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Physicochemical properties of Turkish green tea powder: effects of shooting period, shading, and clone

Ayhan TOPUZ[1,*], Cüneyt DİNÇER[1], Mehmet TORUN[1], İsmail TONTUL[1,2], Hilal ŞAHİN-NADEEM[1], Ayhan HAZNEDAR[3], Feramuz ÖZDEMİR[1]

[1]Department of Food Engineering, Akdeniz University, Antalya, Turkey
[2]Department of Food Engineering, Necmettin Erbakan University, Konya, Turkey
[3]Atatürk Tea Garden Cultures Research Institute, Rize, Turkey

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Abstract: This study aimed to determine the physicochemical properties of the green tea powders produced from 2 different Turkish tea [*Camellia sinensis* (L.) O.Kuntze] clones (Derepazarı 7 and Fener) grown under different shade levels and harvested during 2 consecutive shooting periods. Moisture, ash, crude fiber, and total phenolic contents of the green tea powders were determined based on the experimental factors. Products were also evaluated for their water activity, bulk density, particle size, color, extraction yield, and antioxidant activity. The shooting period, specific to Turkish tea cultivation, showed remarkable effects on the main quality parameters of the green tea powders. It is noteworthy that the phenolic content and antioxidant activity of the products did not change significantly with treatments. The green tea powder produced from Derepazarı 7 clone, grown under dark shade and harvested in the first shooting period, was superior among the tested parameters.

Key words: Antioxidant, green tea powder, phenolics, physicochemical properties, shading level, shooting period

1. Introduction

Tea [*Camellia sinensis* (L.) O.Kuntze] is one of the most popular beverages worldwide due to its taste, aroma, and health effects (Khokhar and Magnusdottir, 2002). Young shoots of tea bushes are mainly processed into black tea, green tea, and oolong tea. Among these, green tea is most beneficial to human health. Recently reported pharmacological properties, e.g., antioxidant, anti-inflammatory, antimutagenic, and anticarcinogenic effects also served to increase the popularity of green tea (Higdon and Frei, 2003; Cabrera et al., 2006; Pharn-Huy et al., 2008; Yuan et al., 2011).

Green tea powder, known as *matcha*, is an important tea product. Centuries ago it was prepared and consumed in rituals by Zen Buddhists in China; later, they transferred this product to Japan. Today *matcha* is rarely drunk in China but commonly consumed in Japan and is prepared by whisking it in hot water with a special whisk (*chasen*) in a bowl (*chawan*) (Heiss, 2008). It has also become a popular additive in the production of beverages, chocolates, candies, cakes, pastries, cookies, puddings, ice creams, etc. (Tokunaga, 2004). Green tea powder is made from young shoots of tea bushes that have been shaded for a few weeks, which enriches the free amino acids content (e.g., theanine). In this manner, green tea becomes flavor-rich before it is hand-harvested (Hirai et al., 2008). Shading leads to greener, tastier, and less astringent tea leaves and, thereby, attracts the consumer (Ku et al., 2009). After harvest, the young shoots are processed into green tea powder by series of processing steps: steaming; drying; removing of stems, midribs, and veins; and fine stone milling (Tokunaga, 2004).

The Turkish Tea Board (ÇAYKUR)—the main tea producer in Turkey—started to produce green tea in 2004. Today, the company markets different blends of green teas. Currently, efforts are underway to process green tea powder. Unlike many tea producing countries, the distribution of tea crops is atypical in Turkey. After a severe winter, the temperature suddenly rises in the spring and the tea season starts in May. The tea crop is ready for harvesting at nearly the same time on all plantations in the country. Therefore, in a single season, tea is plucked 3 times until October—each time under different weather conditions. Thus, the tea can show different quality parameters at each plucking (Ozdemir et al., 1992).

* Correspondence: atopuz@akdeniz.edu.tr

There are reported studies on green tea powder related to milling methods, particle characteristics (Haraguchi et al., 2003; Sawamura et al., 2009; Sawamurai et al., 2010), and foaming properties (Maeda et al., 1999; Sawamura et al., 2012). Catechin contents were also studied in green tea powder (Weiss and Anderton, 2003; Li et al., 2011). The present study was undertaken to identify some physicochemical properties of the green tea powder produced from 2 different Turkish tea clones (Derepazarı 7 and Fener) according to shooting period and shading level. Moisture content, water activity, color values (*L*, *a*, and *b*), total phenolic content, free radical scavenging activity, ash and fiber content, extraction yield, solubility, and particle size were evaluated as physical and chemical properties.

2. Materials and methods

2.1. Chemicals

2,2-Diphenyl-1-picrylhydrazyl (DPPH), Trolox, and gallic acid were purchased from Sigma–Aldrich (Dorset, UK). Folin–Ciocalteu's phenol reagent, sodium carbonate, sodium hydroxide, hydrochloric acid, methanol, acetone, acetic acid, trichloroacetic acid, nitric acid, and sulfuric acid were obtained from Merck (Darmstadt, Germany).

2.2. Material

Young shoots of tea [*Camellia sinensis* (L.) O.Kuntze] clones (Derepazarı 7 and Fener) were plucked (2 leaves and a bud) in the 2 consecutive shooting periods (May and July 2010) at the Hayrat Tea Plantation (41°01′57″N, 40°29′86″E; altitude: 140 m) of ÇAYKUR's experimental station located in Rize, Turkey. Three weeks before harvesting, shading nets (Abdioğulları Plastik, Adana, Turkey) preventing the entry of 0% (control), 50%, and 90% of light were hung 60 cm above the plants. For each shading level, nearly 60 tea bushes were randomly selected as experimental plots (Derepazarı 7 and Fener clones were 35 and 40 years old, respectively). Each plot was approximately 75 m^2. The plants were grown according to recommended agricultural practices without pesticide application. On each occasion, about 40 kg of homogeneous young shoots of the tea clones were hand-harvested and immediately processed into green tea powder at the ÇAYKUR experimental station by a series of processing steps: steaming (120 °C, 90 s); cooling; drying (95 ± 2 °C); removing stems, midribs, and veins; and milling (Tontul et al., 2013). As a result, approximately 120–150 g of green tea powder per kilogram of fresh tea leaves was obtained, depending on experimental factors.

2.3. Moisture content and water activity

Moisture content of the green tea powders was determined by drying in an oven maintained at 70 °C until insignificant consecutive weight changes.

Water activity (a_w) of the samples was measured at 25 °C using a water activity meter (Testo 650 Water Activity System, Cole–Parmer, USA). Approximately 0.5 g of each sample was transferred to a sample holder equipped with a relative humidity probe. Water activity values were recorded at relative humidity equilibration.

2.4. Ash and crude fiber content

The ash and crude fiber content of the samples were determined by standard procedures (AOAC, 1995).

2.5. Color analysis

Color analyses were carried out using a tristimulus colorimeter (Konica Minolta Sensing Inc., Japan) equipped with a CR-400 measuring head (reference illuminant/observer, D_{65}/2°). The color was expressed according to Hunter scale parameters (Quek et al., 2007): *L* (darkness/whiteness), *a* (greenness/redness), and *b* (blueness/yellowness). The sample holder containing 3 g of green tea powder (>0.5 cm sample height) was placed above the light source. Color values were recorded as the mean of 5 determinations. The instrument was calibrated against a white tile ($L = 97.96$, $a = 0.08$, and $b = 1.78$) before viewing each sample.

2.6. Bulk density and particle size

Bulk density of green tea powder was determined by tapping 2 g of sample in a graduated cylinder 40 times and calculating from the occupied volume (Beristain et al., 2001).

Particle size of green tea powder was determined by light scattering technique using a particle size analyzer (Mastersizer 2000, Malvern, Worcestershire, UK) equipped with a dry powder dispersion unit (Scirocco 2000). Particle size of the samples was evaluated as D_{10}, D_{50}, and D_{90} which were the equivalent volume diameters at 10%, 50%, and 90% cumulative volumes, respectively (Zhang et al., 2012).

2.7. Extraction yield

About 2 g of green tea sample was introduced into 200 mL of hot water (90–95 °C) in a 500-mL round bottom flask, refluxed for 1 h, and cooled down to room temperature. This slurry was diluted to 500 mL with distilled water and filtered through coarse filter paper. Then, 25 mL of filtrate was dried in an oven (Memmert, Germany) at 70 °C until a constant weight was obtained. The extraction yield was calculated according to Eq. (1) (Gürses and Artık, 1987):

$$EY = \frac{DE \times 100}{W}, \quad (1)$$

where *EY* is extraction yield, *DE* is dry matter of the total extract, and *W* is weight of the sample dry matter.

2.8. Preparation of phenolic extract

Extraction of the samples was accomplished according to Škerget et al. (2005) with minor modifications. One gram of each sample was extracted with 100 mL of methanol

solution (80% in water). The extraction was carried out for 2 h using an orbital shaking (150 rpm) water bath (GFL 1092, GFL Gesellschaft Labortechnik, Burgwedel, Germany) maintained at 40 °C. The extracts were cooled and filtered (Whatman no. 42). The filtrate was used directly for total phenolic content and antioxidant activity determinations.

2.9. Total phenolic content

The total phenolic content was analyzed by the method of Škerget et al. (2005). First, 0.5 mL of the sample extract was treated with 2.5 mL of 0.2 N Folin–Ciocalteu's phenol reagent and 2 mL of Na_2CO_3 (75 g L^{-1}). The mixture was incubated at 50 °C for 5 min and then immediately cooled. The absorbance of the final solution was recorded with a spectrophotometer (UV-Vis 160A, Shimadzu, Japan) at 760 nm with respect to the blank solution (0.5 mL of 80% methanol solution in place of extract). The results were expressed as gallic acid equivalent (g of GAE 100 g^{-1} dw).

2.10. Antioxidant activity

The antioxidant activity of the sample was analyzed by using DPPH assay according to Gadow et al. (1997) and Maisuthisakul et al. (2007). Diluted sample extract (100 µL) (prepared at 4 different concentrations that showed 10%–90% inhibition for DPPH radical) was added to 4 mL of freshly prepared DPPH (2,2-diphenyl-1-picryhydrazyl radical) solution (6×10^{-5} M in MeOH). The mixtures were shaken and kept in the dark at room temperature for 30 min. Absorbance values of the final solutions were recorded at 516 nm using a spectrophotometer (UV-Vis 160A) with respect to control solution (aq. 80% MeOH v v^{-1} instead of extract in DPPH solution). The antioxidant activity of the samples was expressed as percent inhibition of the DPPH radical and calculated by Eq. (2):

$$I(\%) = \frac{A_c - A_s}{A_c} \times 100, \quad (2)$$

where *I* is the inhibition percentage, and *Ac* and *As* are the absorbance values of the control and test samples, respectively. The sample extract concentration providing 50% inhibition (IC_{50}) of the DPPH radical was calculated from the plot of concentration versus percent inhibition. Using the same procedure, the IC_{50} value of Trolox solution was also determined to compare the antioxidant activity of the samples.

2.11. Statistical analysis

The research was carried out using a factorial design. The plant materials were collected in triplicate, and the measurements were performed in duplicate. The data were subjected to analysis of variance, and appropriate mean separation was conducted using Duncan's multiple range test in SAS software (SAS Institute, Cary, NC, USA).

3. Results

Different physicochemical properties of Turkish green tea powders, according to shading level, shooting period, and clone, were evaluated. Mean squares obtained from the variance analyses are shown in Table 1.

3.1. Moisture content and water activity

Moisture contents of the green tea powders were in the range of 2.79–3.26 g 100 g^{-1} (Table 2). The results changed significantly with respect to shooting period; however, tea clone and shading level did not affect the moisture content of samples. Water activity results were observed in the range of 0.31–0.35. These results were not influenced by any of the experimental factors (Table 1).

3.2. Ash and crude fiber content

Ash content, which represents total mineral content of green tea powders, varied between 5.97 and 7.49 g 100 g^{-1} (Table 2). The ash content of green tea powders changed significantly ($P < 0.01$) according to shooting period and tea clone; however, this was unchanged by shading level of the raw material (Table 1). Shooting period and clone interaction also affected ($P < 0.01$) ash content of the samples.

Crude fiber content of the green tea powders was in the range of 9.23–10.71 g 100 g^{-1}. There were slight but significant ($P < 0.05$) differences in the crude fiber content of green tea powders with respect to the main experimental factors. Shooting period × clone and clone × shading level interactions significantly ($P < 0.01$) affected the crude fiber content of samples (Table 1).

3.3. Color analysis

The color values (*L*, *–a*, and *b*) of the green tea powders were 55.24–60.39, 8.23–6.43, and 17.23–18.71, respectively (Table 3). The shading level, shooting period, and clone significantly ($P < 0.05$) affected all the color values of the green tea powders. Shooting period × clone and shooting period × shading level interactions were also significant for the color of samples (Table 1).

3.4. Bulk density and particle size

Bulk density of the green tea powders was 584.16–609.45 kg m^{-3} (Table 4). Particle size was evaluated as D_{10}, D_{50}, and D_{90} and was 1.71–1.87, 9.36–11.88, and 57.51–107.08 µm, respectively. These parameters of the samples varied significantly only with shooting period. Interaction of the 3 variation sources had a significant effect ($P < 0.01$) on the bulk densities of the samples (Table 1).

3.5. Extraction yield

Extraction yield was determined between 44.71 and 49.45 g 100 g^{-1} dw for the green tea powders (Table 5). The extraction yield of the samples significantly ($P < 0.05$) changed according to shading level and shooting period.

Table 1. Mean squares from analysis of variance of physicochemical properties of the Turkish green tea powders.[a]

Source of variation	DF	Moisture content	Water activity	Ash	Crude fiber	Color			Bulk density	Particle size			Extraction yield	Phenolic content	IC_{50} value
						L	*a*	*b*		D_{10}	D_{50}	D_{90}			
Shooting period (S)	1	7.52*	0.103 ^{NS}	27.79**	29.84**	33.84**	20.43**	54.16**	5.12*	16.22**	18.16**	62.09**	4.76*	2.15 ^{NS}	3.36 ^{NS}
Clones (C)	1	0.19^{NS}	0.613 ^{NS}	24.20**	6.93*	17.09**	5.47*	22.07**	0.18 ^{NS}	0.72 ^{NS}	0.00 ^{NS}	0.81 ^{NS}	0.07 ^{NS}	0.36 ^{NS}	0.15 ^{NS}
Shading level (L)	2	2.82 ^{NS}	0.195 ^{NS}	1.41 ^{NS}	9.95**	60.01**	47.48**	60.84**	0.51 ^{NS}	2.09 ^{NS}	0.88 ^{NS}	8.04**	11.64**	0.26 ^{NS}	0.68 ^{NS}
S × C	1	0.00 ^{NS}	0.430 ^{NS}	38.66**	12.67**	16.16**	55.51**	19.23**	0.63 ^{NS}	1.89 ^{NS}	0.18 ^{NS}	0.00 ^{NS}	4.19 ^{NS}	1.05 ^{NS}	0.54 ^{NS}
S × L	2	2.25 ^{NS}	0.150 ^{NS}	0.92 ^{NS}	3.57 ^{NS}	1.17*	5.84*	7.57**	2.82 ^{NS}	2.20 ^{NS}	0.13 ^{NS}	1.21 ^{NS}	1.45 ^{NS}	0.66 ^{NS}	1.17 ^{NS}
C × L	2	0.92 ^{NS}	0.475 ^{NS}	1.64 ^{NS}	13.27**	0.72 ^{NS}	1.97 ^{NS}	2.04 ^{NS}	3.82 ^{NS}	2.02 ^{NS}	2.22 ^{NS}	4.52*	1.70 ^{NS}	1.00 ^{NS}	3.74 ^{NS}
S × C × L	2	0.53 ^{NS}	0.366 ^{NS}	3.70 ^{NS}	0.14 ^{NS}	0.73 ^{NS}	0.25 ^{NS}	2.18 ^{NS}	8.47**	1.36 ^{NS}	1.38 ^{NS}	2.73 ^{NS}	2.97 ^{NS}	0.41 ^{NS}	1.10 ^{NS}
Error	12	0.15	0.001	0.50	0.38	0.89	0.14	0.07	749.55	0.01	2.09	237.40	4.21	8.60	0.01

[a] NS: not significant; *, significant at $P < 0.05$; **, significant at $P < 0.01$.

Table 2. Moisture content, water activity, and ash and crude fiber contents of green tea powder.

		Moisture content (g 100 g^{-1})	Water activity	Ash (g 100 g^{-1} dw)	Crude fiber (g 100 g^{-1} dw)
Shading level	Control	$2.79^{a} \pm 0.09$	$0.31^{a} \pm 0.01$	$6.46^{a} \pm 0.50$	$10.42^{a} \pm 0.51$
	Light	$3.19^{a} \pm 0.10$	$0.34^{a} \pm 0.01$	$6.68^{a} \pm 0.59$	$9.23^{b} \pm 0.27$
	Dark	$3.17^{a} \pm 0.23$	$0.34^{a} \pm 0.02$	$7.05^{a} \pm 0.67$	$10.42^{a} \pm 0.56$
Shooting period	First	$2.84^{b} \pm 0.07$	$0.32^{a} \pm 0.01$	$7.49^{a} \pm 0.53$	$9.34^{b} \pm 0.30$
	Second	$3.26^{a} \pm 0.15$	$0.35^{a} \pm 0.02$	$5.97^{b} \pm 0.26$	$10.71^{a} \pm 0.40$
Clones	Fener	$3.02^{a} \pm 0.16$	$0.34^{a} \pm 0.02$	$7.44^{a} \pm 0.55$	$10.35^{a} \pm 0.49$
	Derepazarı 7	$3.08^{a} \pm 0.10$	$0.33^{a} \pm 0.01$	$6.02^{b} \pm 0.24$	$9.69^{b} \pm 0.27$

Results are means ± standard error. The values within a column with different superscript letters are significantly ($P < 0.05$) different.

Table 3. CIE *L*, *a*, and *b* color values of green tea powder.

		L	*a*	*b*
Shading level	Control	$60.39^{a} \pm 0.44$	$-6.43^{a} \pm 0.29$	$18.71^{a} \pm 0.23$
	Light	$57.35^{b} \pm 0.69$	$-6.96^{b} \pm 0.31$	$17.83^{b} \pm 0.31$
	Dark	$55.24^{c} \pm 0.82$	$-8.23^{c} \pm 0.32$	$17.23^{c} \pm 0.15$
Shooting period	First	$58.78^{a} \pm 0.59$	$-7.56^{b} \pm 0.30$	$18.33^{a} \pm 0.20$
	Second	$56.54^{b} \pm 0.90$	$-6.85^{a} \pm 0.34$	$17.52^{b} \pm 0.26$
Clone	Fener	$56.86^{b} \pm 0.92$	$-7.02^{a} \pm 0.24$	$18.18^{a} \pm 0.21$
	Derepazarı 7	$58.46^{a} \pm 0.65$	$-7.39^{b} \pm 0.40$	$17.66^{b} \pm 0.29$

Results are means ± standard error. The values within a column with different superscript letters are significantly ($P < 0.05$) different.

Table 4. Bulk density and particle size (D_{10}, D_{50}, D_{90}) values of green tea powder.

		Bulk density (kg m^{-3})	D_{10} (µm)	D_{50} (µm)	D_{90} (µm)
Shading level	Control	$589.14^{a} \pm 15.86$	$1.80^{a} \pm 0.05$	$11.04^{a} \pm 0.60$	$96.91^{a} \pm 11.83$
	Light	$602.61^{a} \pm 8.84$	$1.84^{a} \pm 0.06$	$10.72^{a} \pm 0.72$	$83.85^{a} \pm 12.93$
	Dark	$598.66^{a} \pm 17.75$	$1.74^{a} \pm 0.04$	$10.10^{a} \pm 0.74$	$66.13^{a} \pm 9.06$
Shooting period	First	$609.45^{a} \pm 9.71$	$1.87^{a} \pm 0.04$	$11.88^{a} \pm 0.54$	$107.08^{a} \pm 8.48$
	Second	$584.16^{b} \pm 12.48$	$1.71^{b} \pm 0.03$	$9.36^{b} \pm 0.22$	$57.51^{b} \pm 3.24$
Clones	Fener	$594.46^{a} \pm 13.18$	$1.81^{a} \pm 0.02$	$10.61^{a} \pm 0.53$	$79.47^{a} \pm 8.90$
	Derepazarı 7	$599.15^{a} \pm 10.22$	$1.77^{a} \pm 0.05$	$10.63^{a} \pm 0.59$	$85.13^{a} \pm 10.65$

Results are means ± standard error. The values within a column with different superscript letters are significantly ($P < 0.05$) different.

Table 5. Extraction yield, total phenolic content, and free radical scavenging activity of green tea powder.

		Extraction yield (g 100 g^{-1} dw)	Phenolic content (g GAE 100 g^{-1} dw)	IC_{50} value (mg dw mg^{-1} DPPH)[a]
Shading level	Control	49.45[a] ± 0.59	21.94[a] ± 0.88	0.33[a] ± 0.01
	Light	48.31[a] ± 1.05	22.96[a] ± 0.88	0.36[a] ± 0.04
	Dark	44.71[b] ± 1.02	22.19[a] ± 1.22	0.33[a] ± 0.02
Shooting period	First	46.57[b] ± 0.10	21.49[a] ± 0.47	0.36[a] ± 0.03
	Second	48.40[a] ± 0.81	23.24[a] ± 0.98	0.31[a] ± 0.01
Clones	Fener	47.38[a] ± 0.81	22.73[a] ± 0.63	0.34[a] ± 0.03
	Derepazarı 7	47.60[a] ± 1.07	22.00[a] ± 0.95	0.33[a] ± 0.01

[a]IC_{50} of Trolox was 0.16 ± 0.01 mg/mg DPPH. Results are means ± standard error. The values within a column with different superscript letters are significantly ($P < 0.05$) different.

3.6. Total phenolic content and antioxidant capacity

Total phenolic content of the green tea powders was 21.49–23.24 g GAE 100 g^{-1} dw and was not significantly affected by the experimental factors.

IC_{50} values of the green tea powders were estimated from the curve of concentration versus percent inhibition of the sample extract. IC_{50} values of the green tea powders were observed in the range of 0.31–0.36 mg dw mg^{-1} DPPH (Table 5). Despite slight variation, the IC_{50} values were not significantly affected by the experimental factors.

4. Discussion

4.1. Moisture content and water activity

The processing conditions of the green tea powders produced in 2 consecutive shooting periods were the same, but their climatic conditions, i.e. humidity and temperature, were different. The second shooting period (July 2010) was very humid and hot compared to the first shooting period (May 2010). Therefore, higher moisture content was observed in the July samples.

It is documented that food powders are generally stable against chemical reactions such as browning, oxidation, and enzymatic reaction if they have water activity values between 0.20 and 0.40 during packaging and storage (Marques et al., 2007). Therefore, our drying conditions for the tea leaves targeted the above water activity levels (0.31–0.36) and were in agreement with the above values.

4.2. Ash and crude fiber content

The first shooting period had higher ash content than the second shooting period (Table 2). Likewise, the Fener clone had higher ash content than the Derepazarı 7 clone. Similar ash content variations, depending on the clone, were also reported by Vinson and Dabbagh (1998).

Green tea powder was produced by a series of processing steps including removing of stems, midribs and veins; also, crude fiber content of the product was culled. The efficiency of removing crude fiber content may be affected by the structure and size of these parts. Therefore, crude fiber content of the present samples was analyzed. Table 2 shows that green tea powder of the Fener clone had significantly higher crude fiber content than the Derepazarı 7 clone. Likewise, the product of the second shooting period had significantly higher crude fiber content than that of the first shooting period. An explanation for this variation was formerly described as age of the tea bushes and harvesting time of flushes. The older plants produced higher amounts of crude fiber (Śmiechowska and Dmowski, 2006). In fact, the Fener clone was older than the Derepazarı 7 clone. To the best of our literature-based knowledge, there is no comparative study on crude fiber content of green tea powder. However, the different quality of black and green tea products (5.83–43.27 g 100 g^{-1} dw) has been reported (Ozdemir et al., 1993; Śmiechowska and Dmowski, 2006). The results of the present study were in agreement with the literature.

4.3. Color analysis

Dark shading resulted in lower *L*, *a*, and *b* values in the green tea powders. The dark shading treatment provides the characteristic vivid green color that is the mark of high quality green tea powders. Ku et al. (2009) also reported that shading causes greener tea leaves. In the case of other treatments, the green tea powders produced from the first shooting period and Derepazarı 7 clone had a more brilliant green color, which was desired.

4.4. Bulk density and particle size

The values of bulk density and particle size of the samples were notably higher in the first shooting period. However,

the other factors did not produce considerable differences in these physical features. Particle size and bulk density were correlated with each other. The higher particle size and bulk density of the green tea powders produced in the first shooting period can be related to moisture content differences. Indeed, the moisture content of samples produced in the first shooting period was significantly higher than in samples produced in the second shooting period. Higher moisture content in dried tea leaves alters the bulk density and particle size of the product. Smaller particles can be produced from crisp leaves, resulting in higher bulk density (Jha and Sharma, 2010). Hu et al. (2012) studied the effect of superfine grinding on green tea powders. Their findings regarding particle size (D_{50}; 6.3–32.5 μm) and bulk density (559–722 kg m^{-3}) are mostly consistent with the present results. Slight differences in particle size and bulk density may be related to differences in milling process, equipment, and raw materials.

4.5. Extraction yield

Water extraction is an important part of controlling the quality of tea products. It should be at least 32 g 100 g^{-1} dw for both green tea and black tea (Ozdemir et al., 1992). Previous reports describe the extraction yield of green and black tea (29.2%–43.0%) (Yao et al., 2006; Anesini et al., 2008). The extraction yield values in the present study were higher than the above values. These differences can be related to sample characteristics regarding the separated parts of the leaves (stems, midribs, and veins). The intense shading treatment led to a decrease in the extraction yield. It is noteworthy that extraction yield of the control and light-shaded samples were not significantly different. On the other hand, extraction yield increased in the second shooting period. Water extract of the green tea leaves mainly consists of phenolic compounds, sugars, amino acids, alkaloids, and many minor soluble substances such as minerals and pigments (Yao et al., 2006). Among these constituents, the amount of catechins decreases while amino acid content increases through shading treatment of the tea flushes (Ku et al., 2009). Therefore, decreases in the extraction yield of green tea powders, depending on shading level, can be associated with catechin content.

4.6. Total phenolic content and antioxidant capacity

Komes et al. (2010) reported that the total phenolic content of water extract of green tea powder (1 g of green tea powder in 100 mL of water) was 2.23 g GAE L^{-1}, which corresponds to 22.3 g GAE 100 g^{-1} of dry powder. Our results were in agreement with the above-mentioned report. Likewise, it was 11.9–25.2 g GAE 100 g^{-1} (Astill et al., 2001; Anesini et al., 2008) for green tea. The results of total phenolic content seem to be stable among different green tea products. They are not much affected by the growing conditions of raw materials or processing parameters.

Antioxidant activity is another quality parameter related to phenolic compounds in green tea powders. A lower IC_{50} value represents higher antioxidant activity (Dincer et al., 2012). The antioxidant analysis of tea-like beverages has been extensive. As different authors express their results in different bases and units, it is hard to compare the present results with literature values directly. For example, reported IC_{50} values of green tea products are 1.72–12.54 mmol L^{-1} Trolox equivalent for green tea powder (Komes et al., 2010), 1.722–1.827 mg mL^{-1} extract Trolox equivalent (Andlauer and Héritier, 2011), and 72.98 μM g^{-1} dw Trolox equivalent (Park et al., 2010) for green tea.

This study was conducted to demonstrate for the first time the effects of shooting period and shading treatment on the final quality characteristics of the green tea powder produced from 2 different Turkish tea clones. Shooting period, which is specific to Turkish tea cultivation, showed significant effects on almost all quality parameters of green tea powders. However, shading treatment was only effective on color properties, crude fiber content, and extraction yield of the product. Overall, it can be concluded that the first shooting period and a dark shading treatment are advantageous to green tea powder quality improvement. In fact, green tea powder is rich in some functional components that are useful for human nutrition, and it has the potential to enrich many industrial food products. From an industrial point of view, some specifications for the safeguarding of green tea powders against adulteration and imitation are needed. Therefore, the findings of the present study can be considered a step towards commercialization of the product.

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