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Screening for the active components of seven marketed brands of Shaw Wallace tea produced in Bangladesh

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Abstract
Seven different marketed brands of Shaw Wallace tea available in the local markets of Bangladesh *viz*, Premium Tea Bag, Super Clone, Danadar, Golden leaf, Hotel Special, Shah bag BOP, Fine Dust were studied before expiry dates to screen out their qualitative status of [*viz*; Caffeine, Total Polyphenol (TP), Antioxidant activity (AA), Theaflavin (TF), Thearubigin (TR), Theabrownin (TB), Highly polymerized substances (HPS), Total liquor color (TLC),The Briskness index (BI), Color index (CI), Total Catechin (TC) and nutrient contents N, P, K, Ca, Na And Fe]. All Studied parameters were found to have been varied among the teas of Shaw Wallace brand. The values of Caffeine and TP were found to be varied from 3.98 % (Premium Tea bag) to 5.5% (BOP) and 37.50% (Danadar) to 32.09% (Fine Dust) respectively. Similarly, the estimated values of TF, TR, TB, TC and TLC were detected to be maximum (1.18%, 15.76%, 12.91%, 5.17% and 5.4) in Premium tea and Danadar tea but HPS and BI contents were found to be (5.27% and 21.40) maximum in Hotel special and BOP respectively. In case of Antioxidant activity (AA), the maximum value (88.80) was gained in Golden leaf and minimum value (86.67%) in Premium tea bag. On the contrary, CI was found to be the highest (7.12) in Golden Leaf and the lowest (4.89) in Fine Dust. In Considering the total amount of Nutrient Contents (sum of N, P, K, Ca, Na and Fe), the highest value was also estimated to be 9.045% in Danadar tea and the lowest value was 7.28% in Fine Dust tea. The highest average value of N and K contents were found to be 5.14% and 2.05% in Danadar tea whilst the lowest average value of N and K contents were found to be 4.52% and 1.55% in Fine Dust tea respectively. Similarly, maximum average value of Na and Ca contents determined to be 0.17% and 1.37% in Danadar tea whereas minimum average value of Na and Ca contents were determined to be 0.95% and 0.07% in Fine Dust tea respectively. In case of P and Fe content, the highest average value was detected to be 0.28% in Premium tea bag and 0.055% in Danadar Tea even as the lowest average value was detected to be 0.17% and 0.029% in Fine Dust tea respectively. The Present study concludes that Danadar tea was revealed to be superior over the other brands and all the studied brands may therefore, be ranked as: Danadar tea > Premium tea Bag > BOP tea > Super Clone Tea > Golden Leaf tea > Hotel Special tea > Fine Dust tea.

Keywords: screening, active components, nutrient elements, shaw wallace, Bangladesh

Introduction

Tea stands as the second most consumed non-alcoholic beverage around the world (Sharangi *et al*., 2014) [1]. Tea is derived from terminal three leaves of shoots of tea plant *Camellia sinensis* (L.) O. Kuntze (syn. *Thea sinensis* L.) family Theaceae and it is an evergreen flowering plant (Hampton, 1999) [2]. For thousands of years, people have used tea as a long-term beverage in long-term drinking without any toxicity or allergies, which reveals that a variety of biochemical substances, such as polyphenolic catechins and methylxanthine caffeine are safe to humans (Vancouver, 2011) [3].

Caffeine ($C_8H_{10}O_2N_4$) is an important alkaloid. Tea and coffee are largely used as popular drink where caffeine is one of the most desired components. Caffeine is a pharmacologically active substance and depending on the dose, can be a mild central nervous system stimulant. It imparts bitterness and also acts as a flavour constituent (Leo, 1992) [4]. The polyphenols constitute the most interesting group of tea leaf components and exhibit potent antioxidant activity *in vitro* and *in vivo* (Wu *et al*., 2002) [5]. Tea has been considered a medicine and a healthful beverage since ancient times, but recently it has received a great deal of attention because tea polyphenols are strong antioxidants. Tea polyphenols or tea tannin plays an important role in the colours, briskness and taste and therefore is considered to be important for the quality of black tea. Among all tea polyphenols, especially catechins and gallic acid have been considered to be the main players in these beneficial effects on the human health. Tea flavanols are a group of natural polyphenols found in green and black tea. Four flavanol derivatives are found in tea: The major tea catechins are (-) epigallocatechin gallate (EGCG),

(-) epigallocatechin (EGC), (-)-epicatechin gallate (ECG), and (-)-epicatechin (EC) (Ho *et al*., 1992) [6]. Their biological benefits are due to their strong antioxidant and anti-angiogenic activity as well as their potential to inhibit cell proliferation and modulate carcinogen metabolism (Yang *et al*., 2001) [7].

The most powerful antioxidant tea is green tea which is characterized by the presence of large amount of flavan-3-ols known as catechins.(-) Epigallocatechin-3-gallate (EGCG) is most abundant catechin in green tea and may occur up to 50% of the catechins by weight. Black tea is fully oxidized. The result of catechins oxidation is the formation of catechins dimers, known as theaflavins. These compounds are responsible for the color and taste and also a key factor in the antioxidant activity. The known *in vitro* antioxidant properties of catechins and other polyphenolic compounds in tea have led to interest in the potential health benefits of tea consumption (Frei and Higdon, 2003) [8].

Theaflavins (TFs) [$C_{29}H_{24}O_{12}$] the golden yellow pigment,constitute around 0.5%-2% of dry wt. depending on the type of manufacture of black tea. The attractive colour of the tea infusion is due to the aflavins and it emerges as an important quality index of black tea. TF are responsible for the development of the bright colour and brisk taste of the liquor. TF also provides briskness, freshness and aliveness to the infusion, which is highly valued in taster's parlance (Cloughley, 1980) [9].

Thearubigins (TRs), the orange-brown compounds constituting about 6 to 18% of dry weight are another important group of pigments formed during the processing of black tea but they do not occur in green tea. They are heterogeneous complexes and are responsible for taste, total colour and body of the liquor. They contribute around 35% of the total colour and also play a significant role in brown appearance of made tea (Hilton and Ellis, 1972) [10]. A good quality tea possessing brightness, briskness, and good colour and body may possess a ratio of theaflavins: thearubigins of 1:10 (Deb and Ullah, 2011) [11].

The thearubigins, on reaction with TF and proteins, from complex highly polymerized substances (HPS). Highly polymerized substances increase the colour of the brew. Total liquor colour (TLC) is the measure of brightness of the infusion (Deb and Ullah, 2011) [11]. Theabrownins are pigment compounds formed during oxidation of tea leaves. They dissolve easily in water and not in organic solvents like ethyl acetate. They are the main bioactive components in pu-erh tea, and are characterized by high molecular weight and complex structure. It is known that theabrownins are formed by oxidation of polyphenols (Muthumani and Kumar, 2006) [12].

So far the literature review is concerned; only a few comparative studies on the qualitative status of marketed brand teas of Bangladesh were done (Chowdhury and Alam, 2001; Alam *et al*., 2011, 2015) [13, 14, 15]. With this view in mind, in addition to those brands of tea, a laboratory experiment was done to screen out the comparative status of quality parameters viz; caffeine, TP, TF, TR, TB, TC, HPS, TLC, BI, CI as well as nutrient status (N, P, K, Ca, Na and Fe) in seven marketed brands of Shaw Wallace tea of Bangladesh.

Materials and Methods

Seven different marketed brands of Shaw Wallace tea namely Shaw Wallace super clone tea, Shaw Wallace Danadar tea, Shaw Wallace Hotel Special Tea, Shaw Wallace Shahbag BOP, Shaw Wallace Golden Leaf, Shaw Wallace Fine Dust, Shaw Wallace Premium Blend Tea Bag were collected from Bangladesh tea Expo 2017, Bashundhara Convention Centre, Dhaka and Shaw Wallace trade centre, Rashid Building, Agrabad, Chittagong, Bangladesh.

Determination of caffeine in tea samples

Tea samples were analyzed for Caffeine By the method Reported by Wanyika *et al.*, (2010) [16].

Calibration standards: Caffeine stock solution (1000 ppm) was prepared by dissolving 100.00 mg of pure caffeine in 100ml of distilled water. 0.10, 20, 40, 60 and 80 ppm caffeine working solution were prepared serial dilution of the stock in 25ml volumetric flasks with addition of 1.0 ml hydrochloric acid and tripping to the mark with distilled water.

Sample preparation and analytic determination: 0.25 g sample were accurately weighed and dissolved in water and made to the net volume of 20 ml with distilled water as sample solution. 20 ml sample solution were pipetted to 250 ml flask and 10 ml 0.01 mol/l hydrochloric acid, 2 ml basic lead acetate solution were then added and made to the mark with distilled water, shaken up and filtered to clarify. 50 ml filtered solution were pipetted and added to 100 ml flask, 0.2 ml 4.5 mol sulphuric acid were added and again made to the net volume with distilled water, shaken up and filtered. The absorbance of the working standards and samples were measured on a UV-visible spectrophotometer (Shimadzu UV-160A PC, *Shimadzu* Corporation, *Kyoto, Japan*) at 274 nm using 10 mm quartz cuvette.

Calculation: The caffeine levels of the samples were calculated from the regression equation of the best line of fit of the standards.

Determination of polyphenol in tea samples

Measurement of total phenolic compounds: The method was based on that of Roberts (1962) [17] and the Handbook of the Chinese National Centre of Tea Quality Control and Inspection (CNC, 1991), with modification from the recent work of some researchers (Yao, 2006; Balentine, 1997) [18, 19]. Details of the method are as follows:

Preparation of the tea solution: 200 ml boiling water was added to 2 g of leaf tea or 1 tea bag in a 250 ml conical flask and stirred by a magnetic bar on a heated (~90 °C) hot plate for 10 minutes. After filtration, the tea solution was allowed to cool down to room temperature and then made up to 250 ml with distilled water.

Tartrate solution: 1g $FeSO_4$ and 5g $KNaC_4H_4O_6$ were dissolved in distilled water and made up to 1000 ml.

Buffer solution: 23.377g Na_2HPO_4 was dissolved in distilled water to 1000 ml. 9.078g KH_2PO_4 was dissolved in distilled water to 1000 ml. 85 % (v/v) Na_2HPO_4 solution and 15 % (v/v) KH_2PO_4 solution were mixed as the buffer solution.

Measurement: 1 ml tea solution, 4 ml water and 5 ml tartrate solution were added in a volumetric flask. The buffer was added to make up the mixture to 25 ml. The mixture was measured using a UV-visible spectrophotometer (Shimadzu UV-160A PC, *Shimadzu* Corporation, *Kyoto, Japan*) at 540 nm.

Calculation

Polyphenols (%) = 3.914 E / 1000 * V0 / V1 / W * 100

Where E is the reading of the spectrophotometer; V_0 is the total volume of the tea solution (250 ml); V_1 is the volume used for the measurement (1 ml), and W is the dry weight of the tea sample.

Black tea samples were analyzed for TF, TPC, TR, HPS and Total Liquor Colour (TLC) by following the method reported by Thanaraj and Seshadri (1990) [20]. The briskness and colour indices were worked out as suggested by Ramaswamy (1986) [21]. TB was analysed by the method based on that of Roberts (1962) [17] and the Handbook of the Chinese National Centre of Tea Quality Control and Inspection (CNC, 1991), with modification from the recent work of some researchers (Yao, 2006; Balentine, 1997) [18, 19]. Theabrownin (TB) % = 7.06 x 2Eb / (1-M)].

Determination of nutrient contents in tea samples

Nutrients (viz. N, P, K, Ca and Na) were extracted with sulfuric-peroxide (H_2SO_4+H_2O_2) digestion mixture and determined by standard method (Jackson, 1973) [22]. The assessment of total iron (Fe) content in some black tea brands using mineral digestion and spectrophotometric method. The spectrophotometric method is simple and sensitive method that can be applied for the determination of total Fe content in plant material (Mandal *et al*., 2015) [23].

Analysis of antioxidant activity of tea sample

The radical scavenging activity of the tea extracts from leaf obtained from each zone was determined by the 2, 2-diphenyl-2-picrylhydrazyl (DPPH) radical using a modified method of Nadiah and Uthumporn (2015) [24]. The assay is based on the measurement of the scavenging ability of antioxidants towards the stable DPPH radical (Moreno, 1998) [25]. Details of the method used as follows:

Type of Chemicals: The chemicals used within this investigation are as follows: Methanol, 2, 2-diphenyl-1-picrylhydrazyl (DPPH) reagent, and Ethanol where all of the chemicals were purchased from Sigma Chemical.

Sample preparation: In order to perform extraction, the samples (1g) were infused in 100 ml of (a) distilled water at 100°C and (b) aqueous ethanol at 50% (v/v). After the 5 minutes extraction process, the infusions were filtered through a tea strainer. The filtrates collected from the extraction process are placed in reagent bottles and covered with aluminium foil to avoid light exposure. The extracts were stored at the temperature of 4ºC for further analysis. Each of the extraction were done in a triplicate terms (n=3).

Determination of DPPH radical activity assay: The capacity of the extract to scavenge the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical activity assay was performed according to Moreno(1998) [25]. DPPH reagent was prepared by dissolving 5.9 mg of DPPH powder in 100 ml of methanol, where the mixture was shaken vigorously to ensure that the methanol blended with DPPH powder successfully. After the aforementioned steps, about 0.3 ml of extract solution will be added with 2 ml of DPPH reagent, and subsequently stirred well and kept in a dark environment for 30 minutes. The absorbance of the mixture was measured at 515 nm by using a UV-visible spectrophotometer (Shimadzu UV-160A PC, *Shimadzu* Corporation, *Kyoto, Japan*). The DPPH reagent without the additional extract solution and ethanol were used as the control. The scavenging activity was calculated using the equation mentioned below (Moreno, 1998) [25].

Calculation

Scavenging activity (%) =1- absorbance sample/absorbance control x 100

Determination of Total Catechin

Types of Chemicals: (-) Catechin (HPLC 99%), Folin Ciocalteu agent and Vanillin purchased from Sigma Aldrich.

Brewing method: based on instructions printed on label of products, 3g of dried tea (5 –7% humility) was brewed in 100ml distilled water at 100ºC in 5 minutes, after that, cooled down to room temperature and filter to get brewing water. This procedure was repeated several times until water did not change color when adding drops of indicator solution $FeCl_3$ 3% HCl 0.1 (dark blue color appears if there are polyphenols in water) to extract all polyphenols in tea products. All extracts are accumulated to determine TCC (Total Catechin Content).

Determination of total catechins: Vanillin-HCl method was used to determine total catechin compounds (Ayumiko *et al*., 2003) [26].Vanillin high selectively reacts to catechin and leucoanthocyanidin compounds at 6, 8 positions, solution changes from colorless to pink when add concentrated HCl.- 0.1ml of sample (methanol for blank) was diluted with 0.9ml methanol, after that 2.5ml of vanillin solution (1% in methanol) was added, followed by 2.5 ml of HCl 9N (diluted from concentrated HCl with methanol). The solution was left for color development in 30 minutes and measured at 500nm in UV-visible spectrophotometer (Shimadzu UV-160A PC, *Shimadzu* Corporation, *Kyoto, Japan*).Total catechin content was calculated from absorption value and linear regress equation using (+)- catechin as standard. Results were shown as ppm CE (Catechin equivalent).

Statistical analysis: All statistical analysis was carried out using MS-EXCEL program to determine the means, coefficient of variation and any differences between the samples. Least Significance Difference (LSD) was used separate means. The probability limit was set at $p \leq 0.05$ significant level (Steel *et al*., 1997) [27]. Results of the parameter determined were expressed as a mean of the triplicate determination.

Results and Discussion

The results as presented in Table 1 exhibit that caffeine content of Shaw Wallace tea was found to vary with brands. The maximum value of caffeine content was found to be 5.5% (Premium Tea Bag) and the minimum value was found to be 3.98% (BOP) showing the sequence as Premium Tea Bag > Fine dust > Hotel special > Super Clone > Danadar> Golden Leaf > Shah Bag BOP. Tea generally contains caffeine at about 1-5% of its dry weight (Balentine *et al*., 1998) [28]. The average range of caffeine content in Bangladesh tea is 3.3-4.8% (Chowdhury and Alam, 2001) [13] which is in full agreement with the results of the present study.

Caffeine status of Wissotzky early grey tea, Twinings English breakfast tea, Bigelow Darjeling tea and Lipton tea obtained from the supermarkets of the U.S.A were detected to be 2.71%, 4.54%, 5.51% and 3.62% respectively (Henning *et al*.,

2003) [30]. In Chinese Fujian black tea, caffeine content was estimated to be 4.3% (Zuo *et al*., 2002) [31]. Cabrera *et al.*, 2003 [32] reported that caffeine content was found to be 3.83%, 4.74%, 4.15%, 6.18%, 6.74% and 4.5% in Sencha tea (Japan), Assam tea (India), Keemun tea (China), Ceylan tea (Sri Lanka), English breakfast tea (Srilanka) and Darjeeling tea (India) respectively. These conclusions substantiate with the results of present research.

Caffeine content varies with agrotypes, plucking periods and commercial brands (Cabrera *et al*., 2003) [34]. In Bangladesh, maximum caffeine content is found in increasing plucking period (April-June) and minimum in decreasing plucking period (October-December) (Alam *et al*., 2011) [14]. It is also reported (Davies, 1983) [33] that caffeine content of Bangladesh tea was found to vary from 3.87% to 4.67%, 2.53% to 3.87% and 1.73% to 2.67% in increasing, peak and decreasing plucking periods respectively. So it is evident from the result that the caffeine contents of present experiment can be ranked as medium in respect to Bangladesh standard and all the studied brands might have been harvested in between late peak plucking period (July-September) and decreasing plucking period (October-December).

The results as shown in Table 1 also exhibit that total polyphenol (TP), theaflavin (TF), thearubigin (TR), highly polymerized substances (HPS) and total liquor colour (TLC) contents were found to be varied with brands of Shaw Wallace tea. The highest amount of total polyphenol (TP) was estimated to be 37.5% in Danadar tea and the lowest was 32.09% in Fine dust tea maintaining the sequence as Danadar >Hotel special> Premium Tea Bags> Super Clone> Golden Leaf> Shahbag BOP> Fine Dust. Tea generally contains 15-18% of polyphenol (Chowdhury and Alam, 2001) [13]. The range of total polyphenol content in Bangladesh tea is 22-31% (Chowdhury, 1990) [29]. These findings agree with the TP status of the present experiment.

Total polyphenol content of black tea purchased from the supermarket of Penang, Malaysia was detected to be 17.87% (Nadiah and Uthumpom, 2015) [24]. Total polyphenol content was determined as 8.05% - 13.49% in the Black tea purchased from the supermarkets of Great Britain (Chowdhury and Alam, 2001) [13]. These conclusions are in agreement with the TP status of present study.

It is also reported that total polyphenol content of Bangladesh tea ranged from 20.79 % to 23.57 %, 24.60 % to 31.54%, 6.58% to 10.74% in increasing, peak and decreasing plucking periods respectively(Alam *et al*., 2011) [14]. Caffeine, TP, TF, TR, HPS and TLC contents fluctuates following climatic variations and decreases after rainy season (Malec, 2006) [37]. Karori *et al*., (2014) [38] determined the TP content in Kenyan tea cultivars was 14.96% to 23.21%. In Kenya, TP content of commercial black tea was estimated to be 17.45% to 22.25%. Quan *et al.*, *(*2007) [39] reported that TP content was found to be 45% in Vietnamese commercial black tea. Total polyphenol content was estimated to be 24.58% to 12.76% in the marketed brand teas of Bangladesh (Alam *et al*., 2011) [14].

Table 1: Variation of caffeine, TP, TF, TR and HPS contents (%) in seven marketed brands of Shaw Wallace tea.

Brand	Caffeine	TP	TF	TR	HPS	TB
Premium tea bag	5.50±0.23	34.20±0.15	1.13±0.12	15.96±0.16	4.97±0.03	12.91
Super clone	4.92±0.08	33.86±0.13	1.14±0.14	11.72±0.17	4.56±0.15	7.79
Danadar	4.75±0.15	37.50±0.37	1.18±0.13	15.42±0.26	4.70±0.11	7.33
Golden Leaf	4.50±0.19	33.27±0.15	1.11±0.1	11.32±0.11	4.35±0.15	8.12
Hotel special	5.40±0.17	34.25±0.20	1.12±0.11	11.66±0.13	5.27±0.10	7.13
Shahbag BOP	3.98±0.12	32.29±0.21	1.08±0.11	13.97±0.03	4.0±0.05	9.22
Fine Dust	5.40±0.15	32.09±0.09	0.97±0.04	15.11±0.12	4.82±0.13	8.51
LSD at P >0.05	0.46	0.80	0.06	1.6	0.34	1.62

The mechanism of manufacturing of high, medium and low graded tea with seasons which can be assessed and ranked in the order of monsoon (P_2) > early monsoon (P_1) > late monsoon (P_3) for polyphenol. The harvested tea of monsoon (peak period) is better in term of polyphenol content compared to early monsoon and late monsoon (Alam and Chowdhury, 2007) [34]. From the above discussion, it is evident that all of the brands of Shaw Wallace tea might have been plucked in the peak period or monsoon. So present experiment reveals that total polyphenol content of all the studied brands are reasonable and comparable with Bangladesh standard and consistent with above mentioned research findings.

Maximum value of TF content was observed to be 1.18% (Danadar tea) and minimum value was observed to be 0.97% (Fine Dust) showing the succession as Danadar>Super Clone> Premium Tea bag> Hotel Special > Golden Leaf >Shahbag BOP >Fine Dust (Table 1). The content of total theaflavins in black tea does not usually exceed 2 % and can be as low as 0.3 % (Balentine, 1997) [28], whereas Graham (1992) [40] reported that theaflavins ranged 1.5-2.5 % in the dry leaf which agrees with the results of the present investigation.

Theaflavin contents ranged from 0.96% to 2.072% at a mean value of 1.54% in the black tea of 25 different types of Kenyan tea cultivars (Karori *et al*., 2014) [38]. Theaflavin content was estimated to be 0.79%, 1.54%, 1.15%, 1.47%, 1.17% and 2.21% in the marketed teas of Australia, UK, Continental Europe, Middle East, US and India respectively (Caffin *et al*., 2004; Lakenbink *et al*., 2000; Bhatia, 1960) [41, 42, 43]. TF content was detected to be 1.70% in the Ceylon black tea purchased from the supermarkets of Singapore (Yashin *et al*., 2011; Turkmen *et al*., 2006) [44, 45]. These remarks are consistent with the TF status of the marketed brands of Shaw Wallace tea.

On the other hand, TR content ranged from 11.32% (Golden Leaf) to 15.76% (Premium tea bag) and showed the following sequence as Premium tea bag >Danadar >Fine Dust>Shahbag BOP> Super Clone> Hotel Special>Golden Leaf (Table 1). According to Hilton and Ellis [10] thearubigin (TR) generally constitutes about 6 to 18% of dry weight formed during the processing of black but they do not occur in green tea. Thearubigin content was estimated to be 8.64%, 11.09%, 11.56%, 12.18%, 9.45% and 16.04% in the marketed teas of Australia, UK, Continental Europe, Middle East, US and India respectively (Balentine, 1997;Karori *et al*., 2014; Graham, 1992) [28, 38, 40]. While working on five popular marketed brands of tea produced in Bangladesh, the TR content was estimated to be ranged from 5.725% to 4.282% (Alam *et al.*, 2015) [15]. These observations are comparable to the findings of the present experiment.

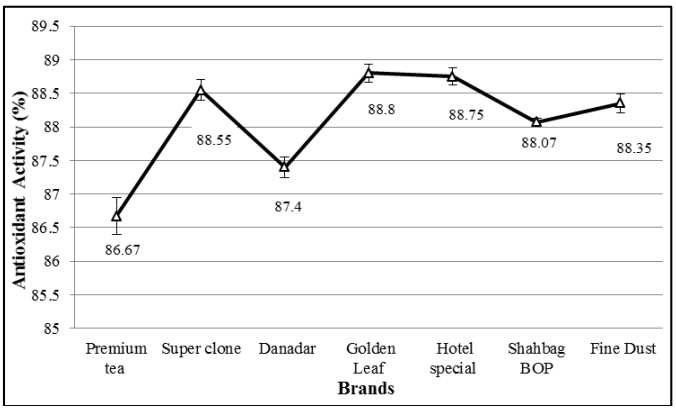

Fig 1: Variation of antioxidants activity in seven marketed brands of Shaw Wallace tea

Theabrownin content varied from 12.91% to 7.13%. The maximum value was found in Premium Tea bag (12.91%) and the minimum value was found in Hotel Special (7.13%) keeping the progression as Premium Tea bag > Shahbag BOP > Fine Dust > Golden Leaf Super Clone >Danadar> Hotel Special. Caffin *et al*. (2004) [41] reported that the theabrownin content ranged from 7.61% to 11.40% in black teabag of Australia with an average of 9.77% which is in full agreement with the findings of present study.

The highest amount of HPS content was determined to be 5.27% (Hotel Special) and the lowest amount was determined to be 4% (BOP) showing the succession as Hotel Special > Premium tea bag > Fine Dust>Danadar > Super Clone > Golden Leaf > Shahbag BOP (Table 1). Literature on the HPS status of marketed teas of Bangladesh as well as world tea is very sparse. However, Alam *et al.*, (2011) [14] studied on ten marketed brand teas of Bangladesh and found maximum HPS in Finlay tea (4.830%) and minimum in Fresh tea (1.924%) which is consistent with the findings of the present study. The present investigation also corroborates with the annotations of Someswararao *et al.*, (2013) [47] who reported that HPS content ranged from 10-22% in Indian black tea.

The results of antioxidant activity (AA) of Shaw Wallace teas are shown in Fig. 1. It is evident from the results that the highest value was found in Golden Leaf (88.80%) and minimum in Premium Tea bag (86.67%) sustaining the sequence as Golden Leaf > Hotel Special > Super Clone >Fine Dust >Shahbag BOP >Danadar > Premium Tea bag. In previous studies conducted on different tea samples using different solvents, the antioxidant activity was found between 2–83% (Leung *et al*., 2001) [46]. In Kenyan tea, Antioxidant activity was determined to be 84.10% to 91.10% (Karori *et al*., 2014) [38]. Antioxidant activity was estimated to be 79.9 mg/g, 91.8-186.6 mg/g, 97.8 mg/g, 88.4mg/g and 55.2 mg/g in Russian tea, Sri Lankan tea, Indian tea, Victorian tea and Indonesian tea respectively (Hilton and Ellis, 1972) [10]. So present experiment reveals that antioxidant activity of all the studied brands are consistent with above mentioned research findings.

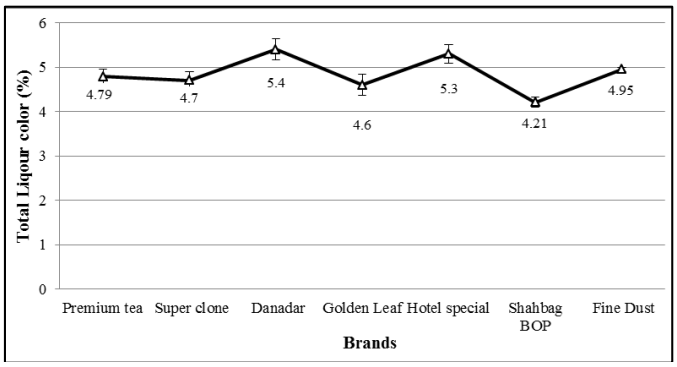

Fig 2: Variation of TLC in seven marketed teas of Shaw Wallace brand

In contrast, Danadar tea contained maximum amount of TLC content (5.4) and Shah Bag BOP contained minimum amount of TLC (4.21) retaining the order as Danadar > Hotel Special > Fine Dust > Premium tea bag >Super Clone > Golden Leaf >Shahbag BOP (Fig. 2). The status of total liquor colour in the seventeen marketed brand teas of Bangladesh substantiates with the findings of Alam *et al*. (2011) [14] who studied on ten marketed brand teas of Bangladesh and found maximum TLC in Finlay tea (2.30) and minimum in Kazi & Kazi (1.56). Someswararao *et. al.*, (2013) [47] reported that total liquor colour in Indian black tea was found to have been ranging from 3.89% to 5.7% which is consistent with the results of the present experiment. While working on five popular marketed brands of tea produced in Bangladesh, Alam *et. al*., (2015) [15] estimated the TLC content ranging from 2.56 to 3.44. This remark is in full agreement with the TLC status of the present study. In case of Bangladesh tea, it is reported that in the tea of two leaves and a bud with third internode the average TF, TR, HPS and TLC contents were determined as 1.035%, 5.798%, 6.821% and 3.350 respectively. But all of these components trends to be decreased downward significantly in the tea of four leaves and a bud with fifth internode whilst the contents were determined as 0.733%, 4.127%, 3.956% and 2.30 respectively (Karim *et al*., 2000) [48]. It is also suggested that plucking standard should be maintained up to two leaves and a bud including third internode for the production of teas having proper caffeine, TP, TF, TR, HPS and TLC contents to optimize the black tea quality (Karim *et al*., 2000) [48].

Fig 3: Variation of Color Index in seven marketed brands of Shaw Wallace tea

Therefore, from the results of this experiment, it can be assumed that TF, TR, HPS and TLC contents of all the studied brands of Shaw Wallace tea were up to the mark in comparison to Bangladesh standard. Every brand possessed low TF, TR, HPS and TLC contents which were supposed to be obtained from four leaves and a bud with fifth internode and downward plucking. So, all the studied brands might have maintained plucking standard as well as manufacturing awareness and might have been prepared from the plucked shoots of increasing plucking period.

Colour index also varied among the studied brands in this experiment (Fig. 3). The results expose that CI ranged from 4.88 (Fine Dust) to 7.10 (Golden Leaf) and followed the sequence as: Golden leaf>Super Clone>Hotel Special> Shahbag BOP >Danadar >Premium Tea Bag >Fine Dust (Fig. 2). For better tea, the colour index should be between 5 and 11 in order to have the liquor balanced with colour and briskness. If the colour index value cross 11, then the tea lacks colour and when it falls below 5, the liquor will be coloured and flat with low briskness (Brown *et al*., 1966) [49]. In the present study, the colour index values for all the brands were between 6 and 7. So the colour indices of all the studied brand teas were not up to the mark in respect to Bangladesh tea standard and can be ranked as medium. The status of colour index in the present investigation corroborates with the findings of Alam *et al*., (2011) [14] who studied on ten marketed brand teas of Bangladesh and found maximum CI in Kazi & Kazi tea (11.72) and minimum in Ispahani tea (5.91). While working on five popular marketed brands of black tea produced in Bangladesh, Chowdhury and Alam (2001) [13] estimated the colour index ranging from 8.75 to 10.94. This remark is also in full agreement with the CI status of the present study.

Briskness index (BI) of this experiment was found to be varied among the studied brands of Shaw Wallace tea (Fig. 4). It is apparent from the result that the highest value of BI was estimated to be 21.66 (BOP) and lowest value was estimated to be 15.27 (Fine dust) and followed the sequence as BOP> Danadar > Golden leaf > Super Clone > Hotel Special > Premium Tea Bag > Fine Dust (Fig. 4). The normal range of briskness index proposed for South Indian teas is 12.5 to 22.5. But, when it drops below 17.5, the liquors tend to have a harsh taste and when it exceeds 17.5 the liquor gets brisker (Thanaraj and Sheshadri, 1990) [20]. Briskness index values of all the brand teas in the present study were between 15 and 19. So it can be said that liquors of all the studied brands were medium in briskness. Alam *et al*. (2011) [14] determined briskness index in ten popular marketed brand teas of Bangladesh and the highest BI was found to be 23.51 in Kazi & Kazi tea and the lowest was found to be 14.46 in Ispahani tea which is in full agreement with the results of present experiment. The status of briskness index in the present experiment substantiates with the observations of Alam *et al*., (2015) [15] who worked on five popular marketed brand teas of Bangladesh and estimated the briskness index ranging from 24.76 to 21.88.

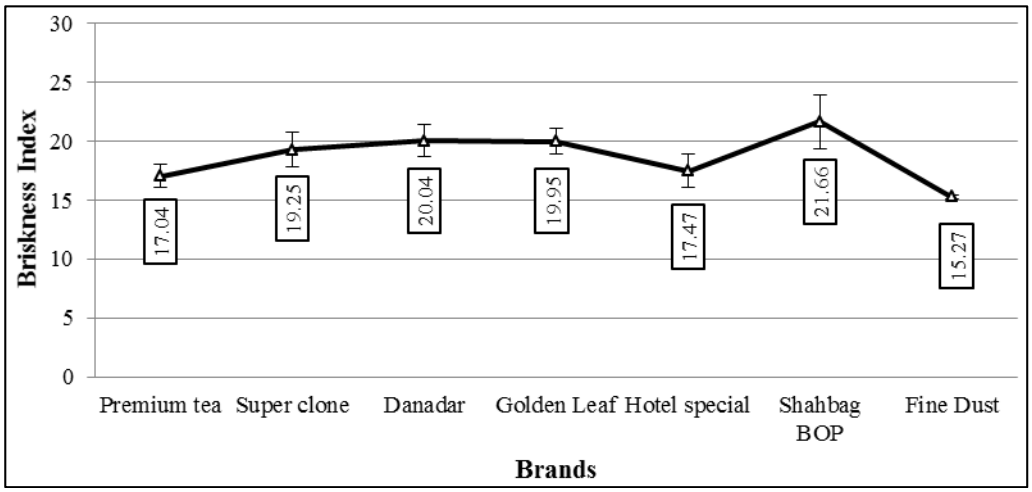

Fig 4: Variation of Briskness Index in seven marketed brands of Shaw Wallace tea

Total Catechin content was found maximum in Danadar tea (5.17%) and minimum in Fine Dust (3.89%) and followed the given series as Danadar> Hotel Special> Premium tea bag > Super clone > Golden Leaf > BOP > Fine Dust (Fig. 5). Total Catechin status of Wissotzky early grey tea, Twinings English breakfast tea, Bigelow Darjeeling tea and Lipton tea purchased from the supermarkets of the U.S.A were estimated to be 1.33%, 2.01%, 0.88% and 1.42% respectively (Henning *et al*., 2003) [30]. Total Catechin content was determined as 0.56% - 4.75% in the Black tea purchased from the supermarkets of Great Britain (Yashin and Nemzer, 2011; Brown *et al*., 1966) [44, 49]. In the black tea of Lipton brand purchased from Taiwan, total Catechin content was found to be 7.75% (Yashin and Nemzer, 2011) [44]. Theppakorn, (2015) [51] studied 28 samples of Oolong tea manufactured in Thailand and total Catechin content was found to be varied from 5.01% to 13.31%. TC content was determined to be 4.62%, 12.69%, 11.19% and 16.59% in Kenyan black tea-orthodox, Japanese Yadukita green tea, Chinese Hanlu green tea and Ceylon black tea respectively (Hilton and Ellis, 1972) [10]. Total Catechin content ranged from 1.52% to 1.94% in five types of commercial black teas obtained from Ho Chi Minh city, Vietnam (Quan *et al*., 2007) [39]. These research findings are comparable with the results of present study.

Nutrient contents (N, P, K, Ca and Na) also varied with the studied brands in this experiment. The results as shown in Table 2 indicate that maximum concentration of nitrogen was determined to be 5.14% in Danadar tea and minimum concentration was 4.52% in Fine Dust tea showing the succession as Danadar Tea > Premium Tea >Super Clone >Golden Leaf > BOP > Hotel Special > Fine Dust. Satisfactory levels of foliar nitrogen content of the first leaf, second leaf and third leaf in the plucked tea shoots are 5.0%, 4.4% and 3.8% respectively which represent the critical levels and are also consistent with the findings of the present study (Wilson, 1975) [52].

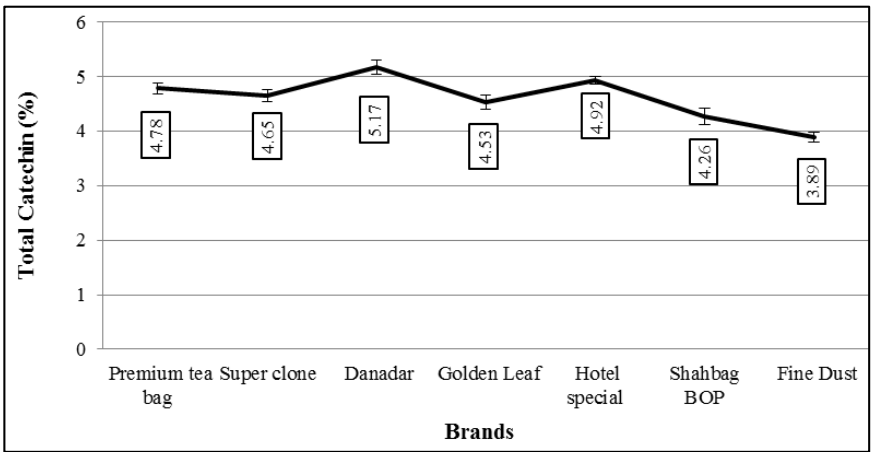

Fig 5: Variation of total catechins in seven marketed brands of Shaw Wallace tea.

The highest amount of Phosphorus was found to be 0.28% in Premium tea bag as well whilst the lowest amount was found to be 0.17% Fine Dust following sequence as Premium tea> Danadar > Golden Leaf >Super Clone > BOP>Hotel Special> Fine Dust (Table 2). The usual range of leaf phosphorus is between 0.6% and 0.9%, (P_2O_5) and P content of 0.25% or less indicates its starvation (Wilson,1975) [52] which corroborates with the Phosphorus status of the present experiment.

Table 2: Variation of nutrient contents (%) in seven different brands of Shaw Wallace tea.

Brand	N	P	K	Ca	Na	Fe
Premium tea bag	5.03±0.036	0.28±0.105	2.01±0.032	1.14±0.101	0.14±0.055	0.048±0.025
Super clone	4.91±0.07	0.21±0.09	1.88±0.12	1.31±0.185	0.15±0.064	0.064±0.037
Danadar	5.14±0.094	0.26±0.066	2.05±0.058	1.37±0.12	0.17±0.062	0.055±0.024
Golden Leaf	4.83±0.145	0.23±0.092	1.96±0.041	1.23±0.198	0.11±0.07	0.038±0.019
Hotel special	5.4±0.2	0.18±0.085	1.72±0.243	1.08±0.104	0.12±0.095	0.042±0.024
Shahbag BOP	4.68±0.15	0.20±0.13	1.63±0.157	1.16±0.115	0.09±0.03	0.035±0.14
Fine Dust	4.76±0.205	0.17±0.107	1.55±0.16	0.95±0.051	0.07±0.052	0.018±0.018
LSD at P < 0.05	0.031	0.010	0.029	0.021	0.005	0.001

Potassium content was estimated to be maximum in Danadar (2.05%) and minimum in Fine Dust (1.55%) and maintained the given order as Danadar > Premium > Golden Leaf >Super Clone> Hotel Special > BOP > Fine Dust (Table 2). The concentration of potassium is higher in two leaves and a bud (about 2.0%) than the third leaf. Potassium concentration below 1.75% in first leaf with a bud, and 1.57% in third leaf are a clear indication that potassium is limiting yield Theppakorn, (2015) [51] which is in full agreement with the results of the present investigation.

In case of Calcium content, Danadar was found to be superior (1.37%) but Fine Dust was found to be inferior (0.95%) and accordingly showed the following sequence as Danadar > Super Clone > Golden Leaf > Premium tea bag >BOP > Hotel Special > Fine Dust (Table 2). Desirable calcium content in North- East India is usually about 0.1% calcium (Choudhury, 1983) [53]. Normal tea leaf as plucked contains an average of more than 0.5% Ca. The concentration of Ca is higher in third leaf (about 1.0%) than the two leaves and a bud (Wilson, 1975) [52]. which bears a close resemblance with the results of present study. In concerning the sodium content, maximum amount was evaluated to be 0.17% in Danadar and minimum was 0.07% in Fine Dust and thus, maintained the given succession as Danadar > Super Clone > Premium>Hotel Special > BOP>Fine Dust (Table 2). The sodium content in Pakistani Black Tea was found to be 0.39-0.83 mg/l (Adnan *et al*., 2013) [55] which is persistence with the findings of the present experiments.

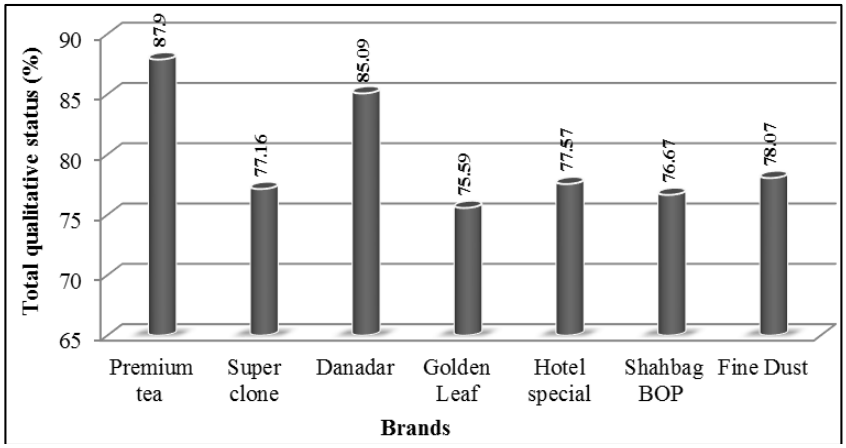

Fig 5: Variation of total qualitative status (Sum of caffeine, TP, TF, TR, TB, TC, HPS and nutrient elements) in seven marketed brands of Shaw Wallace tea

The maximum Iron (Fe) content was found in Super Clone (0.064%) and minimum was found in Fine Dust (0.029%) and chased the sequence as Super clone > Danadar> Premium tea bag> Hotel Special> Golden Leaf > BOP> Fine Dust. The Fe concentrations of imported teas in Czech Republic were found to be varied from 0.037 to 0.142 mg/ml (Street *et al*., 2006) [56]. Fe content in the black teas from the markets of India Marbaniang *et al*., (2011) [57] and Nigeria. Achudume *et al*., (2010) [58] was reported to be 0.439 mg/ml and 0.99 to 2.39 mg/ml, respectively. Fe content was determined to be 2.396±0.040 mg/l in black teas collected from the market of Turkey (Moroydor Derun *et al*., 2012) [59]. Mandal *et al*.,(2015) [23] estimated Fe concentration ranging from 21.3 to 37.6 mg/kg with a mean value of 28.8 mg/kg in the black tea purchased from the market of Bosnia and Herzegovina.

Comparison of price with biochemical composition of Tea

The percentage of the total qualitative status (Sum of caffeine, TP, TF, TR, TB, TC, HPS and nutrient elements) ranged from 75.59% to 87.90%. It is apparent from the result that the maximum percentage of the chemical composition was estimated in Premium tea bag (87.90%) and minimum percentage was in Golden leaf (75.59%) (Fig. 5). The market price of seven brands of Shaw Wallace tea is shown in Fig. 6. The highest price was observed in Premium Tea Bag (1400tk/kg) and the lowest price was observed in BOP (300 tk/kg).

It is evident from the result that market price of the studied brands of Shaw Wallace tea was almost dependent on the amount of biochemical composition. Except Danadar tea, the sequence of biochemical composition in all the studied brands of tea followed the sequence of price. The market price of all the studied brands of Shaw Wallace tea was found to be changed positively with the qualitative status. The results also indicate that the higher the biochemical composition in the brands of tea was as the higher the price.

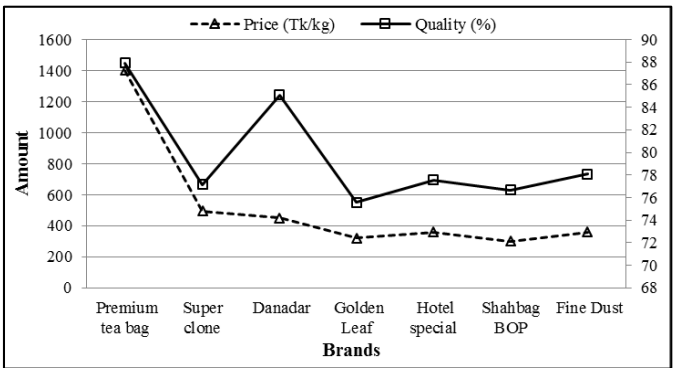

Fig 6: Comparison of price with total qualitative status of seven marketed brands of Shaw Wallace tea.

Conclusion

The present study concludes that among the studied brands of Shaw Wallace tea, Danadar tea was found to be the paramount tea in relation to total polyphenol (TP), theaflavin (TF), total liquor colour (TLC), total catechin content (TC) and nutrient contents (N, P, K, Ca, Na and Fe) whilst Premium tea bag was revealed to be the superlative in respect to caffeine, theabrownin (TB) and thearubigin (TR) contents. On the other hand, Golden Leaf tea was considered to be the most excellent when the antioxidant activity (AA) and color index (CI) were concerned. In considering the highly polymerized substances (HPS) and briskness index (BI) Hotel Special and BOP were determined to be superior among the other brands of Shaw Wallace tea respectively. Finally, in respect to total qualitative status (Sum of caffeine, TP, TF, TR, TB, TC, HPS and nutrient elements) Premium tea bag was detected to be the best among the studied brands of Shaw Wallace tea and all the studied brands may therefore, be ranked as Premium tea bag > Danadar tea > BOP >Super clone> Golden Leaf > Hotel Special > Fine Dust tea. The present study further concludes that The market price of all the studied brands was found to be changed positively with the biochemical status which indicates that the higher the biochemical composition in the brands of Shaw Wallace tea was as the higher the price.

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