benzie and Strain 1996). The results were given as mg GAE/g for phenolic content, μ mole TE/g for antioxidant capacity.

The bioaccessibilities (%) of phenolics and antioxidants were calculated as the bioaccessible phenolics and antioxidant capacity, divided by the total phenolic content

and antioxidant capacities from cookie sample times 100 (Anson et al. 2009).

Sensory evaluation

The sensory analyzes were carried out by 35 untrained panelists. The samples were presented in random order occasionally labelled with three-digit numbers. Cookie samples were evaluated in terms of color, texture, flavor-taste, and general acceptance. A 9-point hedonic scale with 9-like extremely, 8-like very much, 7-like moderately, 6-like slightly, 5-neither like or dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much, and 1-dislike extremely was used. Final evaluation was calculated mean value of the individual scores given by all panelists.

Statistical analysis

Results were evaluated with JMP statistical package (JMP 7.0, SAS Institute Inc.). The differences between means were considered according to 0.05% level of statistical significance ($p \leq 0.05$). One way analysis of Fit Model and LSMeans Student's t were used as statistical comparison methods.

Results and discussion

Baking performances of cookies

Chemical and physical characteristics of cookies are given in Table 2. Appearance of cookie samples can be seen in Fig. 1. Moisture content levels of cookies with CSS (7.66–7.89%) were significantly higher ($p \leq 0.05$) than that of control sample (6.41%). As the CSS increases, the moisture content of the cookies has also significantly (p

Table 2 Baking performances of cookie samples^a

Sample	Moisture (%)	Ash (%)	Diameter (D) (cm)	Thickness (T) (cm)	Spread Ratio (D/T)	Hardness (N)*	Color Values		
							L*	a*	b*
Control	6.41 ± 0.01 ^d	0.47 ± 0.03 ^d	5.75 ± 0.05 ^a	0.90 ± 0.02 ^b	6.39 ± 0.18 ^a	0.63 ± 0.14 ^a	46.65 ± 1.1 ^a	2.96 ± 0.19 ^b	24.25 ± 0.59 ^a
CSS*-2.5	7.66 ± 0.00 ^c	0.64 ± 0.10 ^c	5.23 ± 0.16 ^b	0.93 ± 0.03 ^b	5.62 ± 0.06 ^b	0.54 ± 0.12 ^a	36.36 ± 1.35 ^b	3.84 ± 0.41 ^a	18.83 ± 0.42 ^b
CSS*-5.0	7.73 ± 0.02 ^b	0.66 ± 0.08 ^b	5.12 ± 0.12 ^b	0.94 ± 0.02 ^b	5.45 ± 0.15 ^b	0.52 ± 0.20 ^a	36.18 ± 0.98 ^b	4.52 ± 0.68 ^a	17.27 ± 1.23 ^c
CSS*-7.5	7.89 ± 0.00 ^a	0.70 ± 0.12 ^a	5.08 ± 0.07 ^b	1.10 ± 0.09 ^a	4.62 ± 0.43 ^c	0.45 ± 0.03 ^a	35.17 ± 0.57 ^b	4.65 ± 0.41 ^a	15.17 ± 0.22 ^d

^aMean values ± standard deviation with different superscript in the same row are significantly different ($p \leq 0.05$)

*CSS coffee silverskin powder

≤ 0.05) increased (Table 2). This result may be due to the high dietary fiber content of CSS. Similar results were reported in another study, showing the increases in moisture content of cookies with the increase in fiber content (Gupta et al. 2011). When CSS amounts in formulation were increased, the ash content increased significantly ($p \leq 0.05$) in cookies from 0.47% (control) to 0.70% (CSS-7.5).

Cookies prepared with CSS showed significantly ($p \leq 0.05$) lower diameters (5.23–5.08 cm) than that of control sample (5.75 cm). On the contrary, as the addition levels of CSS were increased, significant ($p \leq 0.05$) increases occurred (0.93–1.10 cm) in thickness of the cookies compared with control (0.90 cm) (Table 2). It can be concluded that CSS affected the spread ratio of cookie due to its high dietary fiber and protein content. Turksoy and Ozkaya (2011) reported that there was a progressive increase in water absorption with increasing levels of pumpkin pomace and carrot pomace powders; probably due to the rich dietary fiber content of these vegetables. In a study by Ajila et al. (2008), they found that mango peel powder added to biscuit lowered the cookie diameter and increased the thickness. The authors reported that this might be due to the reduction of gluten in biscuit dough. In addition to this, it was also notified that increasing fiber addition reduced the spread ratio of high-fiber cookies (Seker et al. 2010).

As a result of the decreases in diameters and increases in thickness of cookies with CSS, the spread ratios (4.62–5.62) of them were determined significantly ($p \leq 0.05$) lower than that of control (6.39). The spreading level of cookie is related to the viscosity of the dough (Pareyt and Delcour 2008). During dough kneading, water-absorbing components limit the spread of cookies by increasing the dough consistency (McWatters et al. 2003; Arshad et al. 2007). The dough of soft wheat flour slowly expands to a maximum diameter and then dramatically collapses and results into good quality cookies (Kaur et al. 2014). Hoojjat and Zabik (1984) reported that water absorption level of proteins other than wheat proteins is higher than that of gluten. This also affects the spreading property of cookie during cooking. Generally, the limited amount of free water in cookie dough plays a critical role on the spreading factor. As the amount of hydrophilic agents added to the cookie formulation is increased, the spread ratio decreases. These hydrophilic molecules have the capacity to compete with other components for free water in the cookie dough. If there is free water remaining in cookie dough without absorbing, dough consistency decreases and thus the spread ratio of the cookie increases (Chung et al. 2014). De Escalada Pla et al. (2007) also found remarkable hydration properties in products enriched with fiber extracts obtained from pumpkin. In their study,

Fig. 1 Appearance of cookies

fiber matrices strongly absorbed water. Tangkanakul et al. (1995) and Ozbas et al. (2010) also determined that the spread ratio of cookies supplemented with fiber decreased as a result of the increase in fiber ratio. Gupta et al. (2011) found that as the barley flour ratio increased, the cookie thickness increased and the spread rate decreased effectively. As can be seen, the results obtained in our study are consistent with these findings.

Hardness values demonstrated the same trend as SR values, and cookies with CSS had slightly lower (0.54–0.45 N) hardness values compared to control sample (0.63 N) (Table 2). The panelists had already stated that CSS added cookies were softer than control. This means that supplementation of CSS reduces hardness of cookies, in other words, causes cookies to soften. This reduction in the hardness of cookies can be attributed to the decrease in the amount of gluten and the delay in the formation of the gluten matrix as a result of the addition of CSS. It is also thought that CSS can absorb large amounts of water and there is no water to be absorbed for gluten proteins. These results are similar to the data previously obtained in a study made by Pongjanta et al. (2006). In some previous studies, similar results were also determined with the addition of pumpkin flour (Giami and Barber 2004), barley flour (Frost et al. 2011; Gupta et al. 2011), potato flour, corn flour (Singh et al. 2003), rice flour (Kim et al. 2002; Chung et al. 2014), and apple fiber (Uysal et al. 2007) to cookies. Szkudlarz et al. (2013) found that white grape pomace supplementation reduced the hardness of cookies and that these cookies were softer, and their resistance to breakage were low. In another study, resistant starch addition to cookie formulation reduced the cookie hardness and increased crumbliness (Laguna et al. 2012).

Although the spread rate (D/T) decreased with CSS content, the samples became softer and provided less resistance to the force applied during texture analysis. Similar results were observed in case of cookies from barley flour (Gupta et al. 2011) and pumpkin concentrate (Giami and Barber 2004). This is a striking result, but

further studies are needed to understand the factors leading to this result.

Table 2 shows the effects of CSS on the colour values of cookie samples. The L^* values which correspond to brightness significantly ($p \leq 0.05$) decreased in the samples ranged from 46.65 (control) to 35.17 (CSS-7.5%). The a^* values which correspond to redness ranged from 2.96 (control sample) to 4.65 (CSS-7.5%). CSS supplementation significantly ($p \leq 0.05$) increased the a^* values of the samples compared to control. When b^* values which corresponded to yellowness were examined, the b^* values of the samples with the addition of 2.5, 5.0, 7.5% CSS were found to be 18.83, 17.27 and 15.17, respectively, and these values were found to be significantly lower ($p \leq 0.05$) than that of control (24.25). As the CSS addition rate increased, L^* and b^* values decreased and the a^* values increased. The fact that cookies with CSS were darker than control sample was due to the fact that CSS has a dark color like cocoa. Recently Garcia-Serna et al. (2014) stated that coffee silverskin can be used as natural coloring agent to obtain a biscuit. Similarly, Ates and Elmaci (2018) reported that as CSS level increased in cake formulations, L^* and b^* values decreased, indicating a darker and more yellow color.

Phenolic contents and in vitro bioaccessibilities of phenolic compounds from cookies

Phenolic contents (TPC) of cookie samples are shown in Table 3. Extractable phenolics of cookie samples ranged from 34.16 mg g⁻¹ GAE (control) to 70.81 mg g⁻¹ GAE (CSS-7.5). Similarly, hydrolysable phenolic content was significantly ($p \leq 0.05$) increased by approximately 50% and reached from 182.24 mg g⁻¹ GAE (control) to 274.24 mg g⁻¹ GAE (CSS-7.5%) (Table 3). Total phenolic contents of the samples with CSS (326.05–345.05 mg g⁻¹ GAE) were also significantly ($p \leq 0.05$) higher than that of control sample (216.40 mg g⁻¹ GAE). The highest total phenolic content (345.05 mg g⁻¹ GAE) was found in the sample with 7.5% CSS with a 60% increase compared to

Table 3 Phenolic contents and in vitro bioaccessibilities of phenolic compounds from cookie samples^a

Sample	Phenolic contents (mg g ⁻¹ GAE)			Bioaccessible phenolics (mg g ⁻¹ GAE)	Bioaccessibility of phenolics (%)
	Extractable phenolics	Hydrolysable phenolics	Total phenolics		
Control	34.16 ± 0.71 ^d	182.24 ± 1.78 ^b	216.40 ± 2.50 ^c	120.64 ± 1.78 ^c	55.74 ± 1.53 ^b
CSS*-2.5	59.78 ± 1.90 ^c	266.27 ± 7.76 ^a	326.05 ± 5.64 ^b	274.27 ± 7.76 ^b	84.12 ± 0.18 ^a
CSS*-5.0	65.95 ± 2.13 ^b	272.61 ± 14.03 ^a	338.56 ± 7.56 ^a	295.61 ± 14.03 ^a	87.31 ± 1.58 ^a
CSS*-7.5	70.81 ± 2.35 ^a	274.24 ± 4.49 ^a	345.05 ± 3.56 ^a	305.24 ± 4.49 ^a	88.46 ± 0.85 ^a

^aMean values ± standard deviation with different superscript in the same row are significantly different ($p \leq 0.05$)

*CSS coffee silverskin powder

control sample (Table 3). Even though by-products such as coffee silverskin (CS) represent a disposal problem, they can also be a source of polyphenolic compounds with great economic potential in industrial applications because they can be used as food additives/supplements with high nutritional value (Martínez-Pinilla et al. 2015; Murthy and Naidu 2012a). Martínez-Saez et al. (2014) also reported that an antioxidant beverage with good nutritional composition and sensorial quality may be formulated by coffee silverskin extract.

Bioaccessible phenolic values of cookies were determined in order to assess CSS as a source of accessible phenolics. The values of bioaccessible phenolics significantly ($p \leq 0.05$) increased in the samples ranged from 120.64(control) to 305.24 mg g⁻¹ GAE (the sample with 7.5% CSS). The highest phenolic bioaccessibility value (88.46%) were also obtained in the sample with 7.5 M % CSS. These values of CSS supplemented samples increased up to 50% compared to control. The results also showed that CSS supplementation to cookie sample had a strongly positive effect on extractable, hydrolysable and total phenolics and their bioaccessibilities (Table 3).

Antioxidant capacities and in vitro bioaccessibilities of antioxidants from cookies

In this study, ABTS, CUPRAC and FRAP assays are selected among the most common antioxidant capacity measurement methods and the results were presented in Table 4. According to the results of all assays (ABTS, CUPRAC and FRAP), antioxidant capacities of cookies with CSS have been found to be higher when compared to control. The higher levels of phenolics might be responsible for higher antioxidant capacities of CSS.

For extractable phenolics; the highest TEACABTS value (247.61 µmole trolox g⁻¹) was observed in the CSS-7.5. It was also observed that the cookies with CSS had significantly ($p \leq 0.05$) higher TEACABTS values than those of control sample (36.03 µmole trolox g⁻¹). TEAC-CUPRAC value of control was 24.74 µmole trolox g⁻¹, and the value significantly ($p \leq 0.05$) increased to 59.17

µmole trolox g⁻¹ upon addition of 7.5% CSS, which is approximately 2.5 times higher than that of control. TEACFRAP value of control was 2.00 µmole trolox g⁻¹, and the value significantly ($p \leq 0.05$) increased to 4.18 µmole trolox g⁻¹ upon addition of 7.5% CSS. As the addition levels of CSS were increased, significant ($p \leq 0.05$) increases occurred in antioxidant capacities of extractable phenolics obtained from cookies compared with control sample (Table 4). Indeed, the coffee silverskin obtained as a by-product of the roasting process has a high antioxidant capacity, possibly due to the presence of compounds such as melanoidin, which is formed by the maillard reaction during the roasting process as well as the phenolic compounds in the coffee beans (Mussatto et al. 2011). According to Murthy and Naidu (2012c), the CSS is high in total dietary fibre, antioxidant capacity and phenolic compounds. Janissen and Huynh (2018) also reported that CSS is a potential added value agent for the food industry due to its dietary fiber content and antioxidant capacity.

In ABTS assay, all cookies with CSS had significantly ($p \leq 0.05$) higher antioxidant capacities of hydrolysable phenolics (681.77–792.30 µmole trolox g⁻¹) than control sample (552.22 µmole trolox g⁻¹).

CUPRAC values of hydrolysable phenolics from cookies with CSS were between 270.79–290.91 µmole trolox g⁻¹ and these results were found significantly higher ($p \leq 0.05$) than that of control (256.63 µmole trolox g⁻¹). The FRAP values of hydrolysable phenolics from cookies with CSS were slightly higher compared to control sample. The highest values in all assays (ABTS, CUPRAC, FRAP) were obtained from the sample with 7.5% CSS (Table 4).

According to ABTS assay, all cookies which were supplemented with CSS had significantly ($p \leq 0.05$) higher antioxidant capacities of total phenolics than control. ABTS value of the sample with 7.5% CSS (1039.91 µmole trolox g⁻¹) found approximately 75% higher than that of control (588.25 µmole trolox g⁻¹). The highest CUPRAC antioxidant capacity value (350.08 µmole trolox g⁻¹) of total phenolics from of cookies was observed in the sample with 7.5% CSS. Control cookie (16.94 µmole trolox g⁻¹)

Table 4 Antioxidant capacities of cookie samples^a

Sample	Antioxidant capacities of extractable phenolics (μmole trolox g ⁻¹)			Antioxidant capacities of hydrolysable phenolics (μmole trolox g ⁻¹)			Antioxidant capacities of total phenolics (μmole trolox g ⁻¹)		
	ABTS	CUPRAC	FRAP	ABTS	CUPRAC	FRAP	ABTS	CUPRAC	FRAP
Control	36.03 ± 0.50 ^d	24.74 ± 1.31 ^d	2.00 ± 0.21 ^c	552.22 ± 6.53 ^c	256.63 ± 1.40 ^c	14.94 ± 0.87 ^a	588.25 ± 6.45 ^d	281.37 ± 5.61 ^d	16.94 ± 0.34 ^c
CSS*-2.5	112.77 ± 1.02 ^c	40.08 ± 1.22 ^c	2.85 ± 0.20 ^b	681.77 ± 16.75 ^b	270.79 ± 6.35 ^b	15.29 ± 0.85 ^a	794.54 ± 8.76 ^c	310.87 ± 9.54 ^c	18.14 ± 0.65 ^b
CSS*-5.0	200.88 ± 8.88 ^b	51.03 ± 0.77 ^b	3.69 ± 0.09 ^a	690.06 ± 7.67 ^b	285.24 ± 8.61 ^a	15.74 ± 0.54 ^a	890.94 ± 5.98 ^b	336.27 ± 4.56 ^b	19.43 ± 0.66 ^a
CSS*-7.5	247.61 ± 2.33 ^a	59.17 ± 3.20 ^a	4.18 ± 0.80 ^a	792.30 ± 13.75 ^a	290.91 ± 10.31 ^a	15.91 ± 0.42 ^a	1039.91 ± 3.45 ^a	350.08 ± 6.78 ^a	20.09 ± 0.33 ^a

^aMean values ± standard deviation with different superscript in the same row are significantly different ($p \leq 0.05$)

*CSS coffee silverskin powder

showed significantly ($p \leq 0.05$) lower FRAP antioxidant capacity value of total phenolics than other cookies with CSS substitutions (18.14–20.09 μmole trolox g⁻¹) (Table 4). The antioxidant properties can be correlated with coffee silverskin fiber. This is attributed to the presence of chlorogenic acid adhering to the dietary fiber matrix formed by a complex carbohydrate structure. Therefore, CSS fiber is classified as antioxidant dietary fiber (Murthy and Naidu 2012b; Napolitano et al. 2007).

In vitro bioaccessibilities of antioxidants obtained from cookie samples were shown in Table 5. The antioxidant capacity of foods arise from compounds with different chemical properties in their contents. Effectiveness of antioxidative compounds (bioactive compounds) is based on their chemical features, interactions between food matrix and physical position within a food structure like nearness to membrane phospholipids, emulsion interfaces, or being in the aqueous phase (Watanabe et al. 2000; González-Aguilar et al. 2017). The bioaccessibility and bioavailability of these bioactive compounds after human digestion determine their biological action in the body (Etcheverry et al. 2012). For this reason, these compounds must be absorbed during digestion to reveal the protective effects in the human body (Hemery et al. 2010).

In recent years, in vitro bioaccessibility studies have become increasingly important in determining the profile and structural properties of food and components (González-Aguilar et al. 2017). Some studies have carried on the potential application of in vitro models for creating in vivo conditions by enzymes for obtaining bioaccessible extraction and investigation of bioactive compounds efficacy (Bouayed et al. 2012; Chen et al. 2016; Juárez et al. 2016).

In our study, when the levels of bioaccessible antioxidants were examined, it was observed that there were increases of 165% in the ABTS values of the samples, 130% in the CUPRAC values of the samples and 100% in the FRAP values of the samples compared to the values of control sample.

According to all assays (ABTS, CUPRAC and FRAP), the sample with 7.5% CSS had the highest values of bioaccessible antioxidants (157.06, 48.37, 4.99 μmole trolox g⁻¹), respectively. The results showed that the samples with CSS exhibited significantly ($p \leq 0.05$) higher bioaccessible antioxidants than those of control sample in all assays (Table 5).

Bioaccessibilities of antioxidants from cookies ranged between 10.04 and 15.10% for the ABTS assay, 7.33–13.82% for the CUPRAC assay and 14.46–24.84% for the FRAP assay. Bioaccessibilities of antioxidants increased linearly with CSS increments and cookies had significantly ($p \leq 0.05$) higher results compared to control sample. In summary, bioaccessibility of antioxidant values increased up to 85% compared to control (Table 5).

Table 5 In vitro bioaccessibilities of antioxidants from cookie samples^a

Sample	Bioaccessible antioxidants ($\mu\text{mole trolox g}^{-1}$)			Bioaccessibility of antioxidants (%)		
	ABTS	CUPRAC	FRAP	ABTS	CUPRAC	FRAP
Control	59.06 $\pm$ 2.38 ^d	20.62 $\pm$ 1.73 ^d	2.45 $\pm$ 0.15 ^c	10.04 $\pm$ 0.47 ^c	7.33 $\pm$ 1.09 ^b	14.46 $\pm$ 0.62 ^c
CSS*-2.5	113.86 $\pm$ 0.54 ^c	40.99 $\pm$ 0.40 ^c	4.27 $\pm$ 0.12 ^b	14.33 $\pm$ 0.10 ^b	13.19 $\pm$ 2.00 ^a	23.54 $\pm$ 0.65 ^b
CSS*-5.0	130.58 $\pm$ 1.96 ^b	45.86 $\pm$ 1.09 ^b	4.69 $\pm$ 0.23 ^a	14.66 $\pm$ 0.45 ^{ab}	13.64 $\pm$ 0.45 ^a	24.14 $\pm$ 0.45 ^{ab}
CSS*-7.5	157.06 $\pm$ 1.77 ^a	48.37 $\pm$ 0.68 ^a	4.99 $\pm$ 0.25 ^a	15.10 $\pm$ 0.20 ^a	13.82 $\pm$ 1.31 ^a	24.84 $\pm$ 0.25 ^a

^aMean values $\pm$ standard deviation with different superscript in the same row are significantly different ($p \leq 0.05$)

*CSS coffee silverskin powder

The higher antioxidant capacities of the cookies with CSS may be related to its higher phenolic content with regards to control sample made with only wheat flour. Accordingly, cookies with CSS could be developed as a functional food with more effective antioxidant properties. Similarly, some authors recommended the use of coffee silverskin as a functional ingredient, considering the high contents of soluble dietary fiber (60%) and marked antioxidant activity, the low amount of fats and providing carbohydrate reduction (Borrelli et al. 2004; Napolitano et al. 2007).

Sensorial properties

The results of the sensory analyzes of the cookies are given in Table 6. The color scores given to the CSS cookies by the panelists were found to be consistent with the results of the instrumental color measurement. Increase in darkness also reflected in L* values (Table 2) which may be due to the color of CSS. Ates and Elmaci (2018) obtained similar results from the cakes with CSS. Authors reported that cakes with untreated coffee silverskin were determined to have a stronger coffee color (brownness) compared to cakes with water treated coffee silverskin and control sample.

Table 6 Sensorial properties of cookie samples^a

Sample	Color	Texture	Flavor and taste	General acceptance
Control	7.83	7.87	7.96	8.05
CSS*-2.5	7.21	6.79	6.80	7.63
CSS*-5.0	7.25	6.75	6.91	7.79
CSS*-7.5	6.94	6.48*	6.60**	7.20

^aA nine-point hedonic scale with 1 dislike extremely and 9 like extremely was used

*CSS coffee silverskin powder

**Significantly different from control ($p \leq 0.05$)

The slight bitter taste of CSS could have also contributed to the relatively lower flavor-taste scores for the samples with CSS. These results were also consistent with the study of Ates and Elmaci (2018).

The cookies became relatively softer compared to control with increase in the level of CSS. The decrease in the hardness scores given by the panelists was parallel to the values measured by a texture analyzer (Table 2). However, the hardness scores of the cookies with CSS were acceptable to the panel.

There was also a steady decline in general acceptance scores due to increased CSS. However, these scores were also moderately like.

In the present study, the liking scores of all cookies supplemented with CSS in the sensory panel were lower than control sample. However, these samples received 6 and above scores (6: like slightly, 7: like moderately) from the panelists. Considering the color, texture, flavor-taste, and general acceptance attributes, it could be said that 5.0% level of CSS was optimum.

Conclusion

CSS supplementation to cookie had a strongly positive effect on extractable, hydrolysable and total phenolic compounds. As a result of this, CSS enriched cookies showed significant improved antioxidant capacity. In addition, bioaccessibilities of antioxidants and phenolics in the cookies with CSS increased up to 85% compared to the control cookie. In the sensorial analyzes, the samples with CSS received 6 and above scores (6: like slightly, 7: like moderately) for color, texture, flavor-taste, and general acceptance attributes from the panelists. It may be concluded from the present study that CSS could be incorporated up to a 5% level in the formulation of cookies without affecting their overall quality. Consequently, CSS is an excellent by-product from the coffee processing industry and it could be utilized for the preparation of healthier,

more nutritious, and more functional cookies and other bakery products as a source of phenolic compounds, antioxidants and a natural colouring agent.

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