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CHEMICAL COMPOSITION AND SENSORY EVALUATION OF TEA (*CAMELLIA SINENSIS*) COMMERCIALIZED IN PAKISTAN

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Abstract

The quality of black and green commercial tea samples was accessed by physicochemical analysis, mineral analysis and sensory evaluation. Significant variations in physicochemical and organoleptic parameters were observed. The moisture, protein, fat, crude fiber, water extracts and ash contents of the commercial tea samples were found to be in the range of 2.46-7.47, 0.87-1.141, 0.94-2.15, 11.23-17.21, 32.34-53.61, and 3.29-5.86%, respectively while caffeine and catechin were found in the range of 2.34-4.33% and 0-7.44%, respectively. The highest percentage of moisture, protein, fat, and crude fiber contents were observed in green tea samples while highest percentage of ash and water extracts were observed in black tea samples. Calcium, magnesium, sodium, potassium and manganese were found to be in the range of 1.47-3.84 mg/l, 2.97-5.66 mg/l, 0.39-1.83 mg/l, 3.01-4.00 mg/l., 1.09-2.43 mg/l, respectively with maximum amounts found in green tea as compared to black tea.

Introduction

Tea is the second most consumed beverages in the world after water and is grown in 30 countries worldwide. It was primarily originated in South Eastern China but recently it is cultivated in many countries across tropical and subtropical regions all over the world and has more than 82 different species (Krafczyk & Glomb 2008; Sultana *et al.*, 2008; Akhlas *et al.*, 2003). Tea is the extract of leaves, leaf nodes and internodes of plant (*Camellia sinensis*) which is consumed as extract in hot water rather than being eaten as such. It is also referred to as an aromatic liquid product which has been made by curing the leaves by applying water in hot form (Xiao *et al.*, 2008).

The high consumption of tea is attributed to richness in important substances having cool, a little bitter flavor, antioxidant properties and health benefits (Dimitrios, 2006). The chemical components in tea include alkaloids (theobromine, caffeine, theophylline), polyphenols (catechins, flavonoids), amino acids, polysaccharides, volatile acids, vitamins, lipids as well as inorganic elements (Monobe *et al.*, 2008; Wei *et al.*, 2010; Xiong *et al.*, 2012). The regular consumption of tea can contribute to the daily dietary requirement of some of the important minerals (Powell *et al.*, 1998).

A lot of health benefits of tea were reported by researchers which may include antitumor (Dimitrios, 2006), anti-carcinogenic (Katiyar & Mukhtar, 1996) and anti-arteriosclerotic agents (Mukhtar *et al.*, 1994). To gain these health benefits tea is used in form of powders, soft extracts and strong infusions (Gardner *et al.*, 2006). Green tea catechins (GTC), is an important constituent of tea which have received much attention as protective agent against cardiovascular disease and cancer (Reto *et al.*, 2007). Tea polyphenols and Tea polysaccharides including flavonoids play an important role in bio-activities of tea (Anesini *et al.*, 2008; Kato *et al.*, 2008).

The chemical composition of tea varies and largely depends on climatic conditions, horticultural practices, soil, growth altitude, plucking season, sorting, grading, processing, extraction, storage and drying (Pelillo *et al.*, 2002; Le Gall *et al.*, 2004). Variability in composition is an important factor that dictates the taste, flavor and health benefits of a specific type of tea (Hara *et al.*, 1995). There is a direct association between tea quality and the content of tea amino acids, caffeine and polyphenols in tea leaf (Cheng, 1983; Khalid *et al.*, 2011).

The per capita consumption of tea worldwide averages 4 fluid ounces per day (Zhu *et al.*, 2006). But in Pakistan per capita consumption is one kilogram and after United Kingdom, Pakistan is the second largest country that imports both raw and processed tea from abroad (Latif *et al.*, 2008). There are different types of tea and tea brands available in the Pakistani market having variation in their composition and quality, but no study has yet been reported in Pakistan regarding compositional analysis of local tea brands in relation to quality. So keeping in view these facts, this research study was planned to evaluate the variation in the composition of commercially tea brands available in the market and to find out the association between tea components that may affect its organoleptic qualities.

Materials and Methodology

Sample collection and preparation: Different brands of tea samples (10 black tea and 5 green tea samples) were collected randomly from different locations in Rawalpindi, Pakistan, the selection was done on the basis of brand popularity and likeness among people. Both local and International brands were selected for this study. Samples were ground and passed through sieve No.30 to get homogenous size material. All the reagents used were of analytical grade except acetonitrile and acetic acid

(Sigma Aldrich Co., St. Louis, USA) which were of HPLC grade.

Physicochemical analysis of tea samples: The moisture content in tea samples was determined by using hot air oven at temperature of 105°C by following the Anon., (2000) method No.925.19. The crude protein contents of tea samples were analyzed by determining the nitrogen content and multiplying the nitrogen with factor 6.25 according to Anon., (2000) by using micro Kjeldahl method. The percent fat contents of the tea samples were determined through Soxhlet apparatus by utilizing petroleum ether as solvent following the method of Anon., (2000).Crude fiber contents of tea samples were determined by digesting samples in 1.25% sulfuric acid and 1.25% sodium hydroxide by following the method of Anon., (2000). The ash content of tea samples was determined according to Anon., (2000) by using muffle furnace at 500-600°C for 5 to 6 hours. The water extracts of tea samples were determined by boiling the samples over low flame for 1hr and then by using hot air oven at 100°C for 1 hr by following the method No.920.104 of Anon., (1990) method No. 920.104.

Caffeine in tea samples: Caffeine in the tea samples was determined by Ultraviolet spectrophotometer at 276 nm by following the Anon., (1990) method No.969.15. Caffeine stock solution (1000 ppm) was prepared in distilled water. Different working solutions were prepared by serial dilution with addition of 1.0 ml hydrochloric acid.

Sample 0.25g were accurately weighed and dissolved in water and made to the net volume of 20 ml with distilled water. 20 ml of prepared sample solution were pipetted in 250 ml flask and 10 ml 0.01 mol/l hydrochloric acid and 2 ml basic lead acetate solution were then added and final volume were made up were with distilled water. 50 ml filtered solution were pipetted and added to 100 ml flask, 0.2 ml of 4.5 mol sulphuric acid were added and again made to the net volume and filtered. The absorbance of the working standards and samples were measured on a UV/Vis spectrophotometer (Shimadzu). The caffeine levels of the samples were calculated through regression equation of the best line of fit of the standards.

Catechin in tea samples: Catechin compounds in tea samples were determined by using high performance liquid chromatography. Samples were prepared by following the Anon., (1990) method No.920.104. A Shimadzu class VP. V6. 13SP1 model HPLC with a UV detector used for analysis of catechin compounds in tea samples. Injection volume was maintained at 10 µl for analysis of each sample with Column C18 and Column temperature was maintained at 40°C, Mobile phase used for solvent A include acetonitrile/acetic acid/ water (6:1:193, v/v) while mobile phase used for solvent B include acetonitrile/acetic acid/ water (60:1:139, v/v). Flow rate was maintained at 1 mL/min. Detection of catechin compounds in tea samples was made by using Shimadzu SPD ultraviolet detector at 280 nm (Neilson *et al.*, 2006).

Mineral analysis: Minerals in tea samples such as calcium, magnesium, sodium, potassium and manganese were determined by Atomic Absorption spectrophotometer (GBC 932 plus, UK), according to standard methods of Anon., (2000).

Sensory evaluation of tea samples: Sensory evaluation of tea samples was conducted to establish preference rating of tea for flavor, taste, color and overall acceptability. Tea samples (5g) were infused with 250ml freshly boiled water for five minutes and then the liquid was poured into 250ml tea tasting porcelain bowl for quality assessment. A trained panel of six judges was employed for sensory evaluation of tea samples. Before start of the evaluation a training session of 15 minutes was conducted with the panelists. Afterwards, one sample at a time was offered to each member. The sensory testing was made in the panel room with controlled temperature and relative humidity. The panel room was completely free of food/chemical odors, unnecessary sound and mixing of daylight. Judges were provided with prescribed questionnaire to record their sensory observations. The information contained on the sensory performa was indicated as 9 = Like extremely; 8 = Like very much; 7 = Like; 6 = Like slightly; 5 = Neither like nor dislike;4 = Dislike slightly;3 = Dislike moderately;2 = Dislike;1 = Dislike extremely (Larmond, 1977).

Statistical analysis: Data obtained from each parameter was analyzed statistically by Analysis of variance and Duncan's Multiple range test ($p<0.05$) by using SPSS 17.0 software package (LEAD Technologies Inc, Chicago, USA) as described by Steel *et al*., (1997).

Results and Discussion

Physicochemical analysis of tea samples: Data regarding physicochemical analysis of commercial tea samples is depicted in Table 1. The results indicated significant variations ($p<0.05$) in different components such as moisture (2.46-7.47%), crude protein (0.87-1.141%), fat (0.94-2.15%), crude fiber (11.23-17.21%), ash (32.34-53.61%) and water extract contents (3.29-5.86%) of commercial tea samples respectively. The maximum and minimum values of these components along with their means and standard deviation are depicted in Table 2. The highest percentage of moisture, crude protein, fat, and crude fiber contents were observed in green tea samples as compared to black tea samples while highest percentage of ash and water extracts were observed in black tea samples in comparison to green tea samples.

The higher moisture content in green tea samples may be due to exclusion of fermentation process during processing of green tea as compared to black tea because during this process much of the polyphenols are destroyed that retain moisture content. Another important factor is use of packaging material to maintain a constant moisture level during storage of commercial tea samples, so moisture content in commercial tea is an essential parameter of quality. Yao *et al*., (2006) also observed 70% of commercial tea samples having moisture content of 6.6% or less and 30% sample containing more moisture percentage up to 8% which can have negative effect on shelf life of the product, so for the better quality of the product moisture percentage should be controlled between 2.5-6.5%.

Table 1. Physicochemical analysis and mineral contents of tea samples.

Sample codes	Moisture (%)	Protein (%)	Fat (%)	Crude fiber (%)	Ash content (%)	Water extracts (%)	Caffeine (%)	Catechins (mg/g)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Manganese (mg/l)
S_1	2.46^{h}	0.95^{ef}	1.21^{ef}	11.23^{h}	4.52^{f}	32.54^{g}	2.34^{i}	0.00^{h}	2.46^{f}	4.49^{cd}	0.39^{h}	$3.26f^{g}$	1.51^{f}
S_2	5.55^{e}	0.96^{ef}	1.00^{gh}	13.57^{g}	5.47^{b}	38.73^{cd}	2.82^{h}	0.47^{f}	2.55^{f}	4.80^{cd}	0.41^{h}	3.47^{e}	1.51^{f}
S_3	4.35^{g}	0.99^{de}	0.94^{h}	16.10^{g}	5.50^{f}	32.51^{g}	3.21^{fg}	0.16^{gh}	2.16^{g}	3.54^{efg}	0.49^{g}	3.54^{d}	1.09^{gi}
S_4	6.43^{c}	0.95^{ef}	0.96^{h}	14.57^{cd}	5.16^{d}	36.33^{be}	3.28^{f}	0.34^{fg}	2.81^{e}	3.69^{ef}	0.41^{h}	3.01^{i}	1.21^{jh}
S_5	4.58^{g}	0.95^{ef}	1.07^{fgh}	14.34^{de}	4.87^{de}	36.97^{cde}	3.04^{gh}	0.00^{h}	1.46^{j}	3.36^{fg}	0.48^{g}	3.13^{h}	1.24^{ij}
S_6	6.11^{d}	0.98^{def}	1.16^{efg}	15.16^{d}	5.86^{a}	32.34^{g}	3.15^{fg}	0.00^{h}	1.74^{i}	3.41^{efg}	0.39^{h}	3.17^{h}	1.19^{jk}
S_7	6.07^{d}	1.01^{de}	1.21^{ef}	13.33^{fg}	4.69^{ef}	35.51^{ef}	3.76^{e}	0.00^{h}	1.66^{i}	3.36^{fg}	0.58^{f}	3.25^{fg}	1.32^{h}
S_8	7.21^{a}	1.03^{d}	2.03^{ab}	16.33^{b}	4.89^{de}	35.51^{eg}	4.02^{cd}	0.00^{h}	1.47^{j}	3.82^{eg}	0.49^{g}	3.05^{i}	1.29^{hi}
S_9	5.43^{e}	0.97^{eg}	1.73^{d}	16.21^{b}	5.18^{c}	36.36^{de}	3.91^{cde}	0.14^{gh}	1.77^{hi}	2.97^{g}	0.83^{e}	3.30^{f}	1.44^{g}
S_{10}	6.15^{d}	0.87^{g}	1.91^{bc}	13.84^{ef}	3.29^{h}	53.61^{a}	4.33^{a}	3.47^{e}	1.87^{h}	4.00^{de}	0.58^{f}	3.24^{g}	2.43^{a}
S_{11}	7.23^{a}	0.92^{fg}	1.02^{gh}	12.75^{g}	5.07^{cd}	35.75^{de}	3.91^{ab}	5.81^{c}	3.40^{c}	5.66^{a}	1.06^{c}	3.81^{c}	2.32^{b}
S_{12}	4.93^{f}	1.40^{a}	1.30^{e}	17.21^{a}	3.37^{h}	32.84^{fg}	4.24^{bc}	6.19^{b}	3.70^{b}	5.55^{a}	1.02^{c}	3.94^{b}	2.25^{c}
S_{13}	7.47^{a}	1.28^{b}	2.11^{a}	17.06^{a}	5.43^{b}	38.22^{cde}	4.06^{de}	6.10^{b}	3.06^{d}	4.78^{bc}	0.97^{d}	3.99^{a}	2.11^{e}
S_{14}	5.98^{d}	1.41^{a}	2.15^{a}	17.14^{a}	4.88^{de}	39.42^{cd}	3.80^{cde}	5.46^{d}	3.84^{a}	5.51^{a}	1.25^{e}	4.00^{a}	2.16^{de}
S_{15}	6.70^{b}	1.17^{c}	1.83^{cd}	16.64^{ab}	4.10^{g}	50.21^{b}	3.91^{ab}	7.44^{a}	2.99^{d}	5.29^{ab}	1.83^{a}	3.84^{c}	2.19^{d}

Values with different superscript letters in columns are statistically significant ($p<0.05$)
Black tea samples (S_1-S_{10}), S_1 = Lipton Yellow Label, S_2 = Supreme, S_3 = Tetley, S_4 = Tapal Danedar, S_5 = A1 Karak Chae, S_6 = Zaiqa Jandar, S_7 = Rachna, S_8 = Kenya Gold, S_9 = Kenya Super, S_{10} = Kenya Bp 14, Green tea samples (S_{11}-S_{15}), S_{11} = Jasmine Green Tea, S_{12} = Lipton Clear Green, S_{13}= Kashmiri Qehwa, S_{14} = Kashmiri Palando Qehwa, S_{15} = Peshawri Palando Qehwa

Table 2. Maximum and minimum values, Means and SD of chemical components and mineral contents of tea samples.

Chemical composition (%)	Black tea samples				Green tea samples			
	Max	Min	Mean	SD	Max	Min	Mean	SD
Moisture	7.21	2.46	5.53	1.34	7.47	4.93	6.46	1.02
Protein	1.03	0.87	0.96	0.04	1.41	0.92	1.23	1.02
Fat	2.03	0.94	1.32	0.40	2.15	1.02	1.68	0.50
Crude fiber	16.33	11.23	14.46	1.58	17.21	12.75	16.16	1.91
Ash content	5.86	3.29	4.94	0.70	5.43	3.37	4.57	0.82
Water extract	53.61	32.34	37.04	6.19	50.21	32.84	39.28	6.60
Caffeine	4.33	2.34	3.38	0.60	4.24	3.80	3.98	0.17
Catechins	3.47	0.00	0.45	1.07	7.44	5.46	6.20	0.74
Minerals (mg/l)								
Calcium	2.81	1.46	1.99	0.47	3.84	2.99	3.39	0.37
Magnesium	4.80	2.97	3.74	0.55	5.66	4.78	5.35	0.34
Sodium	0.83	0.39	0.50	0.13	1.83	0.97	1.22	0.35
Potassium	3.54	3.01	3.24	0.16	4.00	3.81	3.91	0.08
Manganese	2.43	1.09	1.42	0.38	2.32	2.11	2.20	0.08

The highest amount of protein and fat contents in green tea may be due to no fermentation of green tea during processing. These results are in line with previous study of Rehman *et al.,* (2002) who suggested 1-2% protein and 0.95-1.62% fat content for better quality of the commercial tea samples. Fiber content in commercial tea is an important quality parameter. The low fiber content in tea samples may be attributed to younger tea leaves. It also indicates that low quality material is used in production such as 5^{th} or 6^{th} leaf. High fiber content in tea samples may be due to use of impurities like stems during processing. In addition to this, crushing tearing and curling process also destroy the leaf structure that might have effect on fiber content. Previous researchers also indicated positive association between fiber content and keeping quality of the tea and proposed fiber content of less than 16.5% in order to maintain high quality of tea during storage (Venkatesan *et al.,* 2006; Smiechowska & Dmowski, 2006).

Ash content of tea is also an important quality parameter. The higher ash content in tea might be due to less moisture content in tea. Less ash content in tea might be due to adulteration using extracted raw material for the production of tea which lead to the inferior quality of tea. Previous researchers also indicated positive relationship between ash content and keeping quality of tea and proposed that ash content should be controlled less than 5.54% in order to maintain quality of tea during storage (Ismail *et al.,* 2000; Rehman *et al.,* 2002). Water extract of tea is dependent on many components which include, sugars, phenolic compounds, alkaloids, amino acids and many minor soluble substances, such as minerals and pigments. There are number of factors on which the amount of water extract of tea is dependent which includes tea and water ratio, temperature of the infusion, type, particle size and constituents of a tea (Yao *et al.,* 1992; Harbowy *et al,* 1997). According to international

standards it should not be less than 32% of the dry mass basis. The results of the present study are in line with the findings of Yao *et al.* (2006) who observed water extract of different types of tea to be in the range of 35.42%-39.18%.

Caffeine content in tea samples: The results regarding caffeine content of commercial tea samples indicated significant variations ($p<0.05$) among different tea samples (Table 2). The caffeine contents of tea samples were found in the range of 2.34%-4.33%. Maximum and minimum caffeine content of both black and green tea samples along with mean value and SD are depicted in Table 2. In green tea samples caffeine percentage range between 3.80-4.24% in comparison with black tea samples which ranged from 2.34-4.33%, which revealed highest caffeine percentage found in green tea as compared to black tea.

Caffeine is an important component of tea which is essential for the efficiency and other taste characteristics of commercial tea and regarded as an important parameter for commercial tea evaluation (Khokhar & Magnusdottir, 2002)**.** The quality of black tea is strongly associated with the amount of caffeine content for the formation of colored precipitates during infusion process. In the present study high caffeine content was observed in green tea as compared to black tea. This may be attributed to use of more young tea leaves and is in line with previous results of Yao *et al.,* (1992) who described elevated level of caffeine in young leaves. The difference in caffeine content of green tea samples and black teas samples may be due to difference in plucking season, variety and climatic conditions. The results obtained from the present study are in line with the results obtained by Owuor & Chavanji (1986) who suggested that the caffeine content of the commercial tea samples should be controlled fewer than 4% to maintain better quality of the product. Caffeine content of black teas is also affected by clone, stage of plucking, season, geographical locations, late harvesting as well as more mature leaves for commercial tea production (Yao *et al.,* 1992; Hicks *et al.,* 1996).

Catechin content in tea samples: The results pertaining to catechin content of commercial tea samples depict significant variations ($p<0.05$) among different tea samples (Table 1). The catechin content of tea samples ranged between 0.14-7.44 mg/g with maximum amounts (7.44 mg/g and 6.19 mg/g) observed in sample 15 (Peshawri Palando Qehwa) and sample 12 (Lipton Clear Green), respectively while minimum amount was observed in sample 9 (Kenya Super) containing 0.14 mg/g catechin content. No catechin content was observed in samples, 1, 5, 6 and 8. In green tea samples catechin content ranged between 5.46-7.44 mg/g in comparison with black tea samples which ranged from 0-3.47mg/g, which revealed highest catechin content found in green tea as compared to black tea (Table 2).

Catechin content in commercial tea is an important quality parameter for determining the tea quality. The high catechin content in green tea samples may be due to the use of fresh leaves without oxidation process as compared to black tea because during enzymatic oxidation process most of the catechin compounds may be destroyed. These compounds also act as anti-oxidative and anti-carcinogenic agent that helps against cancers and tumors (Blot *et al.,* 1996; Kohlmeier *et al.,* 1997). The results obtained from the present study are in line with the results obtained by Wang *et al.* (2000) who found catechin content of tea to be an important quality parameter imparting bitterness and astringency to the tea, and should be ranged from 3-5% for better quality of the product.

Mineral content of tea samples: The results pertaining to mineral contents of different tea samples are shown in Table 1. These results indicate significant variations ($p<0.05$) of mineral contents among different tea samples. Maximum and minimum values of calcium, magnesium, sodium, potassium and manganese of both black and green tea samples are depicted in Table 2. Highest amounts of calcium, magnesium, sodium, potassium and manganese were found in green tea as compared to black tea.

The higher calcium content in green tea samples may be due the use of fresh tea leaves in the processing of green tea as compared to black tea. The elevated levels of calcium contents are very essential because they play a vital role in teeth formation, in bones strengthening, muscle formation system and better functioning of heart (Obiajunwa *et al.,* 2002). More amount of magnesium content in green tea samples may be due to exclusion of enzymatic oxidation process that lead to more amount of water extracts in tea. Sodium is minor component of tea minerals that having very little impact on tea quality. The higher potassium content in green tea samples may be due no fermentation process during green tea processing in comparison to black tea. The high potassium content in tea samples might be correlated with cultivation of tea in potash-rich soils (Jonah & Willims, 2000). The discrepancy of the mineral content of the tea samples may be due to the differences in the soil properties, species, harvesting times and different climatic conditions.

Sensory evaluation of tea samples

Color: The results regarding color scores of tea samples are depicted in Fig. 1A which revealed significant variation ($p<0.05$) among different tea sample. The average color scores of tea samples ranged between 3 and 8. The highest color scores 8 were assigned to sample 5 (A1 Karak Chae) and sample 3 (Tetlay) while the lowest color scores 3 were assigned to sample 15 (Peshawri palando Qehwa) and sample 4 (Tapal Danedar). The color scores assigned to green tea samples ranged from 3-7 in comparison to 5-8 for black tea samples, which revealed that highest color scores were found in black tea as compared to green tea. The highest color scores observed in black tea in comparison to green tea samples might be due to oxidation and fermentation processes during tea processing. The amino acids in tea have a significant role in color production which may be oxidized by catechins resulting in tea liquor color (Ying *et al.,* 2005; Thippeswamy *et al.,* 2006). In addition to this, other tea components such as thearubigins and theaflavins are also reported to affect the sensory characteristics of the tea especially brightness of tea color (Owuor & Obanda 2001).

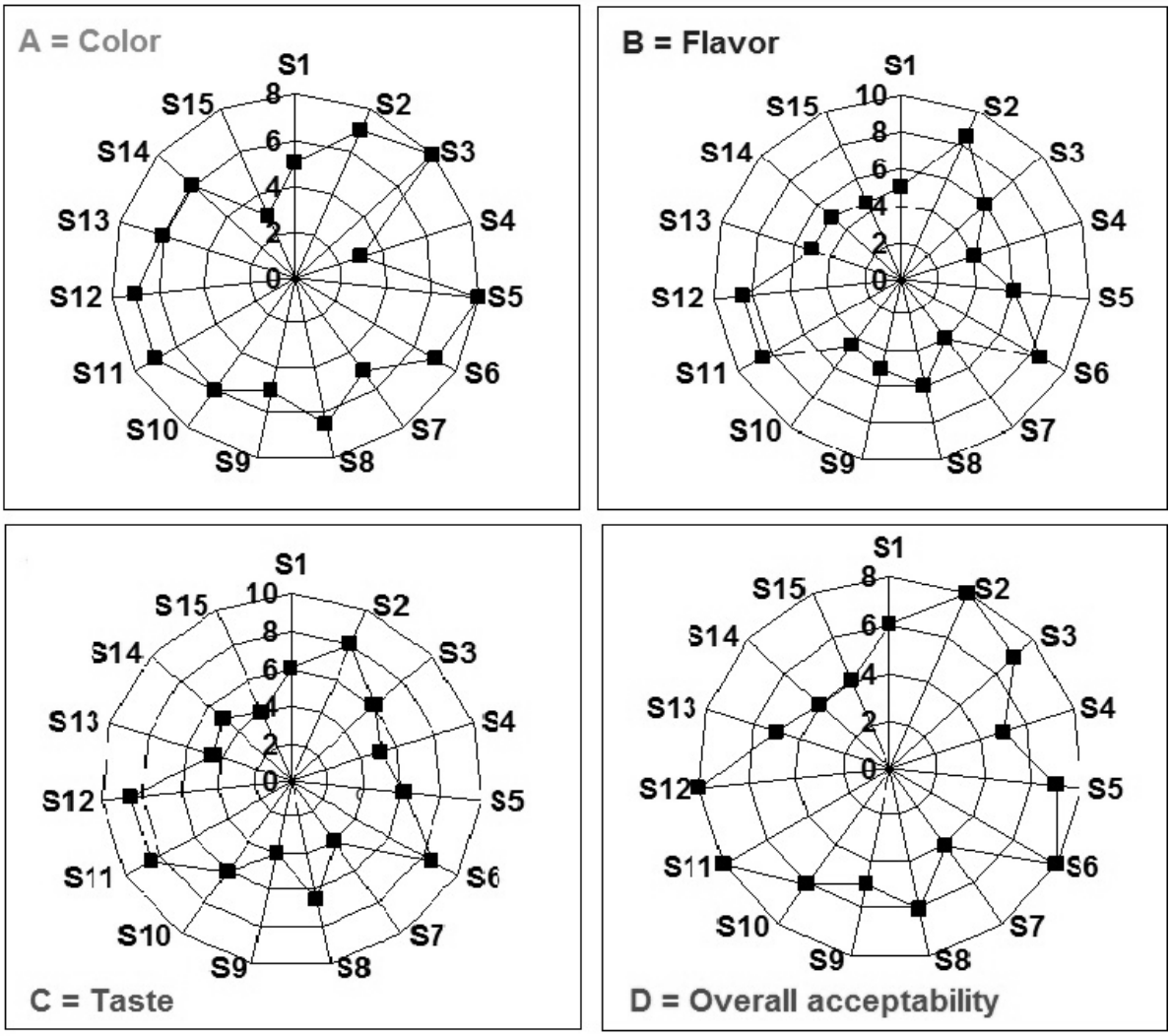

Fig. 1. Sensory evaluation of commercial black and green tea samples. A indicates color of tea samples, B indicates flavor of tea samples, C corresponds towards taste and D indicates overall acceptability of tea samples judged.

Flavor: The results pertaining to flavor scores of different tea samples are depicted in Fig. 1B which indicated significant difference ($p<0.05$) among different tea samples. The average flavor scores of tea samples ranged from 4-8, with highest flavor scores (8.5) were assigned to sample 11 (Lipton Clear Green) and sample 2 (Supreme) while lowest flavor scores (4) were assigned to sample 7 (Rachna) and sample 4 (Tapal Danedar). In green tea samples flavor scores ranged from 4-8.5 scores in comparison to 4-8.5 scores for black tea samples, indicating highest flavor scores of green tea as compared to black tea. The highest flavor scores in green tea in comparison to black tea may be attributed to the use of more young tea leaves as well as controlled fermentation during processing. The difference in flavor score of tea samples may also be due to variations in thearubigins, caffeine and catechin compounds among green and black tea samples (Khokhar & Magnusdottir, 2002)**.** The results obtained from the present study are in line with previous study of Owuor & Obanda (2001) who observed better flavor scores in commercial tea containing more amounts of caffeine and thearubigins.

Taste: The results regarding scores assigned to taste of commercial tea samples are presented in Fig. 1C which revealed significant difference ($p<0.05$) among different tea samples. The average taste scores of tea samples ranged from 4-8.5 with highest taste scores (8.5) assigned to sample 11 (Lipton Clear Green) and sample 12 (Lipton Clear Green) while lowest taste scores (4) were observed in sample 9 (Kenya Super) and sample 15 (Peshawri Palando Qehwa). In green tea samples taste scores ranged from 4-8.5 in comparison with black tea samples which ranged from 4-8.5 scores, it revealed that highest taste was found in both green tea and black tea samples. The scores assigned to taste ranged from 4-8.5 for both green and black tea samples indicating better taste in both types of tea. Caffeine is regarded as important parameter for commercial tea sensory evaluation having significant contribution in the development of taste. The quality of tea is strongly associated with the amount of caffeine content for the formation of flavored precipitates during infusion process (Smith *et al.,* 1993). The amounts of other components such as thearubigins, theaflavins, amino

acids, and catechins also have a significant contribution in the sensory characteristics of tea (Kato *et al*., 2008).

Overall acceptability: The results regarding scores assigned for overall acceptability of tea samples are depicted in Fig. 1D which revealed significant variation ($p<0.05$) among different tea samples. The overall acceptability scores of tea samples ranged from 4-8 with maximum scores 8 assigned to sample 2 (Supreme) and sample 11 (Lipton Clear Green) while minimum scores 4 were assigned to sample 14 (Kashmiri Palando Qehwa) and sample 15 (Peshawari Palando Qehwa). In both green tea and black tea samples, overall acceptability scores ranged between 4-8 scores. Quality evaluation of commercial tea depends up on number of factors such as caffeine, amino acids, catechins, trearubigins and theaflavons. Tea samples with high amount of both chemical and volatile compounds have positive association with respect to sensory attributes of tea including overall acceptability. The results of present study are in line with previous results of Owuor & Obanda (2001) who observed better sensory quality of tea samples having high quality of raw material with maximum amounts of chemical and volatile components used during processing.

Conclusion

Tea is one of the most popular beverages and plays a vital role as a pharmaceutical and neutracutical agent. There are different brands of black and green tea which are commercially available in the market, having variation in their composition and quality which have direct link with its storage stability and sensory qualities. The highest percentage of moisture, protein, fat, and crude fiber contents were observed in green tea samples while highest percentage of ash and water extracts were observed in black tea samples. Maximum amounts of caffeine and catechins were observed in green tea in comparison to black tea. Maximum mineral contents were also observed in green tea in comparison to black tea samples. Tea samples with high amount of both chemical and volatile compounds have positive association with respect to sensory attributes. The study provides a better knowledge regarding the quality of tea beverage available in Pakistan. Similarly, it provides a solid foundation for consumer's preference study regarding beverages in Pakistan and formulating quality standards for safety point of view.

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