COMPARISON OF BLACK TEA TYPES WITH GRADES AND BLENDS

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ABSTRACT

The chemical and sensory properties of conventional and organic black tea kinds (*Camellia sinensis var. sinensis*) regarding of blend and grade were compared. Organic teas were produced from teas harvested from Hemsin region, Rize, Turkey where has a latitude of 41°2'53.53"N and a longitude of 40°53'56.61"E. Conventional black teas were produced from teas harvested from Tirebolu region, Giresun, Turkey where has a latitude of 41°0'26.85"N and a longitude of 38°48'52.54"E. The water extract, cellulose, polyphenol, mineral, and caffeine contents; TF/TR ratio; and a sensory evaluation were used as parameters to compare conventional and organic black tea blends and grades. The polyphenol contents (12.53-8.57%) of conventional teas were higher than that (9.86-7.60%) of organic teas, and the cellulose contents (17.86-13.45%) of organic teas were higher than that (17.55-11.60%) of conventional tea samples. The highest caffeine contents were found in first grades of first blends of tea samples. The amount of caffeine in blend 1 of grade 1 of conventional tea was 2.67% as it was 1.86% for organic tea in the same blend and grade. Regarding the TF/TR ratios and the sensory evaluation scores, both the conventional and organic teas were similar. The grade and blend affected significantly the quality of black tea.

Keywords: black tea, blend, chemical component, grade, sensory

1. INTRODUCTION

Tea (*Camellia sinensis*), which is one of the oldest beverages, is the most consumed, hot or cold, manufactured drink in the world. It is the second most popular non-alcoholic beverage, after water, consumed by approximately half of the world's population. It is available for consumption in different varieties, which are mainly based on the oxidization and fermentation technique used. There are specific climatic requirements for tea crops. Tea can only be grown in tropical and subtropical climates. The tea plant requires temperatures between 10-30°C, an annual rainfall of at least 1250 mm, acidic soils, ideally 0.5-10° slopes and elevations up to 2000 meters. Thus, tea production is geographically limited to a few areas around the world, and the growing conditions are highly sensitive (CAI *et al.*, 2016; CHEN, 2016). The secondary metabolite compounds in plants serve as defense compounds and vary in the amounts depending on the parameters such as environmental conditions, agro-techniques, and producing processes. The amounts of the compounds like polyphenolic catechin compounds in tea plants vary with geographic location, cultivar, herbivory, season, shade, soil, slope, water availability, and management. It can be perceived changes in the amounts of tea functional compounds by their sensory characteristics such as astringency, bitterness or sweetness. thus, tea quality influences the purchasing decisions, farmer livelihoods, and functional benefits derived from crops (AHMED *et al.*, 2014a; AHMED *et al.*, 2014b; AHMED *et al.*, 2012; AHMED *et al.*, 2010; LIN *et al.*, 2003). In general, tea quality is determined via sensory testing and by examining the significant correlations between some of the chemical compounds and the sensory tests. The chemical compounds in tea affect the sensory properties such as color, taste, odor, and flavor in addition to the nutritional and pharmacological benefits of tea (SHEKHAR *et al.*, 2016).

Tea contains many chemical compounds but theaflavin (TF), thearubigin (TR), phenolics, caffeine and minerals are the most important compounds for tea quality. Moreover, the crude fiber content of tea is an important parameter to determine the tea quality (MARBANIANG, 2011), and the presence of water-soluble ingredients in tea is very important for the crude fiber content. The water-soluble substances in tea are flavonols, acids, caffeine, amino acids, carbohydrates and organic acids. In hot water, the low solubility substances are starches, pectins, ashes and pentoses. The insoluble substances are cellulose, lipids, some pigments and volatiles. The fresher the tea leaves are, the higher the water extract is, and this depends on the environmental conditions, ecological impacts and production procedures. Cellulose indirectly affects the tea quality and is an undesirable compound because it reduces the proportions of the other compounds in the total solid. The amount of cellulose in the tea leaves increases as the length of the sprouts increases, which occurs when a standard harvest is not performed (OZDEMIR and KARKACIER, 1997).

Tea leaves contain large quantities of polyphenols, especially catechin, and the catechin amount is related to the black tea quality (OWUOR and OBANDA, 2011). Oxidoreductase enzymes such as polyphenol oxidase (PPO) and peroxidase (PO) interact with the phenolic compounds in tea leaves and react to produce the well-known, golden-yellow color in fermented teas. Golden-yellow theaflavin, a product of the condensation reaction between two molecules of o-quinone (one derived from epicatechin (dihydroxy) and the other derived from epigallocatechin (trihydroxy), is probably generated by PPO due to the exposure of the tea leave surfaces to air. Additionally, thearubigins, which are more intensely colored products with diverse structures, form because of the reactions of o-quinones with amines, phenols, amino acids, peptides, and proteins (MAHANTA and BARUAH, 1992).

The mineral content is 4-5% for fresh tea leaves and 5-6% for processed tea. Mineral substances have an important role in plant physiology and in their chemical and biochemical functions in addition to the growth of the tea plant. Some of the minerals are absorbed by the human body from drinking tea. Minerals are essential for the proper functioning and maintenance of the human body and metabolic events (KACAR, 1997).

The amount of minerals in tea leaf shoots vary depending upon the soil type and husbandry of the bush. Additionally, the genetic characteristics, growing locations, and tea production methods contribute to the quality of black tea. Among the minerals and essential trace elements, Ca, Na, K, Mg, and Mn are present in tea leaves at g/kg levels, and Cr, Fe, Co, Ni, Cu, Zn are present at mg/kg levels (STREET *et al.*, 2006). A previous study reported that there is a wide variation in the percent transfer for the examined elements from the black tea leaves to the tea infusion. The solubilities of Ca and K are the highest among the elements studied. The extraction of trace metals, such as Mn, Zn and Al, is also relatively high. Only Fe is insoluble and remains in the solid particles during beverage preparation (DAMBIEC *et al.*, 2013).

Conventional and organic agriculture are two of the primary cultural agricultures used in the production of food. One of the clearest distinctions between organic tea and conventional tea is that organic tea is grown without the use of chemical fertilizers, pesticides, fungicides, or herbicides. These chemicals have well-documented harmful effects on the environment and farmers and consumers who may ingest the residues. Conventional tea growing methods may maximize production in the short term but with serious environmental consequences and human costs. Additionally, organic farm land is prohibited from being treated with synthetic pesticides and herbicides for at least 3 years prior to harvest (ASAMI *et al.*, 2003).

Camellia plants usually have a rapid growth rate. Typically, they will grow about 30 cm per year until mature, although this does vary depending on their variety and geographical location. When the plant is harvested for tea, the shoot and two to three leaves are harvested every 8 to 10 days. These buds/shoot and leaves are called 'flushes'. A plant will grow a new flush every 7 to 15 days during the growing season. The tea spring leaf tip is valued the most. *Camellia sinensis* usually will produce an abundant crop twice a year, once in the spring and again in the summer. Harvesting can be done every 7 to 15 days during these periods, until the plant no longer produces new growth (DAFF, 2016). In this study, the aim was to investigate effects of blend (blend of tea leave harvested in the first flush period) and grade on the quality of black tea, and to determine chemical and sensory differences among the black teas produced via organic and conventional production techniques depending on blend and grade.

2. MATERIALS AND METHODS

2.1. Materials

The first flush organic and conventional black teas (*Camellia sinensis var. sinensis*) that were harvested at the end of the first growth period during the growing season in 2013 were chosen for this study. Organic black tea was obtained from Hemsin, Rize, Turkey Tea Factory in the Caykur general directorate, and conventional black tea was obtained from the Tirebolu, Giresun, Turkey Factory in the same directorate. The climate in Hemsin (a latitude of 41°2'53.53"N and a longitude of 40°53'56.61"E) is warm and temperate. The rainfall in Hemsin is significant, with precipitation even during the driest month. According to Köppen and Geiger, this climate is classified as Cfb (Oceanic climate). The average annual temperature, rainfall and relative humidity are respectively 12.5°C, 1423 mm and 75% in Hemsin (CLIMATE-DATA 2017a; DISTANCESTO 2017a). The climate in Tirebolu (a latitude of 41°0'26.85"N and a longitude of 38°48'52.54"E) is mild, and generally warm and temperate. The rainfall in Tirebolu is significant, with precipitation even during the driest month. The climate here is classified as Cfa by the Köppen-Geiger system. The average annual temperature, rainfall and relative humidity in Tirebolu are respectively 14.5°C, 1002 mm and 67.5%. The average field slopes and altitues of both regions are 10-20% and 100-300 m (CLIMATE-DATA 2017b; DISTANCESTO 2017b).

2.2. Preparation of the black tea samples

Samples were collected over 30 days from the sorting stages, which are after the drying stage, at the production lines in the factories based on the diameter of the teas. The sorting process was performed at two levels. In the first level, the graded teas were passed through three different sieves with diameters of 1.405, 0.776 and 0.505 mm (12, 20 and 30 mesh), and the teas were coded as grade 1, grade 2 and grade 3. In the second level, the teas that did not pass through the sieves and had diameters of 2.057 and 1.676 mm (8 and 10 mesh) were passed through the sieves (12, 20 and 30 mesh). These teas were coded as grade 4, grade 5 and grade 6. The sorting process was performed five times a day. After the daily sorting process, 100 g of tea were taken for each grade, and a sample of 500 g of tea was taken for one grade in one day. The sorting process was divided into three different periods of 10 consecutive days. These three periods were called blend 1, blend 2 and blend 3. A total of 5,000 g of tea was sampled by mixing the teas of the same grade into one blend. The samples were stored in sealed glass jars in the dark at room temperature until analysis.

2.3. Analysis

All analyses of the tea samples outlined below were replicated three times.

2.3.1. Water extract

The water extract analysis was conducted using the method described by ISO (1994). Distilled boiling water (200 mL) was added to the tea leaf (2±0.001 g) in a balloon and was boiled for 1 h using a reflux condenser. Tea liquor was filtered through cotton wool, and the residue (extract) was washed with distilled water three times. The tea liquor was cooled to room temperature, and the washings were diluted to 200 mL with distilled water. The tea liquor (75 mL) was placed in a weighed evaporating dish and evaporated to dryness over a water bath. The tea residue in the dish was completely dried in a vacuum oven at 103°C for 16 h until the weight of the dish with the residue was constant. The water extract of the black tea was expressed as a percentage of the mass of the dry tea leaf.

2.3.2. Crude fiber content

The tea leaf was ground using a mill and passed through a 1 mm screen. The tea (2±0.001 g) was then weighed into a 1 L conical flask. A 0.255 N sulfuric acid solution (200 mL) was measured at room temperature, boiled, and added to the sample. A reflux condenser was inserted into the neck of the flask, and the solution was boiled gently for 30 min. A Buchner flask with a Hartley funnel and wet filter paper (Whatman No. 541) were used for filtration. After boiling, the acid digest was poured into a shallow layer of hot water in the funnel under gentle suction, and the flask was rinsed with two aliquots of approximately 50 mL of boiling water poured through the filter funnel. Using a dispenser capable of dispensing 200 mL of hot liquid, the insoluble matter was washed from the filter paper into the original 1 L conical flask using 200 mL of a 0.313 N sodium hydroxide solution and boiled for 30 min. Using boiling water, all the insoluble matter was transferred into a sintered glass crucible (porosity no. 1, 40 mm plate diameter and 70 mL capacity) fitted to the Buchner flask via an adaptor by applying gentle suction. The residue was washed with approximately 50 mL aliquots of boiling water, HCl solution (1%; v/v) and boiling water. Finally, the residue was washed twice with ethanol (95%; v/v) and three times with acetone. The crucible and residue were heated in an oven at 103°C for 2 h. The crucible was cooled in a desiccator, weighed to the nearest 0.001 g, returned to the oven and heated again for 1 h. Finally, the crucible was cooled in a desiccator and weighed. The crude fiber content is expressed as a mass fraction, in percent, of the sample on a dry basis (ISO, 2012a).

2.3.3. Total phenolic content

The extraction tube (10 mL) containing the ground tea leaf (0.2±0.001 g) was placed in a water bath set at 70°C. Hot (70°C) 70% methanol (5 mL) was dispensed into the extraction tube, which was stoppered and mixed on the vortex mixer. The extraction tube was heated in the water bath for 10 min with vortex mixing after 5 and 10 min. The extraction tube was removed from the water bath and allowed to cool to room temperature. The stopper was removed, and the tube was placed in a centrifuge at 3500 r/min for 10 min. The supernatant was carefully decanted into a graduated tube. The extraction steps were repeated, and the extracts were combined, diluted to 10 mL with cold 70 % methanol and mixed. The leaf tea extract (1 mL) was diluted to 1/100 (v/v), transferred into a tube and 5.0 mL of dilute Folin-Ciocalteu phenol reagent was added. Within 3 to 8 min after the addition of the Folin-Ciocalteu phenol reagent, 4.0 mL of a sodium carbonate solution were pipetted into the tube, which was stoppered and mixed. The tube stood at room temperature for 60 min, and the optical densities were measured in 10 mm path length cells against water on a spectrophotometer (UV-160 Shimadzu) set at 765 nm. Gallic acid standard solutions were used for the standard curve. The total phenolic content was calculated as a mass percentage of the dry tea leaf using the following formula (gallic acid equivalent; mg GAE). The concentration of gallic acid was established in mg/ml using the calibration curve (ISO, 2005).

$$w_t=((D_{sample}-D_{intercept})*V_{sample}*d*100)/(S_{std}*m_{sample}*10000*w_{(DM,sample)})$$

where D_{sample} is the optical density obtained for the sample solution; $D_{intercept}$ is the optical density at the point; S_{std} is the slope obtained from the best-fit linear calibration; msample is the mass in grams of the sample; V_{sample} is the sample extraction in ml; d is the dilution factor used prior to the colorimetric determination; $w_{DM, sample}$ is the dry matter content expressed as a mass fraction percent.

2.3.4. Caffeine

The tea liquor (50 mL) obtained from the water extract analysis method was poured into a separatory funnel and 5 mL of an ammonia solution (70 g/L) and 50 mL of chloroform were added. After careful mixing, the water phase and the chloroform phase were separated. The water phase was washed twice with chloroform. The chloroform phases passed through a glass cotton filter and were collected in a volumetric flask. The phases were diluted to the mark with chloroform and mixed. Seven different caffeine standard solutions were prepared (0.5, 1, 2, 3, 4, 5 and 8 g/mL) in chloroform. The absorbance of the samples and the standard caffeine solutions in chloroform were measured against chloroform blank at 276 nm using a UV-visible spectrometer (UV-160 Shimadzu). The caffeine content of the sample is expressed as a mass percent of the dry tea leaf (ISO, 2012b).

2.3.5. Theaflavin (TF) and thearubigin (TR)

The TF and TR analysis was conducted using the method described by Kumar *et al.* (2011). Water (125 mL) was added to 3±0.001 g of ground tea leaf and boiled for 10 min. The black tea extract was obtained by filtering the black tea through a cloth filter. After mixing the extract (10 mL) with ethyl acetate (10 mL), the mixture separated into two liquid phases, the water phase (WP) and the organic phase (OP). Five different solutions, S0, S1, S2, S3 and S4, were prepared from the WP and OP as indicated below.

S0 = OP (10 mL) + 2.5% NaHCO3 (10 mL)
S1 = OP (4 mL) + Methanol (21 mL)
S2 = WP (2 mL) + Distilled water (10 mL) + Methanol (13 mL)
S3 = WP (2 mL) + Oxalic acid (2 mL) + Distilled water (6 mL) + Methanol (15 mL)
S4 = OP (4 mL) of S0 + Methanol (21 mL)

The optical densities of solutions 1, 2, 3 and 4 (E1, E2, E3 and E4) were measured at 380 nm using a spectrophotometer (Optimum-One, Chebios, Roma, Italy). The percentages of TF and TR were calculated using the followings formulas:

$$TF\ (\%)=2.25*E3$$

$$TR\ (\%)=(1.77*E4+E1-E3)*7.06$$

$$TF/TR\ Ratio=(TF(\%))/(TR(\%))$$

2.3.6. Minerals

A standard method (NMKL, 1998) based on atomic absorption spectroscopy was used to determine the mineral content. Pure HNO3 (10 mL) was added to the ground tea leaf (0.2±0.001 g), and the mixture equilibrated for 30 min. After 30 min, the mixture was combusted in a microwave oven (Speedwave Four, BERGHOF, Eningen, Germany) at 190°C. The sample solution was then transferred to a 50 mL volumetric flask and diluted to the mark with ultra-distilled water. A standard solution was prepared for each mineral (Cu, Fe, Zn, Mn, Mg, Ca, K). The samples were analyzed using an atomic absorption spectrometer with an inserted hollow cathode lamp (GBC, Avanta P, Australia). The mineral content in the samples is expressed in g/kg.

2.3.7. Sensory test

The tea liquor used in the sensory test was prepared by infusing the tea leaf according to ISO (1980). The tea was weighed (2.8±0.05 g) and transferred to a pot. The pot was filled with approximately 140 mL of fresh, boiling water. The tea was allowed to brew for 6 min, and the liquid was poured through the serrations into a bowl to separate the liquid from the solid tea. The lid was removed and inverted, and the infused leaf was placed on the inverted lid to allow the infused tea leaf to be inspected. Black teas were assessed using sensory test method of TS EN ISO 13299 (TSE, 2016). Eight tea sensory experts (four males and four females, aged 25-40 years) from the Sensory test and Chemical Analysis Laboratory at Caykur Fabric, Rize, Turkey served as the panel. The experts completed 200 h of sensory testing for all samples. The experts evaluated the sensory attributes of the samples by using the sensory evaluation chart from the Turkish Standard Institute (Table 1). The sensory evaluation chart includes 5 disciplines (properties) having different maximum point, totally 100 points. The experts gave a point for each discipline between 0-its maximum point. It is rated as good tea if a tea sample collects 50 points or above on the basis of the total 100 points.

Table 1. Sensory evaluation chart of Turkish black tea.

Sensory properties of black tea	Description	Point
Appearance of the dried tea leaf	should be good appearance, black or dark copper color, and no fiber and stalk	10
Color of tea liquor	should be bright dark red or reddish color. should not be dull, fuzzy and a residual or brownish color	25
Astringency and body	should be a lively puckery sensation on the tongue and gums, and also the good impression of a tea's weight in the mouth, its viscosity and mouth feel	30
Color and odor of the infused leaf	should be bright copper red color, no excess green leaf and no brownish color	15
Aroma of liquor	should be unique and pleasant for good tea	20
TOTAL		100

2.3.8 Statistical analysis

Two types of tea, three blends and six grades were compared. Differences were considered to be significant at $p \leq 0.05$. The data, collected from organic and conventional black tea samples in triplicate, were subjected to a three-way analysis of variance (ANOVA) using the SPSS software (SPSS for Win, Release 19.0, 2012). The means were compared using Duncan's multiple range test for multiple comparisons, and the "Student" T-test was applied to the two sets of data that were significantly different.

3. RESULTS AND DISCUSSION

3.1. Water soluble extract

The water-soluble extract amounts and their statistical results for the samples are presented in Fig. 1. The extract amounts for the conventional teas were in the range of 30.83-35.69% and 31.73-35.26% for the organic teas depending on the grades and blends. In the comparison of teas in the same grade and blend, the extracts amount in the conventional teas were higher than those in the organic teas. The highest values were from the first blends, and the lowest values were from the third blends in both tea blends. The extract amount decreased from grade 1 to grade 6 for all tea blends. The triplet interaction among the tea type-grade-blend was not significant ($p>0.05$), but the double interaction among them was very significant ($p\leq0.05$). The differences between grade 3 and grade 4 in blend 2 for conventional tea and between grade 4 and grade 5 in blend 1 and grade 2 and grade 3 in blend 3 for organic tea were less.

Additionally, compared to the blends, there was no difference between grade 2 and grade 3 in blend 3 of the conventional tea, but this was not seen in the organic tea. The extract amounts for the tea leaves at the beginning of the first flush period are higher than that seen in the other periods. A difference among the tea extracts was not observed for the mid- and end-first flush periods. It was reported that the maximum extract amount for black tea produced in Turkey is from the first harvest season, and the second and third harvest season have less. Additionally, it was reported that the extract amount is higher in fresh tea leaves. Similarly, the extract amounts in the tea produced by different methods decreased from grade 1 to grade 6 (GOKALP *et al.*, 1991; KACAR, 1997).

3.2. Crude fiber content

The crude fiber contents of the conventional teas were in the range of 11.60 to 17.55% and 13.45 to 17.86% for the organic teas with respect to the grades and blends (Fig. 2). The crude fiber contents of almost all the organic teas were higher than that of the conventional teas with the same grade and blend.

The highest crude fiber contents among the blends of both tea types were found in the third blend, and the lowest values were in the first blend. The values increase from the first grade to the final grade, which is the inverse of the extract behavior. The contents of grade 2 and grade 3 teas in blend 2 of the conventional samples were very close, and the contents of grade 1 and grade 2 teas in blend 3 of the organic samples were almost the same. Otherwise, the contents of the tea types with the same grade and blend were different ($p \leq 0.05$). The crude fiber contents in the study were similar to those noted by VENKATESAN and GANAPATHY (2004) for Indian teas.

3.3. Total phenolic content and theaflavin (TF)/thearubigin (TR) ratio

The total phenolic content of the tea samples and the statistical results are given in Fig 3a. The values in the conventional teas were higher than that in the organic teas compared to the polyphenols in the two tea types with the same grade and blend.

The highest and lowest polyphenol contents among the blends in the conventional tea were in blend 1 and blend 3 and in blend 2 and blend 3 in the organic tea. Neither a negative or positive trend was found in the comparison of the grades. The contents of the second, third, fifth and sixth grade teas in blend 1 of the conventional samples and in grade 2, 3 and 5 teas in blend 1 of the organic samples were close to each other. Compared to the blends of one grade, there was very little difference between blend 1 and blend 2 teas in grade 2 of the conventional sample and between blend 1 and blend 2 teas in grade 4 of the organic tea ($p \leq 0.05$). The values (3.79-8.36%) of the tea samples reported by OZDEMIR *et al.* (2008) were lower than those in both the conventional and organic samples.

The TF/TR ratios are shown in Fig 3b. In the conventional teas, the TF/TR ratios of the blends were identified in the range from 0.037 to 0.040 and from 0.034 to 0.044 for the grades. In the organic teas, the ratios were 0.036 to 0.040 for the blends and 0.032 to 0.043 for the grades. The lowest TF/TR was found in blend 3 in the conventional teas, but the ratios in blend 1 and 2 were very close. The lowest and the highest TF/TR ratios were in blend 2 and 1 in the organic teas. An increasing or decreasing trend was not found for the TF/TR ratios of the grades from the blends for all the tea samples.

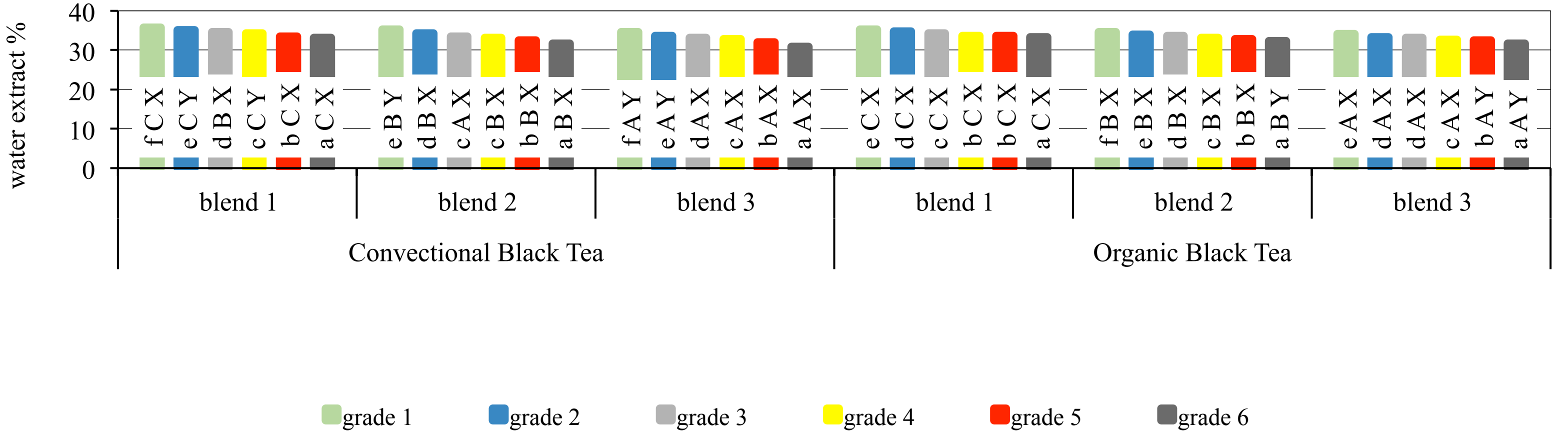

Figure 1. The water soluble extract amounts and their statistical results for the teas.
Values followed by the same letter are not significantly different at the level of 5% (series 'a-f' for grades in a blend of a tea type, series 'A-C' for the same grades in blends of a tea kinds, and series 'X-Y' for teas in the same blend and the same grade).

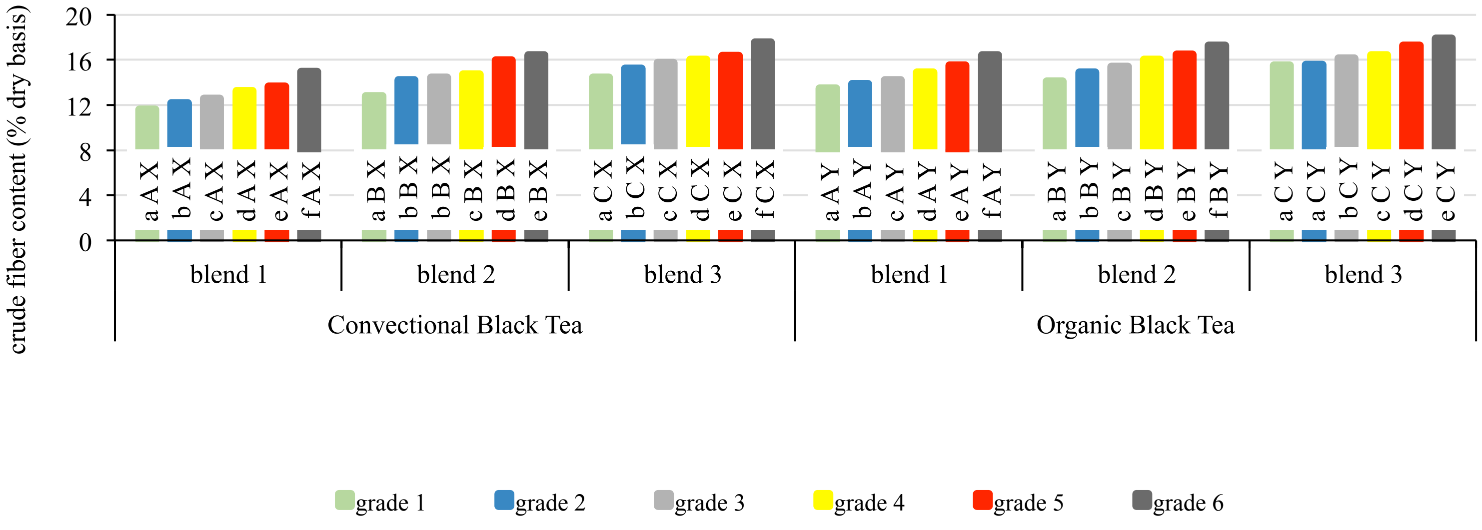

Figure 2. The crude fiber contents of the teas.
Values followed by the same letter are not significantly different at the level of 5% (series ‘a-f’ for grades in a blend of a tea type, series ‘A-C’ for the same grades in blends of a tea kinds, and series ‘X-Y’ for teas in the same blend and the same grade).

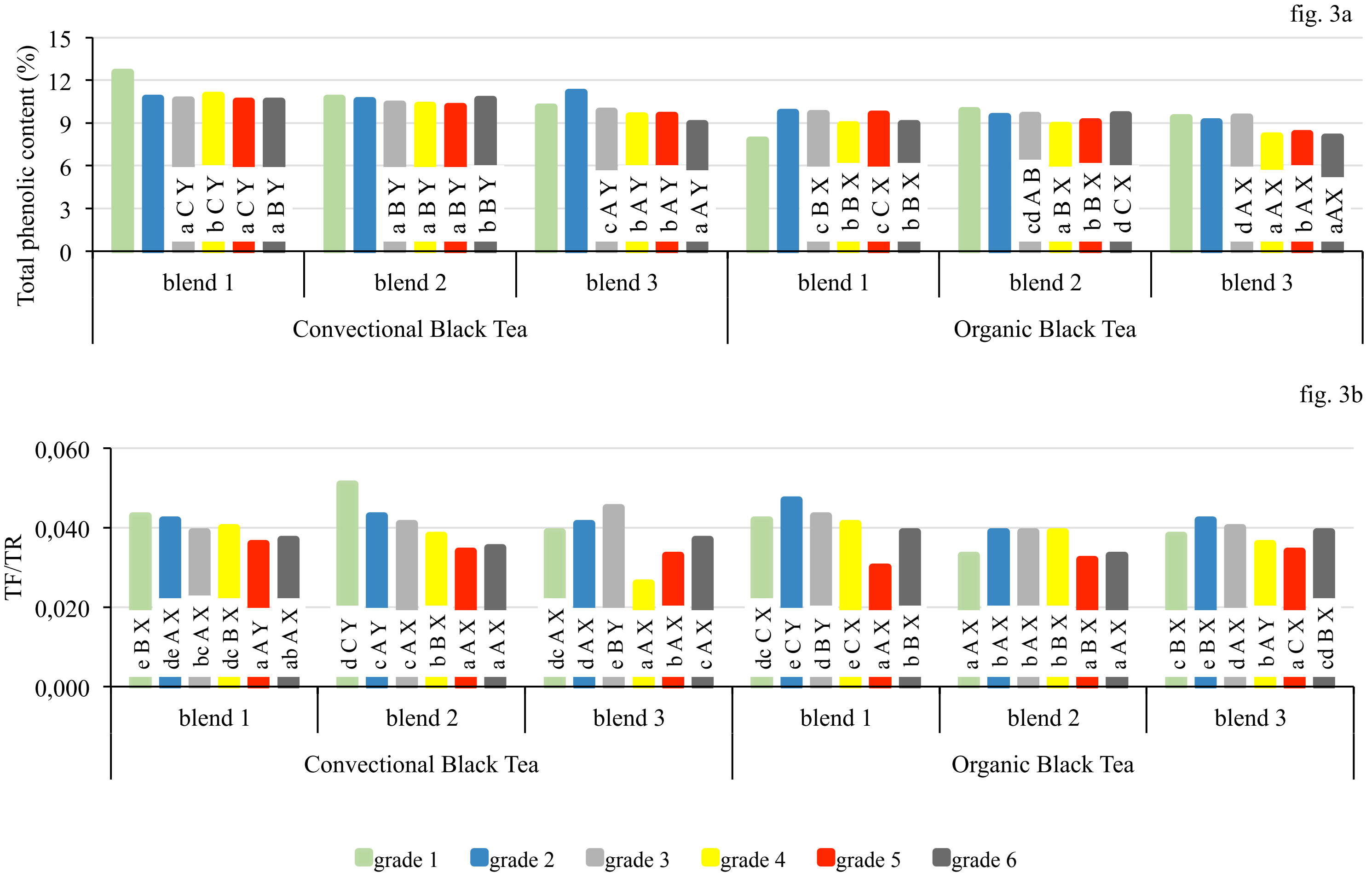

Figure 3. Total phenolic content and theaflavin (TF)/thearubigin (TR) ratio of the teas.
Values followed by the same letter are not significantly different at the level of 5% (series 'a-f' for grades in a blend of a tea type, series 'A-C' for the same grades in blends of a tea kinds, and series 'X-Y' for teas in the same blend and the same grade).

For the statistical evaluation of the tea types at the 5% level, the difference among the blends of grade 2, 5 and 6 in the conventional teas was less, and there was a similarity between blend 2 and blend 3 in grade 3 and blend 1 and blend 3 in grade 6 for the organic teas (Fig. 3b). A decrease in the TF/TR ratio was observed from the beginning of the flush period until the end. The reason for this could be the aging of the tea leaves and a decrease in the oxidative compounds as the flush period continues (GOKALP *et al.*, 1991). OZDEMIR and KARKACIER (1997) reported that black and green teas had a mean TF/TR ratio of 0.032. The TF and TR contents and their ratio are components of the tea quality index (YAO *et al.*, 2006). KUMAR *et al. (*2011) reported that the TF/TR ratio should be in the range of 1:10-1:12 to achieve a taste-water extract balance for a quality tea.

3.4. Caffeine

The ranges and statistical results for the caffeine content in dry tea samples are shown in Fig 4. The results show that the caffeine content in conventional teas was in the range of 2.31-2.67% while organic teas contained 1.50-1.89% caffeine.

The caffeine content in conventional tea was higher than that in organic tea for the same blend and grade. No relationship was found between the caffeine values of the tea types depending on the blend and grade. No similarity was found among tea types belonging to the same blend and grade ($p \leq 0.05$). One of the reasons that conventional teas contain high caffeine and water extract amounts is the usage of nitrogen fertilizer (CHEN *et al.*, 2015). OZDEMIR *et al. (*2008) reported that the caffeine content in black teas was in the range of 1-5% and 1.5-2.49% in seven different tea types within a third flush period. The results in the study are similar to the results (2.21-2.80%) reported by KHOKAR and MAGNUSDOTTIR (2002).

3.5. Mineral elements

The ranges and statistical evaluations of the total element contents in the tea samples are summarized in Table 2. The mean concentrations of the elements in both tea leaf types differed significantly with the grades and blends ($p \leq 0.05$).

Copper (Cu): The Cu concentrations in the organic teas were higher than those in the conventional teas for the same blend and grade. The lowest and highest Cu concentrations were found in blend 1 and blend 2, respectively, in the conventional teas. The lowest Cu concentration was found in blend 3 among the organic tea blends, the Cu values in blend 1 and blend 2 were very close. During the black tea manufacturing process, one of the important chemical changes in the leaves is the oxidation of polyphenols via polyphenol oxidases. A polyphenol oxidase is a tetramer that contains four atoms of copper per molecule (Sullivan, 2015). Therefore, the copper content may vary in blends. MARBANIANG *et al. (*2011) reported that the Cu content varied from 0.072 to 0.105 g/kg. However, STREET *et al. (*2006) reported that different black teas sold in the Czech Republic contained 0.103 to 0.405 g/kg Cu, and these values are similar to the values in the present work.

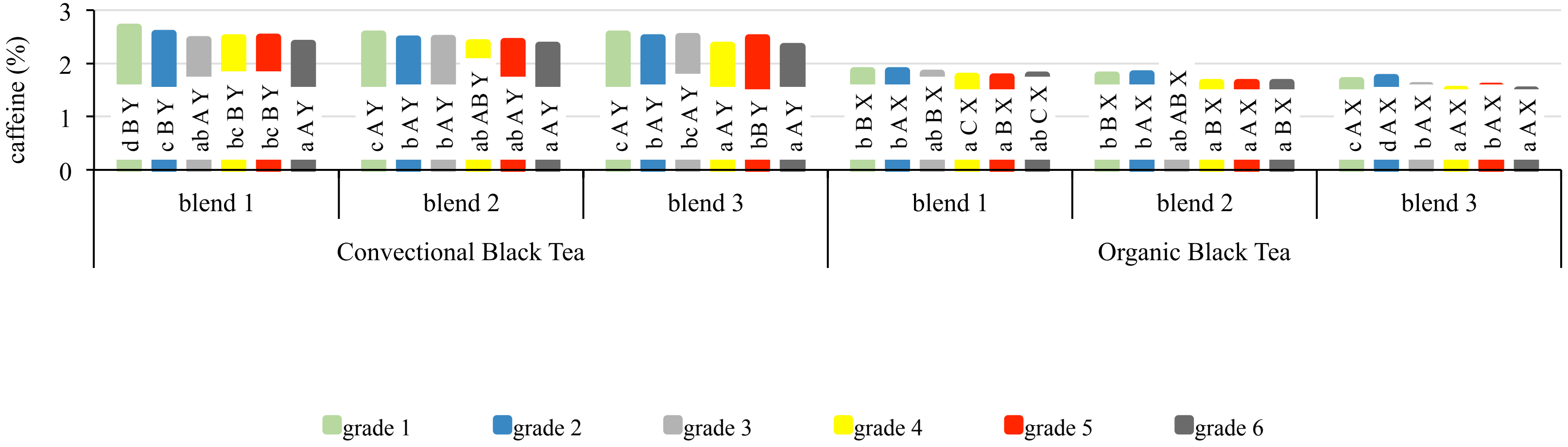

Figure 4. the caffeine content in dry tea samples
Values followed by the same letter are not significantly different at the level of 5% (series 'a-f' for grades in a blend of a tea type, series 'A-C' for the same grades in blends of a tea kinds, and series 'X-Y' for teas in the same blend and the same grade).

Iron (Fe): The Fe concentrations were in the range of 0.145-0.377 g/kg in the conventional teas and 0.049-0.223 g/kg in the organic teas. The iron amounts in the organic teas were higher than those in the conventional teas for the same blend and grade. While the lowest iron values were found in the grades of the third blend for the conventional tea types, the values for the grades of blend 2 and 3 were close. In the organic tea types, the highest values were for the grades of blend 1, and the lowest values were for the grades of blend 3.

Table 2. Mineral contents in the tea samples.

Mineral	Blend	Grade					
		1	2	3	4	5	6
Na	C1	0.055 ^{cBY}	0.047 ^{bBX}	0.047 ^{bBY}	0.059 ^{dCY}	0.046 ^{aBX}	0.047 ^{bAX}
	C2	0.056 ^{eBY}	0.058 ^{fCY}	0.045 ^{aAY}	0.048 ^{dAY}	0.046 ^{bCX}	0.047 ^{cAY}
	C3	0.045 ^{bAY}	0.047 ^{cAY}	0.052 ^{eCY}	0.050 ^{dBY}	0.043 ^{aAX}	0.057 ^{fBY}
	O1	0.050 ^{eCX}	0.048 ^{dCX}	0.041 ^{bCX}	0.038 ^{aBX}	0.046 ^{cAX}	0.047 ^{cBX}
	O2	0.046 ^{dBX}	0.042 ^{cBX}	0.037 ^{aAX}	0.036 ^{aAX}	0.048 ^{eBY}	0.038 ^{bAX}
	O3	0.038 ^{bAX}	0.036 ^{aAX}	0.038 ^{bBX}	0.042 ^{cCX}	0.060 ^{eCY}	0.054 ^{dCX}
K	C1	10.88 ^{fCX}	10.759 ^{eCX}	10.691 ^{dCX}	10.496 ^{cCX}	10.320 ^{aCX}	10.377 ^{bCX}
	C2	10.70 ^{fBX}	9.82 ^{cBX}	9.914 ^{dBX}	9.964 ^{eBX}	9.408 ^{aAX}	9.797 ^{bBX}
	C3	9.79 ^{eAX}	9.39 ^{cAX}	9.869 ^{fAX}	9.127 ^{bAX}	9.641 ^{dBX}	8.916 ^{aAX}
	O1	14.00 ^{fBY}	13.449 ^{eCY}	13.394 ^{dBY}	13.091 ^{bBY}	13.200 ^{cBY}	13.038 ^{aBY}
	O2	14.00 ^{eBY}	13.368 ^{bBY}	13.525 ^{cCY}	13.707 ^{dCY}	13.222 ^{aCY}	14.213 ^{fCY}
	O3	12.63 ^{fAY}	12.222 ^{dAY}	11.629 ^{bAY}	12.334 ^{eAY}	11.925 ^{cAY}	11.510 ^{aAY}
Ca	C1	4.168 ^{bAX}	4.097 ^{aAX}	4.244 ^{cAX}	4.307 ^{dBX}	4.312 ^{dBX}	4.333 ^{eAX}
	C2	4.310 ^{cBX}	4.316 ^{cBX}	4.350 ^{eBX}	4.220 ^{aAX}	4.231 ^{bAX}	4.333 ^{dAX}
	C3	4.434 ^{bCX}	4.568 ^{eCX}	4.379 ^{aCX}	4.458 ^{cCX}	4.559 ^{eCX}	4.506 ^{dBX}
	O1	4.691 ^{bAY}	4.619 ^{aBY}	4.774 ^{dBY}	4.809 ^{fBY}	4.724 ^{cAY}	4.789 ^{eAY}
	O2	4.871 ^{bcBY}	4.864 ^{bCY}	4.796 ^{aCY}	4.868 ^{bCY}	4.875 ^{cBY}	4.925 ^{dCY}
	O3	4.880 ^{dBY}	4.561 ^{aAX}	4.739 ^{bAY}	4.553 ^{aAY}	4.944 ^{eCY}	4.818 ^{bCY}
Mg	C1	1.220 ^{dAX}	1.097 ^{aAX}	1.220 ^{dAX}	1.219 ^{dAX}	1.167 ^{cAX}	1.126 ^{bAX}
	C2	1.339 ^{eBX}	1.277 ^{cBX}	1.265 ^{bBX}	1.309 ^{dBX}	1.195 ^{aBX}	1.192 ^{aBX}
	C3	1.627 ^{dCX}	1.659 ^{eCX}	1.602 ^{cCX}	1.714 ^{fCX}	1.596 ^{bCX}	1.588 ^{aCX}
	O1	1.226 ^{bAY}	1.168 ^{aAY}	1.241 ^{cAY}	1.259 ^{dAY}	1.265 ^{dAY}	1.231 ^{bAY}
	O2	1.388 ^{bBY}	1.438 ^{dBY}	1.398 ^{cBY}	1.473 ^{eBY}	1.367 ^{aBY}	1.534 ^{fBY}
	O3	1.842 ^{eCY}	1.711 ^{cCY}	1.656 ^{bCY}	1.723 ^{dCY}	1.717 ^{cdCY}	1.624 ^{aCY}

Table 2. Continues.

Cu	C1	0.015	dAX	0.014	aAX	0.015	dAX	0.015	cAX	0.015	dAX	0.014	bAX
	C2	0.017	cCX	0.017	cCX	0.017	cBX	0.015	bBX	0.015	bAX	0.015	aBX
	C3	0.016	cBX	0.015	aBX	0.015	aAX	0.015	aBX	0.016	bBX	0.016	bCX
	O1	0.019	cBY	0.018	bBY	0.018	bBY	0.018	aBY	0.018	bBY	0.018	bBY
	O2	0.019	dCY	0.019	cCY	0.018	bBY	0.018	aBY	0.018	aAY	0.018	bBY
	O3	0.018	cAY	0.017	bAY	0.017	bAY	0.017	bAY	0.018	cAY	0.017	aAY
Zn	C1	0.022	bcdCY	0.024	dBY	0.023	cdBY	0.022	bcCY	0.021	bCX	0.018	aCX
	C2	0.020	cBXX	0.017	bAX	0.016	abAX	0.015	aBX	0.016	abBX	0.016	abBX
	C3	0.017	dAY	0.017	dAY	0.016	cAY	0.013	bAX	0.012	bAX	0.011	aAX
	O1	0.020	bBX	0.018	aBX	0.020	bCX	0.019	bCX	0.021	cBX	0.020	bCX
	O2	0.020	dBX	0.019	cCY	0.018	bcBY	0.018	bcBY	0.016	aAX	0.017	bBX
	O3	0.014	dAX	0.013	cAX	0.012	aAX	0.013	bAX	0.015	eAY	0.015	fAY
Fe	C1	0.327	fAY	0.230	dAY	0.236	eCY	0.209	cCY	0.203	bCY	0.177	aBY
	C2	0.362	eBY	0.308	dBY	0.206	cBY	0.182	bAY	0.179	bBY	0.161	aAY
	C3	0.377	fCY	0.236	eAY	0.167	bAY	0.202	dBY	0.145	aAY	0.177	cBY
	O1	0.166	dBX	0.122	cAX	0.163	dCX	0.091	bBX	0.0	aCX	0.125	cCX
	O2	0.223	eCX	0.137	dCX	0.093	cAX	0.062	bAX	0.0	aAX	0.060	bBX
	O3	0.155	eAX	0.130	dBX	0.098	cBX	0.098	cCX	0.0	bBX	0.049	aAX
Mn	C1	1.049	fAY	0.890	aAX	0.947	cAY	0.991	eAY	0.9	dAX	0.924	bAX
	C2	1.159	eBY	1.061	cBX	1.040	aBY	1.140	dBY	1.0	aBY	1.054	bBX
	C3	1.324	dCX	1.170	aCX	1.164	aCX	1.170	aCX	1.2	cCX	1.187	bCX
	O1111	0.986	fAX	0.908	bAY	0.900	aAX	0.978	eAX	0.9	dAY	0.922	cAX
	O2	1.093	eBX	1.086	dBY	1.012	bBX	1.057	cBX	0.9	aAX	1.126	fBY
	O3	1.346	fCY	1.246	bCY	1.258	cCY	1.294	eCY	1.2	dBY	1.193	aCY

Values followed by the same letter are not significantly different at the level of 5% (series 'a-f' for grades in a blend of a tea type, series 'A-C' for the same grades in blends of a tea kinds, and series 'X-Y' for teas in the same blend and the same grade).
O: organic blend, C: convectional blend.

When comparing the Fe values for the grades belonging to blends, a decrease in Fe from grade 1 through grade 6 was observed. The differences between grade 4 and grade 5 in blend 2 of the conventional tea, and the differences between grade 1 and grade 3 in blend 1, grade 4 and grade 6 in blend 2 and grade 3 and grade 4 in blend 3 of the organic teas were very low ($p>0.05$). No such similarity was found among the blends of the organic teas, and the difference between blend 1 and blend 3 in grade 2 and grade 6 of the conventional teas was very low. However, the tea types with the same grade and blend had significantly different values ($p\leq 0.05$) TASCIOGLU and KOK (1998) reported that seven different teas produced in Turkey contained 0.130-0.171 g/kg Fe, and AKSUNER *et al. (*2012) found 0.235 g/kg Fe in black tea.

Zinc (Zn): The Zn concentrations of the conventional teas were higher than that in the organic teas for the same blend and grade. The highest Zn concentration among the blends was in the first blend for both tea types, and the lowest was in the third blends.

A linear increase or decrease in the Zn concentration was not seen among the grades belonging to the blends of teas. There was a small difference among the Zn concentration for grades 1, 2, 3, 4 and 5 in blend 1 of the conventional tea and for grades 1, 3, 4 and 6 in blend 1 of the organic tea. Moreover, there were small differences between blend 2 and 3 in grade 2 of the conventional tea and between blend 1 and 2 in grade 1 and blend 2 and 3 in grade 5 of the organic tea ($p \leq 0.05$). The Zn concentrations in 10 commercial Turkish black blend teas in a previous work (ARSLAN and TOGRUL, 1995) were found in the range of 0.033-0.052 g/kg. The Zn concentration in fresh cells is higher than that found in aged tea plant cells (KACAR, 1997).

Sodium (Na): The Na concentrations in conventional and organic teas were determined to be in the range of 0.043-0.060 and 0.036-0.059 g/kg, respectively. The Na concentration among grades 6, 2 and 3 in blend 1 of the conventional teas were close to each other ($p \leq 0.05$). A similar situation existed between blend 1 and blend 2 for grade 1 of the conventional teas. However, this was not found for the organic teas. The Na concentrations in teas produced in different regions of China were 0.026-0.079 g/kg (ZHANG *et al.*, 2011), and McKENZIE *et al. (*2010) reported concentration in the range of 0.011-0.86 g/kg.

Potassium (K): K was the most abundant macro-mineral in all the tea samples analyzed. The K values in conventional teas and organic teas were in the range of 8.916-10.886 g/kg and 11.510-14.213 g/kg, respectively, depending on the blends and grades. Interaction among the tea type-blend-grade was found to be significant according to the results of the Anova of the K values ($p \leq 0.05$). In organic tea, there was an important difference among the blends except for blend 1 and 2 in grade 1, but all the K values were significantly different in the blends of the conventional teas. The present results correspond to the data of McKENZIE *et al. (*2010).

Calcium (Ca): The Ca concentrations in the conventional and organic teas were in the range of 4.097-4.568 and 4.553-4.944 g/kg, respectively. The Ca concentrations in the organic teas were higher than those in the conventional teas for the same blend and grade. The highest Ca concentration among the blends in the conventional teas was in blend 3, and the lowest concentration was in blend 1. The highest and lowest Ca concentrations in the blends of organic teas were in blend 2 and blend 1, respectively ($p \leq 0.05$). The Ca values in a study by MALIK *et al. (*2008) were 4.33-6.68 g/kg, but PEREIRA *et al. (*2006) reported values in the range of 3.13-9.72 g/kg.

Manganese (Mn): The maximum and minimum values for Mn were in the third blends and first blends of the conventional and organic teas, respectively. A linear relationship between the samples was not observed when comparing the grades of the blends of the teas. The differences between the samples were significant, except for the relationship among grades 2, 3 and 4 of blend 3 in the conventional tea ($p \leq 0.05$). The Mn values in the study are similar to the values in studies by OZDEMIR *et al. (*1999), NARIN *et al. (*2004), PEREIRA *et al. (*2006), and MEHRA and BAKER (2007).

Magnesium (Mg): The magnesium concentration in all the tea samples varied in the range of 1.097-1.842 g/kg. The Mg concentrations of the organic teas were higher than those in the conventional teas for the same blend and grade. It was determined that the triple interaction among the tea samples was significant at the 5% level. The Mg values in a study (HORUZ and KORKMAZ, 2006) were found to be 3.3 g/kg for the first harvest tea, 4.7 g/kg for the second harvest tea and 3.9 g/kg for the third harvest tea.

3.6. Sensory test

Sensory evaluation of tea types is presented in Fig. 5.

The conventional teas collected 76-89 points from the panelists. In the evaluation of the conventional tea blends, the mean points for blend 1, 2 and 3 were 85, 83.16 and 81.16, respectively. The evaluation points for the grades between 1 and 6 were in the range of 87-79. Otherwise, the organic teas collected 75-90 points, and the points for blends 1, 2 and 3 of the organic teas were 86.66, 84.50 and 80.83, respectively. The points for the grades were in the range of 88.33-80.00. The evaluation points for the organic teas were higher than those of the conventional teas depending on the blends and grades. Compared to the grades of blends in both tea types, a decreasing trend in the points from grade 1 to grade 6 was observed. The triplet interaction among the tea type-grade-blend was not significant ($p>0.05$), but the two-way interactions between the tea kind-grade and grade-blend were significant ($p\leq 0.05$). there is a reverse relation between the score of overall acceptability and total catechins amounts (XU *et al.*, 2017). Besides A high amounts of minerals, especially calcium and magnesium (MOSSION *et al.*, 2008; ANANINGSIH *et al.*, 2013) such as high pH (ZHOU *et al.*, 2009) influence the extraction yield and stability of catechins and other chemicals in tea infusions. Therefore, these chemicals may change sensory quality of tea. In a study investigating the relationship between theaflavin and tea quality, it was reported that the scores should be among 18.2-78 for good quality teas and 14.4-53 for poor quality teas (WRIGHT *et al.*, 2002). The astringency of tea infusions increases with increasing Ca^{2+} ion while bitterness and umami intensity decreased (YIN et al 2014). XU *et al.* (2017) reported that total scores (overall acceptability) for different taste attributes, including bitter, astringent and umami tastes of black tea brewing with different water types were in range of 7.6-6.4. Another study reported that the sensory property of organic food was better than that of conventional food. It was stated that the shelf-life of organic food was too long, and there was a good correlation between a low nitrate level and good taste perception (OCO, 2016).

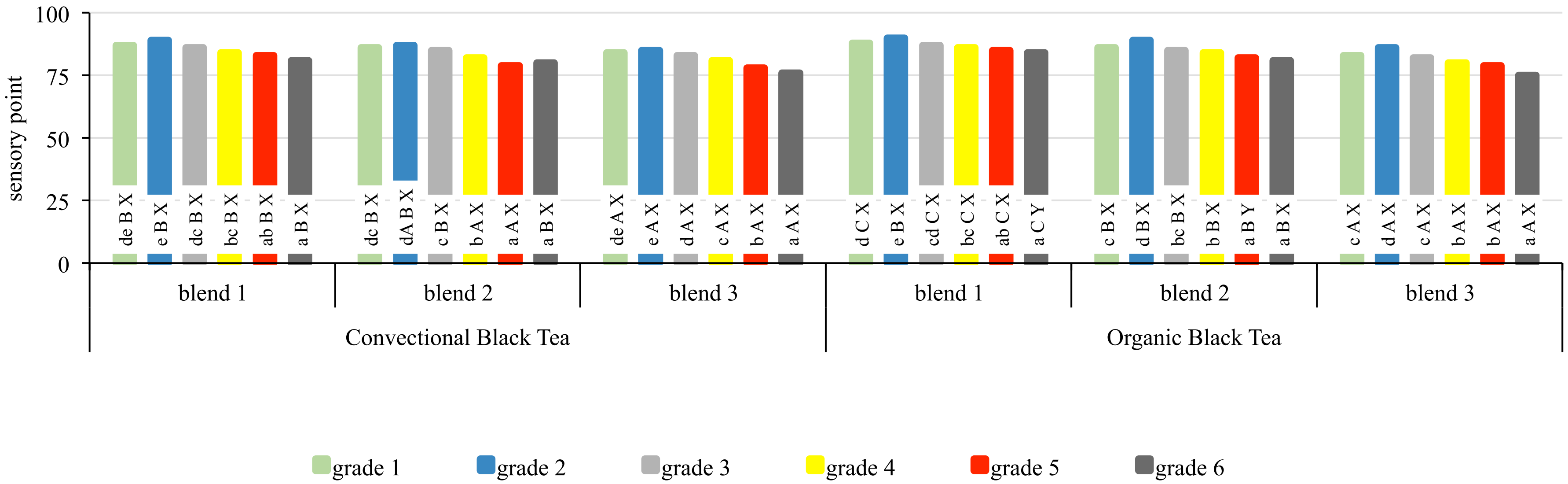

Figure 5. Sensory evaluation of tea types.
Values followed by the same letter are not significantly different at the level of 5% (series ‘a-f’ for grades in a blend of a tea type, series ‘A-C’ for the same grades in blends of a tea kinds, and series ‘X-Y’ for teas in the same blend and the same grade).

4. CONCLUSIONS

Some chemicals and sensory properties of conventional and organic black Turkish teas were investigated according to their grades and blends. The extract, polyphenol and caffeine contents in both teas decreased from blend 1 to blend 3, and the cellulose contents increased from blend 1 to blend 3. Similar trends were observed for the grades.

The extract and TF/TR values were close to each other among the tea types. The cellulose values in organic teas and caffeine and polyphenol values in conventional teas were higher than those of the other tea type. For the TF/TR ratios, there was not a linear increase or decrease among the blends and grades. Whereas the organic black tea was rich in Cu, K, Ca, Mn and Mg, the conventional black tea was rich in Fe, Zn and Na. In the sensory evaluation of the teas, the sensory scores of the conventional and organic black Turkish teas were close, but the scores of the blends in both tea types decreased from blend 1 through blend 3 and there was no linear relationship among the grades.

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