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# Comparative Analysis of Biochemical Compositions and Quality Attributes of Green Tea and Black Tea from Prominent Bangladeshi Brands

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## ABSTRACT

Tea is the most widely consumed non-alcoholic beverage in the world, valued for its economic significance and health benefits, largely attributed to its polyphenolic compounds with potent antioxidant properties. The purpose of this research is to assess the chemical composition and quality of green and black tea products available in the Bangladeshi market. Samples were collected from five leading brands of each type: black tea brands included Ispahani, Kazi & Kazi, Jafflong, Halda Valley, and Seylon, while green tea brands comprised Ispahani, Kazi & Kazi, Jafflong, Halda Valley, and Lipton. The analysis focused on proximate compositions, total phenols, flavonoids, DPPH radical scavenging activity, caffeine levels, theaflavins (TF), thearubigins (TR), high polymerized substances (HPS), and total liquor color (TLC). A comparative analysis of green tea and black tea reveals significant differences in their chemical compositions and potential health benefits. Green tea boasts a higher phenolic content, ranging from 72.94 to 75.68 mg GAE/g, and exhibits greater antioxidant activity, with DPPH (2,2-diphenyl-1-picrylhydrazyl) values between 91.29 to 96.55 ml Trolox/g, compared to black tea, which has phenolic content of 66.21 to 67.32 mg GAE/g and DPPH values of 79.84 to 87.73 ml Trolox/g. Conversely, black tea contains higher levels of caffeine (31.95 to 37.36 ppm), flavonoids (63.70 to 67.78 mg QE/g), and tannins (14.02 to 17.36 mg TAE/g) than green tea, which has caffeine levels of 25.18 to 28.41 ppm, flavonoid content of 27.17 to 37.80 mg QE/g, and tannin content of 5.87 to 7.21 mg TAE/g. The analysis indicates that black tea has higher concentrations of theaflavins, thearubigins, highly polymerized substances, and total liquor color compared to green tea, contributing to its distinctive flavor and appearance. While the moisture, ash, and lipid levels in both tea varieties are comparable, showing only minor differences, the research emphasizes the unique biochemical profiles of each type. Green tea is noted for its greater levels of polyphenols and antioxidants, which enhance its health benefits, whereas black tea is characterized by its higher caffeine content, making it a more stimulating beverage. These findings highlight the distinct qualities of green and black tea, suggesting that each may appeal to different consumer preferences and health needs.

## 1- Introduction

Tea (*Camellia sinensis* L.) is one of the most ancient beverages and enjoys worldwide popularity. Because tea plant farming requires a warm and humid environment, it primarily occurs in tropical and subtropical areas [1]. As a result, most tea is grown on large plantations in East Africa and Southeast Asia [2]. With its rich aroma and diverse flavors, tea consumption is deeply ingrained in the daily lives of millions, contributing significantly to the nation's economy and heritage. The collection of leaves marks the start of tea production, followed by their processing. During the stages of transformation, tea leaves undergo oxidative and hydrolysis reactions triggered by intrinsic enzymes present in the leaf cells (including polyphenol oxidase and peroxidase) [3]. Depending on the level of fermentation and processing methods, tea can be divided into six main categories: yellow, white, and green tea (not fermented), oolong tea (partially fermented), black tea (fully fermented), and dark tea (post-fermented) [4-5]. The production of black tea involves the oxidative polymerization of flavan-3-ols, facilitated by the enzyme polyphenol oxidase. This process results in the creation of compounds such as bisflavanols, theaflavins, thearubigins, and other oligomers. In contrast, green tea is made by quickly steaming or hot air-drying freshly picked leaves to deactivate polyphenol oxidase, thereby preventing fermentation. This method yields a dry and stable product while also contributing to the tea's vibrant green color due to the blanching effect from the steam or hot air exposure [6]. The quality of tea, influenced by a myriad of factors such as geographical origin, climate, soil conditions, cultivation practices, and processing methods, plays a crucial role in determining consumer satisfaction and market competitiveness [7].

Catechins are the most prominent and biologically active compounds in green tea, almost all of which are extracted during the tea brewing process. Catechins and flavonol glycosides, the main contributors to the bitterness and astringency, displayed similar distribution patterns as polyphenols. It offers a range of health benefits, such as antioxidant, anti-inflammatory, and potential anticancer properties [8]. On the other hand, black tea, distinguished by the presence of theaflavins and thearubigens, enhances cardiovascular health and supports the immune system. More than 75% of catechins are converted into complex polymers like theaflavins (TFs), thearubigins (TRs), and asinensins (TSs) during the fermentation process, which is the primary step in the manufacturing of black tea [9]. With their distinct compositions and health-promoting qualities, both types enhance general well-being. Approximately 4000 bioactive chemicals have been found in tea, of which 33% are polyphenols, with catechins making up the majority of these compounds. Additionally, there are other chemical components such as volatile organic molecules, proteins, carbohydrates, proteins, alkaloids, and trace elements [10]. Teas and tisanes differ significantly in their polyphenol profiles, which could help to explain some of their various potential biological activities. These include effects that are anti-obesity, antiviral, antimutagenic, antimicrobial, anticarcinogenic, antiosteoporotic, antioxidant, antiatherosclerotic, antiallergic, antifibrotic, hypolipidemic, and hypocholesterolemia) [11-17].

Tea was transformed into different products or ingredients utilized in food processing. Tea-flavored foods satisfy consumer demand for green products while also providing





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combined benefits for nutrition enhancement and overall human health. Tea powder or ground tea can be directly made into tea bags, whether for instant use or as ready-to-drink (RTD) options. Additionally, numerous studies have indicated that tea extracts or powder are commonly utilized in bread, noodles, biscuits, ice cream, bars, and even in animal feed [18-22]. Tea-based food products, being a significant application, have contributed greatly to enhancing food safety and diversity.

Understanding the biochemical composition and quality attributes of commercially available green and black tea in Bangladesh is vital for ensuring consumer confidence and promoting trade. As tea holds significant cultural importance in the country, consumers must trust that the products they purchase meet quality standards and offer the associated health benefits. Additionally, a thorough understanding of the specific compounds in Bangladeshi teas, such as catechins and flavonoids, can enhance their positioning in the global market, attracting both domestic and international investment. However, there is a notable lack of comprehensive studies assessing the biochemical composition and quality parameters of these teas, which hinders informed decision-making among stakeholders. Therefore, conducting detailed scientific research to evaluate the biochemical makeup and qualitative characteristics of green and black tea in Bangladesh is essential. This study aims to fill the existing information gap, ultimately supporting the development of high-quality tea products that align with both local and international standards and contribute to the sustainable growth of the tea industry.

## 2-Materials and Methods

### 2.1 Chemical and reagents

For several experiments, the analytical grade reagents listed below such as Sodium Carbonate ($Na_2CO_3$), Gallic Acid ($C_7H_6O_5$), Hydrochloric Acid (HCl), Folin-Ciocalteau Reagent, Sodium Hydroxide (NaOH), Sodium Nitrite ($NaNO_2$), Aluminum Chloride ($AlCl_3$), Vanillin ($C_8H_8O_3$), DPPH ($C_{18}H_{18}N_5O_6$), Sodium Dihydrogen Phosphate Dihydrate ($NaH_2PO_4 \cdot 2H_2O$), Potassium Ferricyanide ($K_3[Fe(CN)_6]$), Ferric Chloride ($FeCl_3$), Disodium Hydrogen Phosphate Dihydrate ($Na_2HPO_4 \cdot 2H_2O$), Trichloroacetic Acid ($CCl_3COOH$), Ferrous Sulfate Heptahydrate ($FeSO_4 \cdot 7H_2O$), Sulfuric Acid ($H_2SO_4$), 3,5-Dinitrosalicylic Acid ($C_7H_4N_2O_5$), Phenol ($C_6H_5OH$), Sodium Potassium Tartrate ($KNaC_4H_4O_6$), and Ethyl Alcohol (Ethanol, $C_2H_5OH$) were purchased from Merck (Darmstadt, Germany).

### 2.2 Samples collection

Different brands of tea samples (5 green tea and 5 black tea samples) were collected from the markets of Dhaka & Chittagong, Bangladesh. The selection was done based on brand popularity and overall availability across the country. The names of the collected samples have been given below:

**Table 1: Black Tea and Green Tea samples**



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| Black Tea Samples | Green Tea Samples |
|---|---|
| Ispahani | Ispahani |
| Kazi and Kazi | Kazi and Kazi |
| Jafflong | Jafflong |
| Halda Valley | Halda Valley |
| Seylon | Lipton |

### 2.3 Preparing a solvent extract for the assessment of antioxidant activity and polyphenol content

Halim *et al.* [23] investigated an approach to extracting phenolic compounds from samples involving modifications. 19 mL of 100% ethanol was used to dissolve 1 gram of each sample. 1 hour of stirring at room temperature was performed using a magnetic stirrer (VS-130 SH, Korea) at a rotational speed of 1000 rpm. The filtered slurries were then passed through Whatman filter paper (No. 41) samples were preserved at -4°C for further use.

### 2.4 Determination of proximate composition

The proximate composition of the samples was determined using the methods described by Akhter *et al*. [24]. The moisture level was determined by putting 5 g of the sample in an oven (Model, ED 56, Tuttlingen, Germany) at 105°C for 24 hours or more and recording the weight loss as a percentage. The ash content was determined by incinerating at 550°C in a muffle furnace. The ash content was expressed as the percentage ratio of the sample weight to the ash weight. The lipid content in all analyzed samples was assessed using the method described by [25].

### 2.5 Estimation of theaflavin (TF), thearubigin (TR), highly polymerized substances (HPS), and total liquor color (TLC)

A hot plate was used to steep 2 grams of untreated tea samples in 90 mL of boiling water for 10 minutes. The brew was filtered and then transferred to a 100 ml flask, with hot water added. The study examined the quality of tea using spectrophotometry analyzing parameters like theaflavins (TF), thearubigins (TR), highly polymerized substances (HPS), and total liquor color (TLC) [26].

### 2.6 Determination of total phenolic content (TPC)

The total phenolic content (TPC) was determined using the modified Folin-Ciocalteu method [27]. The absorbance of the supernatant was read at 725 nm (UV-1800 UV/Vis, Shimadzu, Japan). The TPC was expressed using milligrams of gallic acid equivalents (mg GAE) per g of sample.

### 2.7 Determination of total flavonoid content (TFC)

TFC was determined using the colorimetric method with some modifications as described by *Halim et al.* [28]. The absorbance was read at 510 nm (UV-1800 UV/Vis, Shimadzu, Japan). The TFC was expressed as mg Quercetin equivalents (mg QCE) per g of sample calculated from a standard curve for Quercetin.

### 2.8 Determination of tannin content

Using the Vanillin Hydrochloride Method, the samples' tannin content was ascertained [23]. Twenty minutes were spent incubating





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1 ml of the extracted material and 5 ml of vanillin hydrochloride. Next, at 500 nm, the absorbance was measured using a spectrophotometer. In milligrams of catechin equivalent per gram of dry extract, the tannin concentration was reported.

**2.9 Determination of antioxidant activity**

The free radical scavenging activity of the samples was determined using the Anika *et al.* [29] technique. Initially, 40 minutes were spent stirring a solution of 1 mM DPPH in 80% (v/v) methanol. 80% (v/v) methanol was used to adjust the solution's absorbance to 0.650 nm at 515 nm. Following the appropriate vortexing, 50 µl of the extracted sample was combined with 1.90 ml of 0.1 mM DPPH. For thirty minutes, the mixture was then left in the dark. At 515 nm, the absorbance was then measured. The blank in this case was methanol. Percentage inhibition of the DPPH radical was used to express the antioxidant activity. The following equation was used to calculate it:

DPPH scavenging capacity (%) = (A control-A sample)/ (A control) ×100 [An absorbance at 515 nm]

**2.10 Statistical analysis**

Every experiment was repeated three times, obtaining mean values and standard deviations. The experimental results were statistically analyzed using a one-way analysis of variance to ascertain the statistically significant differences between various formulations at a 95% confidence level (ANOVA). Duncan's multiple range test ($p<0.05$) was employed to assess the significance of the mean differences. The statistical analyses were all performed with SPSS 22.0.

## 3-Results and Discussion

**3.1 Moisture, dry matter, lipid, and ash content of black tea and green tea samples**

Controlling the moisture content of materials from the introduction of the raw materials to the packing of the finished product is essential for maximizing efficiency, optimizing yield, and producing a high-quality, consistent output [30-32]. In comparison to the other samples of black tea (Seylon) revealed that it had a higher moisture content while green tea (Lipton) had a noticeably higher moisture content. Based on Table 2's data, that suggests an average stable phenomenon. Since more polyphenols that help retain moisture content are destroyed during the fermentation process, which is excluded when processing black tea, this may be the cause of the higher moisture content in green tea samples. Our results are similar to those of Makanjuola [33], who found that black tea had a moisture content of 3.9-9.5%. Every tea sampled for this study had a moisture content of less than 7.35-10.61%, making it appropriate for a longer shelf life [34]. The use of packing materials to keep commercial tea samples at a consistent moisture level while they are being stored is another crucial element; hence, the moisture content of commercial tea is a crucial indicator of quality. The lower water content in all samples suggested enhanced stability and longer shelf-life due to the lowered possibility for the growth of microbes as well as better stability towards chemical and physical reactions [35].

The ash content of tea significantly impacts its quality. There is a correlation between the mineral and moisture content of a sample and the ash content of tea. According to Faramayuda *et al.* [36], mineral content quantifies the amount of physiological ash, which comes from the plant tissue itself, and non-physiological ash, which is the leftover material that sticks to the plant surface. Table 2 presents the ash content percentages of





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various black and green tea samples, indicating the mineral content and overall quality of each tea. For black tea, the highest ash content is found in the Jafflong sample (6.36%), while the lowest is in Halda Valley (5.48%), with other samples like Ispahani, and Kazi and Kazi showing similar values of around 5.9%. In the green tea category, Jafflong again has the highest ash content (6.22%), and Halda Valley has the lowest (4.73%), with Ispahani, Kazi and Kazi, and Lipton showing lower values between 4.83% and 5.20% respectively. Tea may have less moisture, which would explain the increased ash content. A lower ash percentage in tea could be because tea is produced by adulterating extracted raw materials, resulting in a lower-quality tea. As suggested by earlier studies, ash levels should be kept below 5.54% to preserve tea quality while it is being stored. These findings also showed a favorable correlation between ash content and maintaining tea quality [37].

Lipid is recognized as a significant field in biochemical research since it serves as both a structural and storage element in plant tissues. Neutral lipids, glycolipids, and phospholipids, which form the lamellae fractions or various cell membranes in chloroplasts of leaves, are broken down by acyl hydrolases into free fatty acids. Variations in fatty acids across different molecular species could significantly influence the assessment of cultivars with enhanced tea-making capabilities. Due to differences in withering intensity, rolling method, and particle size in orthodox processing [38]. Lipid constitutes a significant part of the fresh tea leaf. Table 2 shows the lipid levels in black tea samples, which ranged from 4.43±0.74% to 4.73±0.97%. Jafflong black tea exhibited the highest lipid level at 4.73%, whereas Jafflong green tea leaves displayed the most significant lipid content among green teas at 4.84%. These findings correspond with prior research by [39], which discovered that teas in Pakistan had fat content ranging from 4% to 7%, and also stated that teas from Bangladesh had fat levels between 6% and 9%. Additionally, Kodagoda and Wickramasinghe [40] noted that both green and black teas contain lipid 3%. Furthermore, Hosen *et al.* [41] supported these results by indicating that the lipid content of protoplasm may represent 3% to 7% of its dry weight, highlighting the importance of fat content in evaluating tea quality.

**Table 2: Moisture, dry matter, lipid, and ash content in black tea samples**

| Sample | Moisture (%) | Dry matter (%) | Lipid (%) | Ash (%) |
|---|---|---|---|---|
| **Black tea** | | | | |
| Lipton | 10.61±0.72$^{a}$ | 90.40±0.72$^{b}$ | 4.274±0.89$^{a}$ | 4.85±0.41$^{b}$ |
| Ispahani | 7.35±0.23$^{c}$ | 92.64±0.23$^{a}$ | 4.62±1.24$^{a}$ | 5.97±0.17$^{a}$ |
| Kazi and Kazi | 7.20±0.46$^{c}$ | 92.79±0.46$^{a}$ | 4.43±0.74$^{b}$ | 5.81±0.24$^{a}$ |
| Jafflong | 9.05±0.82$^{a}$ | 90.94±0.82$^{b}$ | 4.73±0.97$^{a}$ | 6.36±0.31$^{a}$ |
| Halda Valley | 8.00±0.37$^{b}$ | 92.02±0.37$^{a}$ | 4.50±0.83$^{b}$ | 5.48±0.17$^{a}$ |
| Seylon | 9.16±0.92$^{a}$ | 90.83±0.92$^{b}$ | 4.58±1.12$^{b}$ | 5.604±0.53$^{a}$ |
| **Green tea** | | | | |
| Ispahani | 7.50±0.51$^{b}$ | 92.50±0.51$^{b}$ | 4.40±0.87$^{a}$ | 5.20±0.12$^{b}$ |
| Kazi and Kazi | 10.47±0.21$^{a}$ | 89.52±0.21$^{b}$ | 4.79±0.91$^{a}$ | 4.83±0.17$^{b}$ |
| Jafflong | 7.60±0.37$^{b}$ | 92.40±0.37$^{a}$ | 4.84±1.05$^{a}$ | 6.22±0.21$^{a}$ |
| Halda Valley | 10.01±0.41$^{a}$ | 90.00±0.41$^{b}$ | 4.621±0.97$^{a}$ | 4.73±0.37$^{b}$ |





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Values are the Mean ± standard deviation of three replicates. [a-c] Different superscript alphabets indicate significant differences among the black tea and green tea samples (p <0.05).

### 3.2 Caffeine content in black tea and green tea samples

The amount of caffeine in tea is quite significant due to its potential health implications and its effect on the sensory experience associated with drinking tea. Additionally, caffeine content is a crucial factor in evaluating commercial tea products. This research aims to investigate the caffeine levels in different samples of green and black tea to better understand the variations in caffeine concentration across various tea types. The caffeine levels in the black tea samples ranged from 31.95±1.28 ppm to 37.36±1.89 ppm, while the green tea samples exhibited caffeine concentrations between 25.18±1.21 ppm and 28.41±0.73 ppm (Table 3). Importantly, the caffeine levels in black tea are associated with its quality, as they contribute to the formation of vibrant precipitates during the brewing process. The highest caffeine level was observed in green tea sourced from Halda Valley, measured at 37.36±1.89 ppm. The results of this study are consistent with previous research conducted by Shokrzadeh *et al.* [42]. Furthermore, the findings align with those of Adnan et al. (2013), who suggested that to ensure superior product quality, the caffeine level in commercial tea should be limited to below 4%. Various factors influence the caffeine levels in black teas, including the specific tea variety, the timing of leaf harvesting, the season, and the geographical region. Additionally, harvesting later and using older leaves in commercial tea production may also affect caffeine content [37].

**Table 3: Caffeine content in black tea and green tea samples**

| Black tea samples | Caffeine (ppm) | Green tea samples | Caffeine (ppm) |
|---|---|---|---|
| Ispahani | 31.95±1.28$^{b}$ | Ispahani | 26.37±1.37$^{b}$ |
| Kazi and Kazi | 35.51±1.32$^{b}$ | Kazi and Kazi | 27.91±1.89$^{b}$ |
| Jafflong | 32.86±2.40$^{b}$ | Jafflong | 26.67±1.94$^{b}$ |
| Halda Valley | 37.36±1.89$^{a}$ | Halda Valley | 28.41±0.73$^{a}$ |
| Seylon | 33.72±2.97$^{b}$ | Lipton | 25.18±1.21$^{b}$ |

Values are the Mean ± standard deviation of three replicates. [a-c] Different superscript alphabets indicate significant differences among the black tea and green tea samples (p <0.05).

### 3.3 TF, TR, HPS, and TLC content in black tea and green tea samples.

Different samples of black and green tea showed differences in the concentrations of the following: total liquor color (TLC), highly polymerized substances (HPS), theaflavin (TF), and thearubigin (TR). Among the black tea samples, the highest TF content was detected in Kazi and Kazi (1.029%), while the lowest TF content was found in Jafflong (0.875%). Similarly, among the green tea samples, Halda Valley exhibited the highest TF content (0.520%), whereas Ispahani had the lowest (0.22%) (Table 4). These discrepancies in TF levels are likely influenced by factors such as tea variety, elevation, local cultivation practices, and processing methods. Chy *et al.* [43] noted that TF content in black tea typically ranges from 0.3% to rarely exceeding 2%, aligning with our findings. The attractive color of tea infusion is linked to TF, which acts as a vital quality measure of black tea and significantly contributes to producing premium tea. Hazra *et al*. [44] noted that the hue of tea is an important factor that can attract and increase value for consumers. Moreover, the TR level was notably higher in the black tea sample from Kazi and Kazi (5.452%) compared to others. Increased TR content enhances the richness, intensity, and mouthfeel of the tea liquor, as supported by Khan *et al*. [26], who reported TR concentrations ranging from 2.32% to 6.25% in black tea samples. TR lowers the brightness of the tea liquid. The larger quantity of thearubigin mainly adds to the ashy flavor of the beverage, with a slight enhancement in astringency. TR affects the texture (thickness) and brownish color of the tea [19].

Highly polymerized substances (HPS) play a significant role in defining the body, strength, and color of tea beverages. In our study, the range of HPS content was 6.34% to 3.79% in black tea and 3.44% to 1.72% in green tea. This is consistent with the findings of Khan *et al.* [26], who reported HPS levels in black tea samples ranging from 3.70% to 7.21%. A highly polymerized substance is very effective in evaluating and classifying the quality of tea. Together with HPS, TR in tea liquor contributes to the color and mouth feel. Total liquor color (TLC), which encompasses TR, TF, and HPS, was highest in the black tea sample from Kazi and Kazi (4.61%). Alam *et al*. [45] assessed different tea brands in Bangladesh and found results consistent with our study. The total liquor color in Indian black tea was observed by Someswararao *et al.* [46] to range between 3.89% and 5.7%, which is in good agreement with our results. Furthermore, as particle size increased, concentrations of TF, TR, HPS, and TLC also increased. This phenomenon can be attributed to finer tea grades having a larger surface area, facilitating greater oxidation of catechins and the production of TF, TR, HPS, and TLC, thereby enhancing extraction during brewing. TF, TR, HPS, and TLC exhibit a multitude of health advantages, such as aiding in fat reduction and blood sugar regulation, as well as offering protection against lifestyle-related illnesses including obesity, cancer, atherosclerosis, inflammation, viral and bacterial infections, osteoporosis, and dental caries [47-49].

**Table 4:TF, TR, HPS, and TLC content in black tea and green tea samples**

| **Black Tea Samples** | **TF (%)** | **TR (%)** | **HPS (%)** | **TLC (%)** |
|---|---|---|---|---|
| Ispahani | 0.92±0.27$^{b}$ | 5.11±1.31$^{a}$ | 4.25±1.43$^{b}$ | 3.02±0.62$^{b}$ |
| Kazi and Kazi | 1.02±0.19$^{a}$ | 5.45±1.08$^{a}$ | 4.36±1.29$^{b}$ | 4.61±0.48$^{a}$ |
| Jafflong | 0.87±0.32$^{b}$ | 4.84±2.19$^{a}$ | 6.34±1.72$^{a}$ | 2.56±1.07$^{b}$ |
| Halda Valley | 1.01±0.17$^{a}$ | 4.95±0.89$^{a}$ | 5.23±0.98$^{b}$ | 3.21±0.91$^{b}$ |
| Seylon | 0.98±0.51$^{b}$ | 3.21±1.51$^{b}$ | 3.79±1.86$^{b}$ | 2.95±1.13$^{b}$ |
| **Green Tea Samples** | **TF (%)** | **TR (%)** | **HPS (%)** | **TLC (%)** |
| Ispahani | 0.22±0.15$^{a}$ | 2.07±1.81$^{a}$ | 2.21±1.21$^{b}$ | 4.13±0.44$^{b}$ |
| Kazi and Kazi | 0.51±0.18$^{a}$ | 2.73±1.05$^{a}$ | 2.33±1.22$^{b}$ | 5.22±0.36$^{a}$ |
| Jafflong | 0.22±0.41$^{a}$ | 1.76±2.12$^{b}$ | 3.44±1.77$^{a}$ | 1.78±1.00$^{c}$ |
| Halda Valley | 0.52±0.11$^{a}$ | 1.95±0.51$^{a}$ | 2.28±0.60$^{b}$ | 3.25±0.80$^{b}$ |
| Lipton | 0.29±0.11$^{a}$ | 1.84 ±2.50$^{b}$ | 1.72±1.82$^{c}$ | 2.51±1.19$^{b}$ |

Values are the Mean ± standard deviation of three replicates. $^{a-c}$ Different superscript alphabets indicate significant differences among the black tea and green tea samples ($p < 0.05$)

### 3.4 Bioactive compounds and antioxidant activity of black tea and green tea samples

Tea is a popular beverage to drink all around the world, and its nutritional worth is being researched as a possible way to enhance other





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nutritional attributes. Therefore, knowledge regarding its nutritional evaluation is practically necessary for both tea promoters and final consumers. A few of these have been taken into consideration in the current effort. Tea's antioxidant properties are attributed to several bioactive secondary metabolites, making it a potential source of antioxidant supplements. The antioxidant characteristics of tea polyphenols are responsible for their beneficial benefits. Table 5 displays the total phenol and flavonoid, tannin, and DPPH concentrations of green and black tea types.

The relationship between phenolic content and antioxidant activity in plants is strong and significant. Phenolic compounds can scavenge a variety of oxidizing free radicals, such as hydrogen peroxide, hydroxyl radicals, singlet oxygen, and more, since they are efficient reducing agents and hydrogen donors. Phenolic compounds are useful tools in the battle against oxidative stress and its harmful effects on the body because of their capacity to neutralize and combat oxidative free radicals, which greatly increases their antioxidant activity [50]. The total phenolic content in black tea samples varied from 63.64±0.81 to 67.32±0.58 mg GAE/g, while in green tea samples, it varied from 72.94±0.47 to 75.68±0.37 mg GAE/g. The present values are less than those mentioned by Zhao et al. (2019). They assessed the total phenol content in black tea, which varied from 37.23 ± 0.28 to 101.29 ± 1.58 mg GAE/g, and in green tea, it ranged from 148.16 ± 2.72 to 252.65 ± 4.74 mg GAE/g. This result was consistent with the study conducted by Abdullah & Mazlan [51], which showed that all green tea samples had greater phenolic content than those of herbal teas. Additionally, factors affecting catechin levels include the cultivation area, the surrounding environment, and the initial processing of the leaves before drying. Furthermore, the general composition of the teas is greatly influenced by the season, climatic conditions, and the maturity of the tea leaves.

The flavonoid content in tea is a key indicator of its antioxidant capacity, with significant variations observed between black and green tea samples. In black tea, flavonoid content ranged from 63.60 ± 1.03 to 67.78 ± 0.53 mg QE/g in Halda Valley. Specifically, Ispahani contained 63.60 ± 1.03 mg QE/g, Kazi and Kazi 65.14 ± 0.23 mg QE/g, Jafflong 64.53 ± 0.40 mg QE/g, and Halda Valley had the highest at 67.78 ± 0.53 mg QE/g. In contrast, the flavonoid content in green tea samples showed more variability. Ispahani green tea contained 31.87 ± 1.38 mg QE/g, Kazi and Kazi 32.67 ± 1.44 mg QE/g, Jafflong 33.67 ± 1.22 mg QE/g, Halda Valley the highest at 37.80 ± 1.28 mg QE/g, and Lipton the lowest at 27.17 ± 1.52 mg QE/g. These results indicate that black tea generally has higher flavonoid content, contributing to its antioxidant properties. Our findings partially corroborate Nhu-Trang *et al.* [52], who reported that black tea extracts have the highest total flavonoid content, followed by green tea. The variations in flavonoid content between black and green tea samples underscore the influence of processing techniques and intrinsic differences in the tea leaves. The higher flavonoid content in black tea may be attributed to the fermentation process, which enhances certain polyphenolic compounds. In contrast, the lower flavonoid content in green tea is likely due to the minimal oxidation it undergoes, preserving different sets of polyphenols. Ullah *et al.* [53] noted that flavonoids are believed to be responsible for antioxidant activity, anticarcinogenic effects, and anti-arteriosclerosis benefits.

The tannin content in tea plays a significant role in determining its taste profile and potential health benefits, with notable



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variations observed among different tea samples. In our analysis, the tannin content was measured in milligrams of tannic acid equivalents per gram (mg TAE/g). Among the black tea samples, Ispahani exhibited a moderate tannin content of 14.02 ± 1.03 mg TAE/g, while Kazi and Kazi showcased a slightly higher level at 14.37 ± 1.03 mg TAE/g. Jafflong tea, on the other hand, displayed a lower tannin content of 13.16 ± 1.43 mg TAE/g, providing a potentially smoother taste experience. Halda Valley black tea stood out with the highest tannin concentration at 17.36 ± 0.02 mg TAE/g. In green teas, Ispahani featured a lower tannin content of 5.87 ± 0.01 mg TAE/g compared to its black tea counterpart. Kazi and Kazi's green tea displayed a slightly higher tannin concentration at 6.26 ± 1.10 mg TAE/g, while Jaflfong's offering mirrored this profile at 6.04 ± 0.02 mg TAE/g. Halda Valley's green tea had the highest tannin content among the green teas at 7.21 ± 0.01 mg TAE/g. Lipton green tea had a moderate tannin content at 6.70 ± 0.12 mg TAE/g. As such, tea's color is significantly influenced by the amount of tannin in it. The quantity of tannins in tea is directly correlated with its blackness, as mentioned by Piyasena *et al.* [54]. To explain it simply, darker-colored teas have more tannin in them. Many plant-based meals and beverages, including tea, include tannins, which are polyphenolic chemicals. The unique bitterness and astringency of black tea are attributed to tannins. The industrial processes used to produce black tea are mostly responsible for its greater tannin content. Tea leaves are subjected to rolling, oxidation, and withering to produce black tea. Tea leaves develop and accumulate tannins as a result of various processes, most notably oxidation. According to these findings, the flavor and possible health advantages of various tea kinds are influenced by the varied tannin profiles found in them.

An antioxidant molecule is characterized as a compound that can prevent or reduce the oxidation of biomolecules, even in minimal amounts. These antioxidants are essential in protecting food and plants from deterioration caused by oxidation and shielding the body's biomacromolecules from oxidative damage. Evaluating the antioxidant capacity in food and plants is highly important [55-56]. To evaluate the antioxidants' capacity to scavenge free radicals, DPPH assays are frequently used as methods. Rahman *et al.* [32] point out that the DPPH radical's ability to scavenge free radicals stems from its propensity to decolorize in the presence of antioxidants. The results have shown that the antioxidant activity levels were significantly higher in green tea (91.29±0.75 to 95.47±0.94 ml Trolox/g) compared to those of black tea (79.84±0.93 to 87.73±1.04 ml Trolox/g). Similar results were reported in earlier studies [57]. The higher antioxidant activity is due to the potent antioxidant activities of catechins in green tea which are due to their three adjacent hydroxyl (OH) groups on the β-ring as in epigallocatechin gallate (EGCG), gallocatechin gallate (GCG), epigallocatechin (EGC) and gallocatechin (GC) which are more effective in scavenging free radicals than the two adjacent OH groups as in catechin gallate (CG) and epicatechin (EC). The content of EGCG and EGC in green tea is much higher than in black tea [58]. Nevertheless, the antioxidant effectiveness of catechins relies not only on their chemical structure but also on the surrounding environmental conditions [59].

In the case of black tea, antioxidants found in black tea include catechins and their derivatives, along with theaflavin and thearubigin, which are produced through enzymatic oxidation and impart color to the infusion of black tea. The aromatic component additionally acts as an antioxidant in black tea. Carotenoids, fatty acids, glycosides, and amino acids act as fundamental components in the formation of aroma compounds in tea, and their concentrations are affected by the processing techniques. Some examples of aroma compounds with amino acid or carbohydrate precursors are (E)-2-Hexenal, Hexanal, Hexanoic acid, (Z)-3-Hexen-1-ol, (E)-Linalool oxide (furanoid), and phenylacetaldehyde. All of these components exist in larger amounts in black tea compared to green tea [60-61].

**Table 5: Bioactive compounds and antioxidant activity of black te and green tea samples**

| **Black tea sample** | Total Phenol (mg GAE/g) | Total Flavonoid (mg QE/g) | Tannin (mg TAE/g) | DPPH (ml Trolox/g) |
|---|---|---|---|---|
| Ispahani | $63.64\pm0.81^{b}$ | $63.60\pm1.03^{b}$ | $14.02\pm0.01^{b}$ | $80.29\pm0.73^{c}$ |
| Kazi and Kazi | $67.32\pm0.58^{a}$ | $65.14\pm0.23^{b}$ | $14.37\pm0.03^{b}$ | $85.43\pm0.92^{b}$ |
| Jaflong | $64.21\pm0.95^{b}$ | $64.53 \pm 0.40^{b}$ | $13.16\pm1.43^{b}$ | $87.73\pm1.04^{a}$ |
| Halda valley | $66.30\pm0.37^{a}$ | $67.78 \pm 0.53^{a}$ | $17.36\pm0.03^{a}$ | $84.13\pm0.87^{b}$ |
| Seylon | $66.22\pm1.2^{a}$ | $63.70\pm1.19^{b}$ | $15.30\pm0.02^{b}$ | $79.84\pm0.93^{c}$ |
| **Green tea sample** | | | | |
| Ispahani | $72.63\pm0.49^{b}$ | $31.87\pm1.38^{b}$ | $5.87\pm0.01^{c}$ | $93.32\pm1.39^{b}$ |
| Kazi and Kazi | $74.48\pm0.86^{a}$ | $32.67\pm1.44^{b}$ | $6.26\pm1.10^{b}$ | $96.55\pm1.02^{a}$ |
| Jafflong | $73.08\pm1.07^{b}$ | $33.67\pm1.22^{b}$ | $6.04\pm0.02^{b}$ | $92.46\pm0.98^{b}$ |
| Halda valley | $75.68\pm0.37^{a}$ | $37.80\pm1.28^{a}$ | $7.21\pm0.01^{a}$ | $95.47\pm0.94^{a}$ |
| Lipton | $72.94\pm0.47^{b}$ | $27.17\pm1.52^{c}$ | $6.70\pm0.12^{ab}$ | $91.29\pm0.75^{b}$ |

Values are the Mean ± standard deviation of three replicates. [a-c] Different superscript alphabets indicate significant differences among the black tea and green tea samples ($p < 0.05$).

## 4-Conclusion

This study investigated the antioxidant potential and active component profiles of five marketed brands of green and black tea in Bangladesh. The results revealed significant differences in the concentrations of key bioactive compounds among the brands analyzed. Notably, the levels of total phenols, DPPH radical scavenging activity, theaflavins, thearubigins, and highly polymerized substances were assessed, revealing that Kazi and Kazi tea exhibited the highest overall quality among the brands analyzed. This suggests that Kazi and Kazi tea may offer superior health benefits compared to other brands. In contrast, Halda Valley tea was noted for its highest caffeine content, which may cater to consumers seeking a stronger stimulant effect. Other brands, including Jafflong, Ispahani, and Lipton, also demonstrated adequate nutritional value, indicating a diverse range of options available to consumers in the Bangladeshi tea market. These findings emphasize the importance of brand selection in optimizing the health benefits associated with tea consumption. The notable variations in antioxidant properties and active components highlight the necessity for consumers to be informed about the quality of the tea they choose. Future research should continue to explore the health implications of these findings and the potential for enhancing the antioxidant profiles of tea through processing methods.

## 5-Data Availability

The datasets analyzed during the current study are available from the corresponding author upon reasonable request.





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## 6-Conflict of interest

The authors have no conflicts of interest to disclose that are compatible with the subject matter of this article.

## 7-Consent to participate

All authors have expressed their authorization to engage in this publication.


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## 9-Author Contributions

**Md. Ashraful Islam:** Formal analysis, Investigation, Supervision, Methodology, Software, writing – original draft. **Fahriha Nur A Kabir:** Writing – review & editing. **Sourav Biswas Nayan:** Writing – review & editing. **Anwara Akter Khatun:** Writing – review & editing, **Adrita Afrin:** Writing – review & editing, **Md. Shohel Rana Palleb:** Software, writing – review & editing & **Md. Abdul Halim:** Conceptualization, Formal analysis, Investigation, Supervision, Methodology, Software, writing – original draft, Writing – review & editing.

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