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# Quality, antioxidant activity and composition of Indian black teas

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**Abstract** A comparative study was undertaken to determine the difference in quality, antioxidant activity, and mineral content of northern and southern Indian tea varieties. The results showed that the antioxidant activity, theaflavin and thearubigin content, color particle size and total soluble solids influence the tea leaf and tea dust. Assam leaf showed higher values for all the physico-chemical properties followed by Darjeeling leaf. In addition, the mineral composition of the tea infusion was also influenced. The preparation method, including the amounts of tea and water used, infusion time was shown to be a major determinant of the component concentrations of tea beverages as consumed. An illustration of the variation introduced by these varieties of tea is provided by comparing solids, caffeine, minerals and antioxidant activity of black teas available locally.

**Keywords** Total polyphenols · Theaflavins · Thearubigins · Antioxidant activity · Caffeine · Mineral content

## Introduction

India is one of the largest tea producers in the world, though over 70% of the tea is consumed within India itself. Tea is used not only as fresh drink but also as traditional herb which has many health benefits. Teas vary by type (black, green, oolong, pu'er), variety (blended, unblended) and further details such as processing [conventional; cut, tear, curl (CTC)]. Unblended teas are named by their country or region (Assam, China, and Darjeeling) because the hybrids of either the Chinese or Assamese tea subspecies are better suited to and grown in these different geographical locations. The Indian tea industry has grown to own many global tea brands, and has evolved to be one of the most technologically equipped tea industries in the world.

Black tea is sold at wholesale in single grades of uniform quality as assessed by variety, brewing color and taste. Black tea manufactured from young tender shoots of *Camellia sinensis* (L.) O. Kuntze, is the most widely consumed non-alcoholic drink and its flavour quality and taste have been shown to change with variations in geographical (Takeo and Mahanta 1983; Yamanishi et al. 1968) and climatic (Cloughley et al. 1982; Howard 1978) conditions. Yamanishi et al. (1968) compared flavours of tea from different parts of the world, while Cloughley et al. (1982) compared flavours of tea in different seasons in Malawi, Africa. Indian teas especially from Darjeeling, Assam and Nilgiris (Trinitea) are valued for their characteristic aroma and taste. These teas are much sought after and used by consumers throughout the world (Subramaniam 1995). Many reports are available about antioxidant and anticancer properties and health benefits of tea (Dreosti et al. 1997; Tijburg et al. 1997; Wiseman et al. 1997; Yang et al. 1998; Yang and Wang 1993).

The important chemical constituents which influence the taste and flavour in tea brew are polyphenols, caffeine, sugars, organic acids, volatile flavour compounds and amino acids. Phenolic compounds of tea such as theaflavins and thearubigins, are very important from an intrinsic quality point of view. These are responsible for the colour,

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flavour and brightness of tea. Caffeine is responsible for the briskness. The physicochemical parameters, such as total soluble solids (TSS) of the brew and bulk density (packed/loose) of the tea are important quality indicators. The volatile flavour compounds of tea and their variation in composition due to geographical and other process variables are of paramount importance from a quality point of view. Though considerable work has been done (Gulati and Ravindranath 1996; Gulati et al. 1999; Ullah 1985) on the quality aspects of tea, a comparative study covering Indian regions has not been done so far. In view of the complexity of tea quality, a study has been carried out on the Indian black tea obtained from different regions. The data generated, based on the studies, may compliment to trace the origin of teas. Four varieties of tea each of northern and southern Indian origin were procured and compared for antioxidant activity, physico-chemical properties, minerals and caffeine content. North Eastern Indian tea includes Darjeeling tea and different varieties of Assam tea and South Indian teas were from popular hill stations of Munnar and Nilgiris.

## Materials and methods

Different varieties of tea (Northern Indian and Southern Indian origin) were procured from local market in Mysore The analytical grade chemicals were procured from Merck (India). The 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) and Caffeine were procured from Sigma Aldrich chemical co.

### Determination of polyphenols

Samples were analyzed for total polyphenol content according to the Folin-Ciocalteu method (Singleton and Rossi 1965). A known volume of the powdered tea (10 mg) was dissolved in 10 ml water and subjected to centrifugation. A known aliquot (0.5 mL) of the resulting solution was mixed with Folin–Ciocalteau reagent (0.5 ml), and saturated solution of $Na_2CO_3$ (1.5 ml) was added. This was made up to 10 ml with distilled water and incubated at 27 °C for 2 h. Optical density was measured at 765 nm using a UV–visible spectrophotometer (GBC Cintra 10, Australia). The total phenol content was estimated by comparison with a calibration curve generated from the analysis of Gallic acid solution, and the results were expressed as mean (SD) percent of Gallic acid equivalents for the extracts in triplicate.

### Free radical scavenging activity

Free radical scavenging activity was measured by the 1,1-diphenyl-2-picrylhydrazyl (DPPH) method (Oktay et al.

2003; Jayaprakasha et al. 2001). Different concentrations (100, 200, and 300 ppm) of black tea were taken in different test tubes. The volume was adjusted to 1 ml by adding methanol. Four ml of a 0.1 mM methanol solution of DPPH was added to these test tubes and shaken vigorously. The tubes were then incubated in the dark at room temperature for 20 min. A control sample was prepared as above without extract, and methanol was used for the baseline correction. Changes in the absorbance of the samples were measured at 517 nm using a UV–visible spectrophotometer (GBC Cintra 10, Australia). All analyses were run in triplicate and the values were averaged. The percent decrease in the absorbance was recorded for each concentration, and percent quenching of DPPH was calculated on the basis of the observed decrease in the absorbance. Radical scavenging activity was expressed as the inhibition percentage and was calculated using the following formula

$$\text{Antiradical activity} \, (\%) \\ = \frac{(\text{Control absorbance} - \text{Sample absorbance}) \times 100}{\text{Control absorbance}}$$

### Reducing power assay (RPA)

The reducing power was determined according to the method of (Oyaizu 1986). Various concentrations (100, 200, 300 ppm) of black tea extracts were made up to 1 ml with distilled water and mixed with 2.5 ml of 200 m mol/l sodium phosphate buffer (pH 6.6) and 2.5 ml of 1% potassium ferricyanide. The mixture was incubated at 50 °C for 20 min. A portion 2.5 ml of 10% trichloroacetic acid (w/v) was added, the mixture was centrifuged at 3000 rpm for 10 min (MSE, Mistral, 2000, UK). The upper layer (5 ml) was mixed with 2.5 ml deionised water and 0.5 ml of 0.1% of ferric chloride, and the absorbance was measured at 700 nm. Higher absorbance indicates higher reducing power. These assays were carried out in triplicate and the results are expressed as mean values ±SD.

### Spectrophotometric estimation for theaflavins (TFs) and thearubigins (TRs)

Biochemical assessment of tea quality was done by estimation of TFs and TRs of black tea. In the present studies, a rapid procedure for estimating theaflavins and thearubigins of black tea was adopted (Ullah 1986). The absorbance was measured on a UV–visible spectrophotometer (Cintra-10, Australia). Tea infusion was prepared as described by Ullah 1972, by refluxing 4.5 g tea with 187 ml freshly boiled distilled water for 10 min on a water bath.

Six ml infusion was mixed with 6 ml 1% (w/v) aqueous solution of anhydrous disodium hydrogen phosphate and the mixture extracted with 10 ml ethyl acetate by quick repeated inversion for 1 min. On separation of the two phases, the bottom layer was drained off and the ethyl acetate extract containing the TF fraction was diluted with 5 ml ethyl acetate.

10 ml of theaflavin extract was diluted with methanol to 25 ml ($E_1$). To 1 ml tea infusion, 9 ml water was added and made up to 25 ml with methanol ($E_2$). To 1 ml tea infusion, 1 ml aqueous oxalic acid and 8 ml water were added and made up to 25 ml with methanol ($E_3$) optical densities of $E_1$, $E_2$, $E_3$ were measured in 3 cm cells at 380 and 460 nm with spectrometer.

At 380 nm  $\%TF = 2.25 \times E_1$   $\%TR = 7.06(4E_3 - E_1)$

At 460 nm  $TC = 6.25 \times 4E_2$
   $\%\text{Total Brightness} = E_1/4E_2 \times 100$

## Estimation of caffeine by HPLC method (Pura Naik and Nagalakshmi 1997)

A Sep-Pak C18 cartridge was obtained from Waters Associates, London, and a Millipore filter, type FH (pore size 0.5 μm) was from Millipore (India) Pvt. Ltd. All solvents were of HPLC grade filtered and degassed under vacuum prior to use. HPLC analysis of extracts was carried out using Waters HPLC system consisted of Waters binary HPLC 515 pump, manual injector 7725 and UV detector. A μ-bondapak C18 column (3.9 mm × 15 cm) was used to separate caffeine. The mobile phase consisted acetonitrile and water (20:80) at a flow rate of 1 ml/min at a wavelength of 276 nm.

*Standard Caffeine* Stock solution of standard caffeine was prepared by dissolving 80 mg of BDH grade caffeine in 100 ml of water. Working standard was prepared by diluting 10 ml of stock solution to 100 ml to give a concentration, 0.08 μg/μl.

*Calibration graph* Working standard solution was injected on the HPLC, and peak area responses were obtained. A standard graph for caffeine was prepared by plotting concentration versus area.

*Sample preparation* Black tea: 2 g of tea was weighed into a 250 ml beaker, and 177 ml of boiling water was added. The tea was brewed for 6 min on a boiling water bath, with the temperature maintained at 80 °C. The brew was filtered through Whatman no. 44 filter paper. And 2 ml of filtrate was subjected to the cleanup procedure as described below.

*Cleanup procedure* A sep-pak C18 cartridge was prepared by first passing 2 ml methanol by means of a glass syringe. Using an empty syringe, air was passed through the cartridge to expel any remaining methanol. Tea extract (1–2 ml) was then passed through the cartridge and elute was rejected. Again, air was passed to expel any water. Caffeine was eluted from the cartridge with 6 ml of chloroform (drop by drop), followed by air into an evaporating flask. The chloroform was removed on a water bath under vacuum. The residue in the flask was dissolved in water and made up to 4 ml. An aliquot (5–10 μl) of this solution was injected on the HPLC.

*Minerals* A Thermo ICP-AES was used for metal determinations. Nitric acid (E. Merck) was of ultrapure grade. Working standard solutions were prepared by serial dilutions of the stock solutions. All aqueous solutions and dilutions were prepared with ultrapure water (Milli-Q, Millipore). Tea samples were selected for this study. The minerals in tea samples were determined by Inductively Coupled Plasma (ICP). Two gram tea powders w converted to ash and dissolved with 2 mL concentrated $HNO_3$ solution and the volume made up to 25 mL using double distilled water. The calibration curves were prepared from standards. The sample solution was aspirated and the concentration determined.

## Analysis for physicochemical parameters

Moisture, packed bulk density, loose bulk density, soluble solids are the physiochemical parameters. Bulk density: Bulk density (packed bulk density and loose bulk density) of black tea samples was carried out as per method of Ramaswamy (1995). Total soluble solids (TSS) of tea brew was determined (Borse et al. 2002), using a refractometer. Tea (2 g) was added to boiling distilled water (140 ml) in a clean beaker and allowed to boil (infuse) for 4 min. The brew was filtered through Whatman no. 4 filter paper, using a Buchner funnel, by applying a vacuum. The refractometer (Atago, Japan) was calibrated using distilled water. The brew was well mixed and a drop of cooled brew placed on the prism of the refractometer. Readings were taken in triplicate and an average taken as TSS (%).

## Statistics

All the analyses were carried out in triplicate and the results were provided as mean value with standard deviation. The obtained data were subjected to statistical analysis and the means compared by Duncan's new multiple range test ($p < 0.05$) are presented.

**Table 1** Antioxidant activity of northern and southern Indian tea

| Samples | RSA (%) | | | RPA (%) | | | TPP (g %GAE) |
|---|---|---|---|---|---|---|---|
| | 100 ppm | 200 ppm | 300 ppm | 100 ppm | 200 ppm | 300 ppm | |
| Assam leaf | $84.3 \pm 0.2^h$ | $85.2 \pm 0.6^f$ | $86.3 \pm 0.4^f$ | $0.641 \pm 0.07^g$ | $0.865 \pm 0.01^g$ | $1.141 \pm 0.09^h$ | $5.1 \pm 0.03^g$ |
| Assam dust | $46.9 \pm 0.2^d$ | $59.0 \pm 0.6^c$ | $84.0 \pm 0.1^e$ | $0.054 \pm 0.03^b$ | $0.092 \pm 0.01^b$ | $0.213 \pm 0.09^b$ | $3.6 \pm 0.04^d$ |
| Assam o.p. | $10.5 \pm 0.6^a$ | $10.7 \pm 0.4^a$ | $10.9 \pm 0.7^a$ | $0.033 \pm 0.03^a$ | $0.047 \pm 0.02^a$ | $0.062 \pm 0.05^a$ | $0.6 \pm 0.02^a$ |
| Darjeeling leaf | $62.3 \pm 0.3^f$ | $71.2 \pm 0.4^e$ | $80.7 \pm 0.7^d$ | $0.222 \pm 0.04^d$ | $0.263 \pm 0.03^d$ | $0.346 \pm 0.05^d$ | $1.8 \pm 0.03^b$ |
| Nilgiri leaf | $69.3 \pm 0.4^g$ | $89.8 \pm 0.2^g$ | $90.9 \pm 0.3^g$ | $0.441 \pm 0.03^f$ | $0.597 \pm 0.05^f$ | $0.714 \pm 0.06^g$ | $4.7 \pm 0.03^f$ |
| Nilgiri dust | $31.6 \pm 0.2^b$ | $58.0 \pm 0.5^b$ | $89.6 \pm 0.9^g$ | $0.082 \pm 0.07^c$ | $0.215 \pm 0.02^c$ | $0.300 \pm 0.05^c$ | $4.0 \pm 0.04^e$ |
| Kelagur leaf | $41.1 \pm 0.1^c$ | $61.6 \pm 0.3^d$ | $59.6 \pm 0.7^b$ | $0.244 \pm 0.03^d$ | $0.333 \pm 0.03^e$ | $0.400 \pm 0.02^e$ | $3.1 \pm 0.03^c$ |
| Kelagur dust | $55.5 \pm 0.3^e$ | $70.7 \pm 0.4^e$ | $78.7 \pm 0.4^c$ | $0.398 \pm 0.05^e$ | $0.541 \pm 0.04^f$ | $0.611 \pm 0.06^f$ | $3.4 \pm 0.05^c$ |

Values are mean ± SD of triplicates

Values having different superscripts are significantly ($p < 0.05$) different

**Table 2** Determination of TF/TR/TC and brightness of northern and southern Indian tea

| Samples | %TF | %TR | %TC | %TB |
|---|---|---|---|---|
| Assam leaf | $0.472 \pm 0.02^g$ | $7.257 \pm 0.1^d$ | $3.087 \pm 0.2^e$ | $12.247 \pm 0.2^g$ |
| Assam dust | $0.276 \pm 0.01^f$ | $7.857 \pm 0.1^e$ | $2.675 \pm 0.1^d$ | $8.407 \pm 0.3^d$ |
| Assam o.p. | $0.258 \pm 0.02^e$ | $8.08 \pm 0.2^f$ | $1.775 \pm 0.1^b$ | $9.504 \pm 0.3^e$ |
| Darjeeling leaf | $0.234 \pm 0.01^d$ | $3.625 \pm 0.3^a$ | $0.827 \pm 0.1^a$ | $13.093 \pm 0.5^h$ |
| Nilgiri leaf | $0.193 \pm 0.02^c$ | $5.83 \pm 0.5^b$ | $2.07 \pm 0.1^c$ | $6.86 \pm 0.9^c$ |
| Nilgiri dust | $0.195 \pm 0.02^c$ | $6.41 \pm 0.5^c$ | $2.57 \pm 0.1^d$ | $10.57 \pm 0.3^f$ |
| Kelagur leaf | $0.166 \pm 0.03^b$ | $6.67 \pm 0.3^c$ | $2.06 \pm 0.1^c$ | $5.75 \pm 0.2^b$ |
| Kelagur dust | $0.081 \pm 0.02^a$ | $6.56 \pm 0.2^c$ | $1.71 \pm 0.1^b$ | $2.02 \pm 0.2^a$ |

Values are mean ± SD of triplicates

Values having different superscripts are significantly ($p < 0.05$) different

## Results and discussion

### Antioxidant activity of northern and southern Indian tea

The antioxidant activities of Northern and Southern Indian tea varieties were evaluated by DPPH method. Antiradical activity using 1,1-diphenyl-2-picrylhydrazyl radical (DPPH*) method was used to evaluate the free radical scavenging ability of tea. The percent decrease in the absorbance at 517 nm was recorded for each concentration and the percent quenching of DPPH* was calculated on the basis of the observed decrease in absorbance of the radical and expressed as inhibition percentage. Table 1 reveals that Nilgiri leaf and Nilgiri dust had a maximum activity of 90% followed by Assam leaf and Assam dust 85% which may be attributed to its hydrogen donating ability (Tables 2, 3, 4).

The results indicated that silver cloud leaf and dust of Southern India showed maximum activity followed by Assam leaf and Assam dust and has high radical scavenging activity at the concentration of 300 ppm compared to other sample. Higher the concentration of total polyphenols, stronger the DPPH radical scavenging activity. Clinical studies reveal that natural plant antioxidants found in tea, called polyphenols, have beneficial effects on many biochemical processes in the body via a range of mechanisms, including antioxidant and anti-inflammatory actions. Comparison between northern and southern Indian tea indicated that tea from Northern India, Assam leaf has higher polyphenolic content followed by silver cloud leaf of Southern India. Therefore higher the polyphenol content higher the quality of tea. Total polyphenol content was high in Assam leaf 5.1% followed by Niligiri leaf 4.7% and Niligiri dust 4.0%.

Reducing power assay showed that Assam leaf recorded higher reducing power, followed by silver cloud leaf. In reducing power assay, a linear increase in reducing power was observed over the concentration range 100–300 ppm. The results indicate that more the hydrophilic polyphenolic compounds the greater the reducing power. Assam leaf had higher reducing power assay of 1.15 followed by Niligiri leaf 0.714.

**Table 3** Physico-chemical analysis of northern and southern Indian tea

| Samples | Moisture (%) | Loose bulk density (g/cc) | Packed bulk density (g/cc) | Total solid soluble of tea infusion | Caffeine g/100 g |
|---|---|---|---|---|---|
| Assam leaf | $5.5 \pm 0.1$ | $6.8 \pm 0.2^c$ | $8.3 \pm 0.1^c$ | $26.8 \pm 0.5^e$ | $1.1 \pm 0.09^a$ |
| Assam dust | $3.8 \pm 0.1^b$ | $9.6 \pm 0.1^f$ | $11.6 \pm 0.1^f$ | $24.8 \pm 0.4^d$ | $3 \pm 0.12^f$ |
| Assam o.p. | $5.9 \pm 0.1^e$ | $3.5 \pm 0.3^a$ | $4.7 \pm 0.1^a$ | $21.3 \pm 0.2^b$ | $1.9 \pm 0.13^d$ |
| Darjeeling | $5.7 \pm 0.1^d$ | $5.6 \pm 0.2^b$ | $7.2 \pm 0.1^b$ | $24.9 \pm 0.3^d$ | $1.7 \pm 0.09^c$ |
| Nilgiri leaf | $5.6 \pm 0.1^d$ | $8.5 \pm 0.1^e$ | $11 \pm 0.2^e$ | $22 \pm 0.5^b$ | $1.5 \pm 0.09^b$ |
| Nilgiri dust | $3.5 \pm 0.1^a$ | $9.4 \pm 0.1^f$ | $12.5 \pm 0.1^g$ | $18 \pm 0.6^a$ | $1.4 \pm 0.1^b$ |
| Kelagur leaf | $5.7 \pm 0.1^d$ | $7.8 \pm 0.1^d$ | $9.3 \pm 0.0^d$ | $23 \pm 0.2^c$ | $1.5 \pm 0.12^b$ |
| Kelagur dust | $4.3 \pm 0.1^c$ | $10.2 \pm 0.3^g$ | $11.5 \pm 0.1^f$ | $30 \pm 0.1^f$ | $2.1 \pm 0.07^e$ |

Values are mean $\pm$ SD of triplicates

Values having different superscripts are significantly ($p < 0.05$) different

**Table 4** Color measurement of northern and southern Indian tea

| | $L$ | $a$ | $b$ | $\Delta E$ |
|---|---|---|---|---|
| | 92.68 | $-1.01$ | 0.68 | |
| Assam leaf | $20.3 \pm 0.1^c$ | $4.58 \pm 0.1^e$ | $8.17 \pm 0.1^d$ | $73.39 \pm 0.1^b$ |
| Assam dust | $20.18 \pm 0.05^b$ | $4.23 \pm 0.05^d$ | $7.52 \pm 0.05^c$ | $73.41 \pm 0.05^b$ |
| Assam o.p. | $17.13 \pm 0.07^a$ | $2.62 \pm 0.07^b$ | $3.80 \pm 0.07^a$ | $75.56 \pm 0.07^e$ |
| Darjeeling leaf | $21.08 \pm 0.06^d$ | $2.35 \pm 0.06^a$ | $6.55 \pm 0.06^b$ | $72.70 \pm 0.06^a$ |
| Nilgiri leaf | $18.76 \pm 0.04^b$ | $4.24 \pm 0.04^d$ | $7.50 \pm 0.04^c$ | $74.42 \pm 0.04^d$ |
| Nilgiri dust | $20.20 \pm 0.03^c$ | $4.51 \pm 0.03^e$ | $8.13 \pm 0.03^d$ | $73.42 \pm 0.03^b$ |
| Kelagur leaf | $19.21 \pm 0.05^b$ | $4.16 \pm 0.05^d$ | $6.88 \pm 0.05^b$ | $74.09 \pm 0.05^c$ |
| Kelagur dust | $20.24 \pm 0.07^c$ | $3.88 \pm 0.07^c$ | $7.32 \pm 0.07^c$ | $73.36 \pm 0.07^b$ |

Values are mean $\pm$ SD of triplicates

Values having different superscripts are significantly ($p < 0.05$) different

## Determination of TF/TR/TC and brightness of northern and southern Indian tea

Theaflavin (TF) and its derivatives, collectively known as *theaflavins*, are antioxidant polyphenols that are formed from flavan-3-ols such as in tea leaves during the enzymatic oxidation (called fermentation by the tea trade) of tea leaves, such as in black tea. Theaflavins are reddish in color. It is believed that theaflavins and thearubigins are important contributors to the taste of black tea. TF is associated with different beverage characters such as color, brightness, strength, briskness and quality. Theaflavins and thearubigin contents were high in Northern Indian teas as compared to south Indian tea, whereas brightness was more in Darjeeling tea. Theaflavin content showed a similar trend for both northern and southern Indian tea. Thearubigin content was high in Assam dust and Assam leaf followed by southern Indian teas. Total color is associated with total brightness which was higher for Darjeeling leaf 13.09%.

## Physico-chemical analysis of northern and southern Indian tea

Tea powders moisture content varied from 3.5 to 6.0%.

The results of the bulk density (packed/loose) showed a definite trend. Loose bulk density was the lowest attainable density and packed bulk density was the highest attainable density for a sample without compression. Loose bulk density and packed bulk density varied from 3.5 to 10.2% and 4.7 to 12.5%. This is attributed to the grades and granular size of the teas. Total soluble solid content extracted as a function of brewing time yield typical infusion curves in which the rate of extraction of tea solubles was high during the first minute of infusion but gradually fall with increasing time. Total soluble solids of Assam leaf (26.8), Darjeeling leaf (24.9) and Assam dust (24.8) respectively.

Caffeine is a purine derivative, which is 1,3,7-trimethylxanthine. Caffeine content in black tea was around 2–4% of dry weight. It has stimulating property and

**Table 5** Mineral profile of northern and southern Indian tea

| Minerals (µg/g) | Calcium | Copper | Iron | Magnesium | Manganese |
|---|---|---|---|---|---|
| Assam leaf | 3274 ± 0.2[h] | 17.6 ± 0.2[f] | 468.2 ± 0.7[h] | 1046.6 ± 0.5[g] | 899.8 ± 0.9[f] |
| Assam dust | 3212.4 ± 0.3[g] | 16.2 ± 0.8[e] | 382.2 ± 0.5[g] | 982.0 ± 0.3[f] | 580.6 ± 0.6[d] |
| Assam o.p. | 3147.0 ± 0.4[f] | 14.6 ± 0.6[d] | 345.6 ± 0.5[f] | 947.0 ± 0.3[e] | 768.0 ± 0.9[e] |
| Darjeeling leaf | 723.5 ± 0.8[a] | 2.8 ± 0.7[a] | 11.5 ± 0.8[a] | 184.8 ± 0.4[b] | 56.8 ± 0.7[a] |
| Nilgiri leaf | 3124.4 ± 0.7[d] | 29 ± 0.9[g] | 217.6 ± 0.4[d] | 934.6 ± 0.5[d] | 1163.8 ± 0.6[h] |
| Nilgiri dust | 3132 ± 0.6[e] | 16.8 ± 1.0[e] | 303 ± 0.3[e] | 806.4 ± 0.7[c] | 1033.4 ± 0.8[g] |
| Kelagur dust | 2165 ± 0.1[c] | 8.8 ± 0.2[c] | 133 ± 0.5[c] | 380 ± 0.5[b] | 568.8 ± 0.4[c] |
| Kelagur leaf | 988.8 ± 0.2[b] | 6.0 ± 0.3[b] | 61.5 ± 0.5[b] | 172.5 ± 0.2[a] | 128 ± 0.3[b] |

Values are mean ± SD of triplicates

Values having different superscripts are significantly ($p < 0.05$) different

removes mental fatigue. The contribution of caffeine to the infusion is the briskness and creaming property resulting from the complex formed by caffeine with polyphenols. Briskness is a taste and sensation while creaming is the turbidity that develops from a good cup of tea when cooled. Caffeine content was maximum in Assam dust (3.0%) followed by kelalgur dust (2.1%).

The color of the Assam tea changed due to brewing which was absent in Darjeeling tea. The Assam tea has high strength as compared to the Darjeeling tea. Darjeeling tea has a lighter taste. *L a b* value of northern and southern Indian teas showed a similar trend (Peterson et al. 2004).

Its taste has been described as a lighter muscatel owing to its spiciness. After drinking this tea, the drinker experiences a cool sensation in the mouth. On the other hand, Assam tea is known for its malty taste. Therefore comparatively Northern Indian teas are more superior to the Southern Indian teas.

### Mineral profile of northern and southern Indian tea

The results of minerals content of different profiles tea are given in Table 5. Among the investigated minerals, calcium was the highest whereas copper showed minimum levels. The levels of calcium were in the range of 723.5–3274 µg/g. The highest and the lowest levels of calcium were found in Assam leaf and Darjeeling leaf, respectively. Manganese was the second the highest element found in black tea samples. The levels of manganese were in the range of 56.8–1163.8 µg/g. Gallahera et al. (2006) and Yasmeen et al. (2000) reported 175 µg/g manganese in tea samples from Pakistan. Manganese content in black tea samples from China was reported to be 607 ± 2 µg/g Xie et al. (1998). Magnesium content was in the range of 184.8–1046.6 µg/g. Iron content was in the range of 11.5–468.2 µg/g. Pedro et al. (2001) have shown Fe to be in the range of 74–1000 µg/g for black tea samples. Minimum and maximum concentrations of Cu in our tea samples found in Darjeeling leaf (2.2 µg/g) and Nilgiri leaf (29 µg/g). Similar

results for copper have been reported by other workers (Narin et al. 2004; Ferrara et al. 2001; Xie et al. 1998).

## Conclusion

Comparison between northern and southern Indian tea indicate that tea from Northern India, Assam leaf has higher polyphenolic content followed by silver cloud leaf of Southern India. Higher the polyphenol content higher the quality of tea. Higher the concentration of total polyphenols, stronger the DPPH radical scavenging activity and reducing power assay. Of the chemical quality parameters, Assam leaf has higher theaflavin content used for assessing the quality of black tea, irrespective of geographical area of production. The results suggested that the tea growing environment largely influences the phenolic compound distribution in black tea. The contribution of caffeine to the infusion is the briskness in tea. The Northern Indian teas had the highest TF and TR. Loose bulk density and packed bulk density attributed to the grades and granular size of the teas.

## References

Borse BB, Jagan Mohan Rao L, Nagalakshmi S, Krishnamurthy N (2002) Fingerprint of black teas from India: identification of the regio-specific characteristics. Food Chem 79(4):419–424

Cloughley JB, Ellis RT, Pelnlington S, Humphrey P (1982) Volatile constituents of some Central Africa Black-tea clones. J Agric and Food Chem 80:842–845

Dreosti IE, Wargovich MJ, Yang CS (1997) Inhibition of carcinogenesis by tea: the evidence from experimental studies. CRC Crit Rev Food Sci Nutr 37:761–770

Ferrara L, Montesanoa D, Senatore A (2001) The distribution of minerals and flavonoids in the tea plant. II Farmaco 56:397–401

Gallahera RN, Gallaherb K, Marshalla AJ, Marshallc AC (2006) Mineral analysis of ten types of commercially available tea. J Food Comp Anal 19:S53–S57

Gulati A, Ravindranath SD (1996) Seasonal variation in quality of Kangra tea (Camellia sinensis) in Himachal Pradesh. J Sci Food Agric 71:231–236

Gulati A, Tamang MB, Ravindranath SD (1999) Clonal variation in quality related biochemicals in Kangra tea (Camellia sinensis). J Plant Crops 27:175–178

Howard GE (1978) The volatile constituents of tea. Food Chem 4:79–106

Jayaprakasha GK, Singh RP, Sakariah KK (2001) Antioxidant activity of grape seed (Vitis vinifera) extracts on peroxidation models in vitro. Food Chem 73:285–290

Narin I, Colak H, Turkoglu O, Soylak M, Dogan M (2004) Heavy metals in black tea samples produced in Turkey. Bull Environ Contam Toxicol 72:844–849

Oktay M, Culcin I, Kufrevioglu OI (2003) Determination of in vitro antioxidant activity of fennel (Foeniculum vulgare) seed extracts. Lebensmittel-Wissenschaft and -Technologie 36:263–271

Oyaizu M (1986) Studies on the product of browning reaction prepared from glucose amine. Jpn J Nutr 44:307–315

Pedro LF, Martin MJ, Pablos F, Gonzalez AG (2001) Differentiation of tea (Camellia sinensis) varieties and their geographical origin according to their metal content. J Agri Food Chem 49:4775–4779

Peterson J, Dwyer P, Jacques W, Rand R, Prior K, Chui K (2004) Tea variety and brewing techniques influence flavonoid content of black tea. J Food Comp Anal 17(3–4):397–405

Pura Naik J, Nagalakshmi S (1997) Determination of caffeine in tea products by an improved high-performance liquid chromatography method. J Agri Food Chem 45:3973–3975

Ramaswamy V (1995) An instrument for determining the free flow bulk density of black tea. Plant Chron 90:323–325

Singleton VL, Rossi JA (1965) Colorimetry of total polyphenolic with phosphomolybdic—phosphotungstic acid reagents. Am J Ecol Vitic 16:144–158

Subramaniam B (1995) Tea in India. Publication and information directorate. CSIR, and Wiley Eastern Ltd, New Delhi

Takeo T, Mahanta PK (1983) Comparison of black tea aromas of orthodox and CTC tea and of black tea made from different varieties. J Sci Food Agric 34:307–310

Tijburg LBM, Mattern T, Folts JD, Weisgerber UM, Katan MB (1997) Tea flavonoides and cardiovascular diseases: a review. CRC Crit Rev Food Sci Nutr 37:771–785

Ullah MR (1972) A simplified spectrophotometric method for measuring theaflavins and thearubigins in black tea liquors. Curr Sci 41:422–423

Ullah MR (1985) Aroma constituents of Assam and China hybrid teas and their manifestation during tea processing. Two Bud 32:60–62

Ullah MR (1986) A rapid procedure for estimating theaflavins and thearubigins of black tea. Two Bud 33:46–48

Wiseman SA, Balentine DA, Frei B (1997) Antioxidants in tea CRC. Crit Rev Food Sci Nutr 37:705–718

Xie M, von Bohlen A, Klockenkamper R, Jian X (1998) Multielement analysis of Chinese tea by total reflection X-ray fluorescence. Z Lebensm Unters Forsch A 207:31–38

Yamanishi T, Kobayashi AH, Uchida A, Mori S, Ohsawa X, Sasakura S (1968) Flavour of black tea: comparison of various types of black tea. Agric Biol Chem 32:379–386

Yang CS, Wang ZY (1993) Tea and cancer. J Nat Cancer Inst 85:1038–1049

Yang J, Liao K, Kim EJ, Yurkow CS, Yang CS (1998) Inhibition of growth and induction of apoptosis in human cancer cell lines by tea polyphenols. Carcinogenesis 19:611–616

Yasmeen F, Aleem R, Anwar J (2000) Determination of iron and manganese in tea samples by flame atomic absorption spectroscopy. J Chem Soc Pak 22:94–97