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Biochemical investigation of Bangladeshi black tea and their correlation to organoleptic quality evaluation

Md Rashedul Munim Khan [a], Md Atiqual Islam [a], Rayhan Uddin [a], Md Abul Kalam [a,b], Nabil Nawrose Baishakh [a], Pranti Barua [a], Md Habibur Rahman Talukder [c], Iftekhar Ahmad [a,*]

[a] *Department of Food Engineering and Tea Technology, Shahjalal University of Science and Technology, Sylhet, 3114, Bangladesh*
[b] *Abul Khair Condensed Milk and Beverage Limited (Tea Testing and Blending), Chittagong, 4210, Bangladesh*
[c] *Department of Chemistry, Shahjalal University of Science and Technology, Sylhet, 3114, Bangladesh*

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ABSTRACT

Black tea samples were investigated for theaflavin (TF), thearubigin (TR), highly polymerized substances (HPS), total liquor color (TLC), color index (CI), caffeine (CAF), total polyphenol content (TPC), antioxidant activity (DPPH) and organoleptic evaluation. The objectives of the study was to perform the biochemical analysis and organoleptic test of various black tea and develop a correlation between them. Overall correlation study showed that TF:TR and total liquor color, are significantly ($p < 0.01$) and positively correlated with the total quality score where the correlation coefficient was 0.970 and 0.969 respectively. Additionally, statistical analysis revealed a significant ($p < 0.01$) and positive correlation between total phenol contents and antioxidant scavenging activity (0.986), supporting the notion that TPC accounts for most of the antioxidants in tea extract. Qualitative characteristics and organoleptic tests were shown identical outcomes in this study.

1. Introduction

Tea (*Camellia sinensis*) is a widely consumed non-alcoholic beverage throughout the world and it has therapeutic properties against different diseases [1,2]. It has anti-inflammatory and anti-cancer properties especially against liver, breast, and colorectal cancers [3]. Fermentation (oxidation) is one of the most important stages among different stages (leaf handling, withering, rolling, drying, and sorting) of tea production [4]. Based on the level of oxidation performed in tea processing, tea has been classified into three different categories: i) non-oxidized tea, ii) oxidized tea and iii) semi-oxidized tea which are known as green tea, black tea and oolong tea respectively [5]. The quality of tea depends on several pre-and post-harvest technologies used in the tea manufacture process, environmental factors and biochemical compounds.

There are different kinds of biochemical compounds in tea. The primary biochemical components of tea are catechins. Catechins were oxidized during tea processing into theaflavins (TF), which were further converted into thearubigins (TR) via enzyme-catalyzed reactions [6–8]. The presence of TF and TR and their ratio significantly affect the taste, strength, color and overall quality of black tea [9,10]. The ideal TF and TR ratio of a high-quality cup of tea is around 1:10 [11]. Besides the TF and TR content, total phenolic content

* Corresponding author.
E-mail address: iftekhar-ttc@sust.edu (I. Ahmad).

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(TPC) and high polymerized substance (HPS) are also positively correlated with the quality of tea. Both TPC and HPS increase during oxidation. Proteolytic enzymes increase the antioxidant activity of tea by hydrolysing phenolic compounds into free phenols through fermentation (oxidation) [12].

Black tea is extremely popular in Bangladesh. Bangladeshi people drink at least 1 cup of tea every day. But the information on different biochemical compounds of Bangladeshi teas is not sufficient. Moreover, in the tea industry, the quality of tea has been evaluated by qualified and skilful specialists (tea testers) who assess the commercial worth of tea based only on their own personal preferences. The market price of teas depends on the tea taster's rating. In this study, we investigated the biochemical compound of commercially available black tea and investigated their relation to the organoleptic test.

2. Materials & methods

2.1. Sample collection and preparation

Five black tea samples from different renowned tea companies (Seylon, Kazi & Kazi, Tata, Tazza and Ispahani Mirzapur) which are levelled as sample A-E, were procured from the local market. The choice was made based on the popularity of the tea brand. Samples were vacuum sealed and stored in a desiccator until analysis. Methyl isobutyl ketone (MIBK), Butanol ($C_4H_{10}O$), Disodium phosphate (Na_2HPO_4), chloroform, ethanol (96%), sodium carbonate, methanol, Folin–Ciocalteu's phenol reagent, and 1,1-diphenyl-2-picrylhydrazyl (DPPH) were used in this study were of analytical grade and purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA).

2.2. Chemical analysis of made tea

Sample (2 g) was dispersed into 100 ml of hot water and infused for 10 min in a shaking water bath (FSGPD28, Fisher Scientific, Canada) at 100 °C and 100 rotation per minute (RPM) for 10 min. After that, made tea was filtered with cotton wool. Different tea quality parameters including theaflavins (TF), thearubigins (TR), highly polymerized substances (HPS), and total liquor color (TLC) were investigated using spectrophotometry [13]. In a separating funnel, 25 ml sample was agitated with 25 ml of Methyl isobutyl ketone (MIBK) and kept still to separate into two phases called organic (B) and aqueous. The aqueous (E) and organic (D) phases were made by swirling 10 ml of the aqueous phase with 10 ml of Butanol ($C_4H_{10}O$). 10 ml of organic (B) phase solution was agitated with 10 ml of 2.5% Disodium phosphate (Na_2HPO_4) solution, and the organic (C) and aqueous phases were separated. In distinct test tubes, 1 ml of each A, B, C, and D phase was inserted into 9 ml of 45% ethanol using a pipette. 1 ml sample was mixed into 9 ml of distilled water in a test tube (A). Using a UV spectrophotometer, the absorbance of all the solutions was calculated. TLC of samples is indicated by the absorbance of solution (A) observed at 460 nm wavelength. The absorbance of solutions B, C, D, E was measured at 380 nm wavelength. The absorbance measurements was used to compute the contents of TF, TR, HPS, and TLC by equations (1)–(4) where;

$$\text{Total Liquor Color }(\%) = \frac{(10 \text{ x A x 2 x } 100)}{(\text{Sample weig ht x DMC})} \tag{1}$$

$$\text{Thearubigins }(\%) = \frac{(13.643 \text{ x } (B + D - C) \text{ x 2 x } 100)}{(\text{Sample weight x DMC})} \tag{2}$$

$$\text{Theaflavins }(\%) = \frac{4.313 \text{ x C x 2 x } 100}{\text{Sample weight x DMC}} \tag{3}$$

$$\text{High Polymerized Substance }(\%) = \frac{13.643 \text{ x E x 2 x } 100}{\text{Sample weight x DMC}} \tag{4}$$

$$\text{Color Index }(\%) = \frac{\text{TF} * 100}{\text{TR} + \text{HPS}} \tag{5}$$

where DMC is the dry matter content. The TF and TR's multiplication factors were calculated using the molar extinction coefficients of pure substances and the dilution factor [14,15]. In the case of TLC, value 10 is the dilution factor [16]. Determination of tea color index (CI) was performed according to Ramaswamy, (1986) [17] from equation (5). All the analysis were performed in triplicates the mean values were presented.

2.3. Estimation of caffeine, polyphenol, DPPH radical scavenging activity (%)

Caffeine content was determined according to the method described by Ref. [18]. Briefly, 0.10 g of tea was dispersed into 50 ml of deionized distilled water (DWW) that was heated to 40 °C and stirred for 30 min. The sample mixture was then filtered with Whatman No. 1 filter paper and cooled down at room temperature. Then 50 ml of chloroform was added into the filtrate and stirred for 10 min and transferred into a separating funnel and allowed to separate the organic layer which contains caffeine. The separated organic layer was then subjected to measure absorbance using a spectrophotometer (UV-1601, Shimadzu Corporation, Japan) at 260 nm.

The total polyphenols were estimated according to the method described by Zzaman et al. (2021) [19]. In brief, 1 g of tea was powdered with mortar and pestle and mixed with 100 mL 96% ethanol. The components were filtered by Whatman No 1 filter paper.

Table 1
Physical characteristics of some tea samples.

Samples	Color	Even	Stalk	Dust	Fibre	Clean/Unclean
A	Fully brown	Even	Absent	Absent	Absent	clean
B	Brownish	–	Present	Present	Present	unclean
C	Full brown	–	Present	Absent	Present	unclean
D	Light brown	Even	Absent	Absent	Present	unclean
E	Moderate brown	Even	Absent	Absent	Present	unclean

Then, 2 ml of diluted extract was added with 2 ml of 35% sodium carbonate, and 4 ml of 1:1 Folin-ciocalteu's phenol reagent (reagent: DDW = 1:1, v/v). The mixture was then volume up to 10 ml using ethanol and shaken thoroughly and kept in dark for 30 min. After 30 min absorbance was measured at 700 nm using a spectrophotometer (UV-1601, Shimadzu Corporation, Japan [20]). All the experiments were performed in triplicates and the result was expressed as mg/g Gallic acid equivalent (GAE).

Antioxidant activity of tea was evaluated by 2, 2 diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay based on the method described by Adiletta et al. (2018) [21]. Briefly, 2 g of sample was dispersed into 100 mL of 96% methanol. Extraction was then carried out at room temperature for 60 min in a shaking water bath (FSGPD28, Fisher Scientific, Canada) at 200 RPM. After filtering with Whatman No 1 filter paper 2.0 ml of 0.16 mM solution of DPPH was incubated with 2 mL sample extracts with a concentration of 0.2 mg/mL. Subsequently, the mixture was vortexed (VM-2000, Taiwan) for 1 min and then kept at room temperature for 30 min in the dark, as DPPH is extremely light-sensitive; its absorbance at 517 nm was determined using a UV-Spectrophotometer (T60U, United kingdom). DPPH radical scavenging activity was expressed as inhibition percentage and was calculated as: Inhibition (%) = $[1-(A_{sample} - A_{sample\ blank})/A_{control}] \times 100$.

2.4. Organoleptic test

Sensory evaluation was performed to assess the biochemical characteristics of the tested entities. These experiments were conducted in compliance with the International Organization for Standardization (ISO) standard 3103 [22]. Tea tasters were chosen based on previous experience and knowledge. They were informed about the study's objectives and provided written consent to conduct the sensory analysis in accordance with the SUST Research Ethics Board's (SREB) ethical guidelines. Tea Infusions were prepared by pouring 142 mL of boiling distilled water into a cup containing 2.5 g of black tea and allowing it to brew for 5 min. Tea tasters sniffed and tasted the infusions, including tea leaves. They scored their sensory evaluation based on infusion, liquor color, briskness, strength and creaming down on a hedonic scale of 1–9 for each parameter, where like extremely = 9, like very much = 8, like moderately = 7, like slightly = 6, neither like nor dislike = 5, dislike slightly = 4, dislike moderately = 3, dislike very much = 2, dislike extremely = 1 [23]. A panel of three tea tasters evaluated all samples collected from the local market. Different brands of tea samples were assessed in concern to the made tea's cup quality. Based on the organoleptic test score, the tea was categorized as "excellent," "above average," "average," and "below average." Above 34 points was considered "Excellent" (E) above 32 to below 34 points was considered "Above Average" (AA) above 30 to below 32 points was considered "Average"(A) and below 30 points was considered "Below Average" (BA) [24].

2.5. Statistical analysis

Obtained results were analyzed by the analysis of variance (ANOVA) procedures and Duncan's Multiple Range Test (DMRT) with significance defined at $P < 0.05$ and the correlation between qualitative and sensory parameters were investigated. All statistical analysis were carried out using the IBM SPSS (Statistical Package Social Science) version 26 statistical software. All data were expressed as mean ± standard deviation (SD) of three independent replicates.

3. Results and discussion

3.1. Physical appearance

Considering the physical characteristics of all five tea samples, sample A seemed to have excellent quality. Table 1 shows that the leaves in sample A were grainy, black, even, dust-free, fibre-free, and well-made, and the liquor was clean, strong and entirely brown leaf. Sample E was moderate brown in color and the leaves of sample E were black but spongy, flat and flaky, including some fibres, leaf was clean whereas the liquor was not very clean, and the strength was moderate. On the other hand, sample D had blackish, mixed fibre leaves, unclean leaves and clean liquor but plainer type, lack of strength, and a light brown color. Sample B and C both had an almost similar appearance, but sample C is better than Sample B as it was dust free and also full brown in color. Hence, Sample B experienced the lowest quality, which consisted of a brown flaky, uneven, unclean, mixture of spongy fibre, stalk and dust combined with leaves that were not clean. Its infused leaves contribute a brownish color to them.

Table 2
Cup quality assessment of different brands tea samples.

Samples	Infusion (9)	Liquor Color (9)	Briskness (9)	Strength (9)	Creaming Down (9)	Total (45)	Remarks
A	7.5 ± 0.28^b	8.5 ± 1.26^a	7.5 ± 1.2^b	7 ± 0.65^a	8 ± 1.32^a	38.5^a	E
B	6.5 ± 0.76^c	4.5 ± 0.23^c	4 ± 0.23^c	6 ± 0.37^c	3 ± 0.82^c	24^c	BA
C	7 ± 0.45^b	6.5 ± 0.87^b	6 ± 1.3^b	6 ± 0.45^c	3 ± 0.37^c	28.5^b	BA
D	8 ± 0.78^a	7 ± 0.35^b	8 ± 0.54^a	6.5 ± 0.76^b	6 ± 0.56^b	35.5^b	E
E	7 ± 0.5^b	7 ± 0.85^b	7 ± 0.67^b	7 ± 1.4^a	7.5 ± 0.86^a	35.5^b	E

Values are presented in mean ± standard deviation where different letters in a column denote statistically significant ($p < 0.05$).

Table 3
Qualitative parameter of tea brands samples.

Samples	TF%	TR%	TF:TR	HPS %	TLC	CI
A	0.58 ± 0.05^b	$5.58 \pm .07^b$	1:9.61 ± 0.73	3.70 ± 0.25^c	3.57 ± 0.21^a	6.25 ± 0.33^a
B	0.321 ± 0.07^c	$2.32 \pm .07^c$	1:7.22 ± 0.55	5.20 ± 0.275^{ab}	2.32 ± 0.20^b	4.26 ± 0.569^b
C	0.81 ± 0.06^a	$6.03 \pm .065^a$	1:7.41 ± 0.43	7.21 ± 0.226^a	2.53 ± 0.161^b	6.138 ± 0.28^a
D	0.65 ± 0.06^b	$6.02 \pm .07^a$	1:9.33 ± 0.77	4.58 ± 0.25^b	3.02 ± 0.241^a	6.088 ± 0.380^a
E	0.71 ± 0.05^{ab}	$6.65 \pm .07^{ab}$	1:9.40 ± 0.58	4.71 ± 0.285^b	3.26 ± 0.290^a	6.23 ± 0.249^a

Values are presented in mean ± standard deviation where different letters in a column denote statistically significant ($p < 0.05$). TF=Theaflavin; TR=Thearubigin; HPS=High Polymer Substance; CI=Color Index TLC- Total Liquor Color.

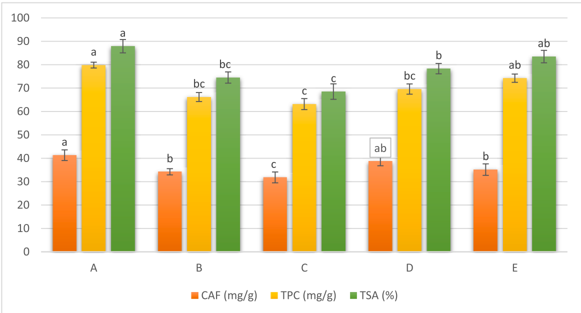

Fig. 1. Caffeine, Total polyphenol content and Total scavenging activity of tea samples.

3.2. Organoleptic investigation

Tea tasters are crucial to the evaluation of tea quality. They provided the following results of the given tea sample (Table 2). Sample A was found to have excellent (E) cup quality during organoleptic analysis (score >34) followed by samples D and E. Samples B and C showed below average (BA) cup quality which were 24 and 28.5 in total quality score respectively. In terms of liquor color and strength, samples A and E were rated as Excellent (E), whereas sample D looked to have a higher level of briskness and infusion than those in other samples, but there was no statistically significant difference ($p > 0.05$) between D and E in terms of the total quality score.

3.3. Estimation of TF, TR, HPS, TLC, CI

The amounts of theaflavin (TF), thearubigin (TR), total liquor color (TLC), highly polymerized substances (HPS) and color index (CI) varied among the samples (Table 3). The greatest TF content was found in sample C (0.813%) and the lowest TF was found in sample B (0.321%). The descending order of the values of all the five samples were C, E, D, A and B. The variation in TF levels may be attributable to tea type, height above mean ocean level, local practices and processing factors that impact the quality of black tea [25]. According to Balentine et al. (1997) [26], theaflavin content in black tea rarely exceeds 2% and can be as low as 0.3%; which corresponds with our findings.

Thearubigin level was higher in sample E followed by sample C, D, A, and B. The higher TR content increase the depth of liquor color, strength and mouthfeel of tea liquor [27]. Our present study is strengthen by Alam et al. (2015) [28] who found the TR concentration ranged from 5.725% to 4.282% in five popular Bangladeshi tea brands'. A significant factor in defining the body, strength, and color of the tea beverage is the presence of a highly polymerized substance (HPS). The range of HPS content found in our study was between 7.21 and 3.70%. TLC refers to the whole liquor color which relies on TR, TF, and HPS. The highest TLC was observed in sample A followed by samples E, D, C, and B. The TLC and HPS of this study corroborate the findings of Alam et al. (2011) who investigated ten marketed brands teas in Bangladesh. According to Someswararao et al. (2013) [29], the total liquor color in Indian black tea ranged

Table 4
Overall correlation coefficient of qualitative traits and organoleptic test.

	TF	TR	HPS	TLC	TR/TF	CI	CAF	TPC	TSA	INF	LC	BRSK	ST	CD	TQS
TF	1	0.91[a]													
TR	0.912[a]	1													
HPS	0.398	−0.007	1												
TLC	0.294	0.626	−0.734	1											
TR/TF	0.264	0.634	−0.776	0.95[a]	1										
CI	0.870	0.97[b]	−0.087	0.714	0.674	1									
CAF	−0.174	0.174	−.889[a]	0.794	0.798	0.321	1								
TPC	−0.037	0.321	−0.867	.934[a]	0.854	0.429	0.831	1							
TSA	−0.120	0.266	−.922[a]	.903[a]	0.867	0.350	0.829	0.986[b]	1						
INF	0.384	0.594	−0.419	0.604	0.719	0.658	0.696	0.386	0.375	1					
LC	0.548	0.761	−0.456	0.913[a]	0.820	0.88[a]	0.688	0.752	0.669	0.700	1				
BRSK	0.594	0.839	−0.445	0.820	0.88[a]	0.88[a]	0.648	0.582	0.556	0.91[a]	0.878	1			
ST	0.209	0.565	−0.765	0.961[b]	0.934[a]	0.605	0.695	0.936[a]	0.96[a]	0.439	0.781	0.712	1		
CD	0.200	0.570	−0.803	0.978[b]	0.97[b]	0.622	0.773	0.939[a]	0.94[a]	0.549	0.814	0.775	0.99[b]	1	
TQS	0.425	0.740	−0.655	0.970[b]	0.97[b]	0.809	0.774	0.829	0.802	0.761	0.93[a]	0.935[a]	0.91[a]	0.94[a]	1

[TF=Theaflavin; TR=Thearubigin; HPS=High Polymer Substance; TLC- Total Liquor Color CI=Color Index CAF=Caffeine, TPC = Total Polyphenol Content, TSA = Total Scavenging Activity, INF=Infusion; LC=Liquor Color; BRSK=Briskness; ST=Strength; CD=Creaming Down; TQS = Total Quality Score].

[a] Correlation is significant at the 0.05 level (2-tailed).

[b] Correlation is significant at the 0.01 level (2-tailed).

from 3.89% to 5.7%, which is compatible with the results of the current study. As particle size increased, TF, TR, HPS, and TLC concentrations increased. This is because finer grades have more surface area, which facilitates increased catechins oxidation and the production of TF, TR, HPS, and TLC, enabling better extraction during brewing. Another crucial element in evaluating black tea quality is the TR/TF ratio. To achieve a balanced liquor and taste, the TR/TF ratio should be 10–12 [11]. The highest TR/TF ratio was discovered in samples A, E, and D, which indicates a good characteristic in the sample liquor. It is hypothesized that excessive tea fermentation during processing led to this imbalance. The color index (CI) is a measure of the depth of the liquor color. Evidently, the color index must be between 5 and 11 in order to produce a liquor with the desired color and briskness. If the color index is larger than 11, the tea will be colorless, and if it is less than 5, the liquor will be dark, flat, and lacking in briskness [27]. In the present study color index of tea samples had scores ranging from 4.26 to 6.25. Table 3 displays that all of the color indices for the tested brand teas met Bangladesh tea standard requirements, with the exception of sample B.

3.4. Estimation of caffeine, polyphenol and total scavenging activity

Caffeine, total polyphenol content, and DPPH radical scavenging activity varied significantly across tea samples (Fig. 1). Caffeine is an essential component in infused tea, which stimulates the human central nervous system [27]. Sample A contained the highest amount of caffeine (41.32 mg/g) compared to the other samples. Sample C contained the least amount of caffeine (31.84 mg/g). The caffeine content of tea varies by agro type, harvesting period, and commercial brand. When comparing samples B and E, no discernible change can be found. The amount of caffeine is highest from April to June, when plucking is at its peak, and lowest from October to December, when plucking slows down [30]. Polyphenols are the most influential chemical elements in the flavor and aroma of tea. The findings, which are displayed in Fig. 1, demonstrate that the total phenolic content varied with different tea brands and ranged from 63.17 to 79.82 mg GAE/g. The sample with the greatest total polyphenol content (TP) was A, followed by E, D, B, and C. The diversity in TPC among black tea brands could be ascribed to a variety of factors such as agronomic circumstances, harvested leaf age, storage during and after transportation, and the level of fermentation. According to Ref. [31], the TPC and antioxidant activity of Malaysian tea leaves vary with their degree of maturation. The total polyphenol content ranged from 56.6 ± 1.56 to 80.3 ± 0.61 mg GAE/g DW, as reported by the authors. These results align with the TPC status of the current experiment. Due to the presence of a phenolic hydroxyl group connected to the flavan-3-ol structure, tea polyphenols have been found to exhibit significant antioxidant and free radical scavenging activity [31]. Free radicals are constantly produced as a result of dietary item metabolism, physical stress, and oxidative stress caused by numerous environmental pollutants/chemicals/toxins, radiation, and other factors. These free radicals are linked to a variety of human ailments, including cancer, angina pectoris, neurological disorders, and atherosclerosis [32]. Antioxidants are advantageous for slowing or delaying the progression of various diseases due to their ability to neutralize free radicals. The utilization of the free radicals 2, 2-Diphenyle-1-picrylehydrazyl (DPPH) is a quick, easy, and inexpensive approach for measuring tea's antioxidant capacity. Widespread use of DPPH to assess substances' ability to act as free radical scavengers or hydrogen donors and to quantify antioxidants in complicated biological systems. In Fig. 1, similar to TPC, sample A had the highest scavenging activity (87.92%) while sample C had the lowest (68.52%).

3.5. Overall correlation analysis of different tea samples

Table 4 shows the result of a correlation analysis of qualitative traits and tea taster's ratings. Qualitative measures (TF, TR, HPS, TLC, TR/TF ratio, CAF, TPC and TSA) and organoleptic parameters (INF, STN, LC, BRSK, CD, and TQS) were found to have a strong connection. TF had a significant positive correlation with TR and a positive connection with TLC, CI, INF, BRSK, ST, CD and TQS. TF is a crucial chemical constituent of black tea infusion's color as well as flavor attribute and it is positively correlated with the black tea's taste and liquor quality [33,34]. TR/TF ratio had significantly strong and positive correlations with TLC, BRSK, STN, CD and TQS. INF had a positive correlation with all the parameters whereas negative correlation with HPS but not significant. As a result, infused leaf color could be a good organoleptic quality indicator. Moreover, we observed that TQS had extreme significant correlation with TLC (0.970), TR/TF ratio (0.969), CD (0.940), LC (0.934), BRSK (0.935), and STN (0.901). Therefore, it can be assumed that the qualitative traits such as TLC and TR/TF ratio can reflect the majority of black tea's total quality score.

The score of CI was extremely significant and positively correlated with TR content, which correlation coefficient was 0.972 while TF and TR/TF value with CI correlation coefficient was 0.870 and 0.674 respectively, only showing positive correlation. Therefore, it is feasible to employ the TR content to reflect the color of black tea infusion. On the other hand, TPC had a strong positive correlation with TSA (0.986) which is significant at 1% level. This suggested that polyphenols might be one of the primary elements in charge of these tea extracts' antioxidant properties. A similar trend was also found in Ethiopian commercial tea brands that a strong relationship between antioxidant activity and total polyphenols content [35]. The total quality score was positively correlated with polyphenol and caffeine content indicating that determination of polyphenol and/or caffeine contents can assay total black tea quality.

The above overall correlation (between qualitative traits and organoleptic test) is more in line with past research findings [25,27,34]. Furthermore, expert tea tasters judged the quality of tea brands using sensory evaluation, and the current findings suggested that incorporating biochemical factors to obtain more meaningful conclusions regarding black tea quality is worthwhile.

3.6. Comparative analysis of qualitative traits and sensory evaluation of different tea samples

The study reveals the comparison of the findings of TF:TR and Total Quality Score by using the defined range of TF:TR, which is 1:10 to 1:12 [11], and the standardized scale score of organoleptic test in samples A, D, and E had excellent cup quality scores

Table 5
Comparative analysis of qualitative parameters and Cup quality test of different tea samples.

Samples	Qualitative traits (TF:TR)	Organoleptic test (TQS)	Observation
A	Excellent	Excellent	Similar result
B	Below average	Below average	Similar result
C	Below average	Below average	Similar result
D	Excellent	Excellent	Similar result
E	Excellent	Excellent	Similar result

(Table 2). These samples were discovered to be so close to the requisite TF:TR (Table 3) which can be referred to as excellent quality. Samples B and C, on the other hand, have below average cup quality (Table 2) as well as being far away from the acceptable TF:TR (Table 3), which can be referred to as Below Average. In Table 5, it's discernible that our lab test of qualitative parameters and total organoleptic test score of tea samples are quite identical.

4. Conclusion

In this research, the qualitative parameters of samples A, E, and D were demonstrated higher values than those of samples B and C in terms of high TR, TLC, TR/TF ratio, CAF, TPC and TSA. TQS positively correlated with TLC, TR/TF ratio, CD, LC, BRSK, and STN. The presence of a significant positive correlation between TR with TF and TR with CI influences the quality of black tea significantly. TR/TF ratio is significantly and positively correlated with TQS but negatively correlated with HPS. As a result, higher-quality teas can be made by precisely controlling the TR/TF ratio. In addition, TPC of tea extract has an extremely significant positive correlation with total scavenging activity. This leads us to conclude that the maximum antioxidant of black tea extract is contributed by TPC. The current study has shown a highly significant relationship as well as a profound understanding of the interaction between multiple qualitative traits and organoleptic test. The TF, TR, HPS, and TLC levels in the five tea brands studied were moderate yet comparable to the Bangladesh tea quality standard. The current investigation showed that TF:TR and Total Quality Score yielded identical findings. It is also reasonable to infer that, in terms of qualitative status, sample A was found to be superior to the other samples. The quality of processed CTC black tea, however, may ultimately depend on the precise control of process factors including withering and oxidation (fermentation). Furthermore, it is necessary to know the contribution of specific chemical constituents to black tea's distinctive flavour and aroma, as well as its mellowness, astringency, umami taste, sweetness, brightness and redness of liquor, by conducting advance research.

Author contribution statement

Md. Rashedul Munim Khan: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.
Md. Atiqual Islam: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.
Rayhan Uddin, Pranti Barua, Md. Habibur Rahman Talukder: Analyzed and interpreted the data; Wrote the paper.
Md. Abul Kalam, Nabil Nawrose Baishakh: Performed the experiments; Wrote the paper.
Iftekhar Ahmad: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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