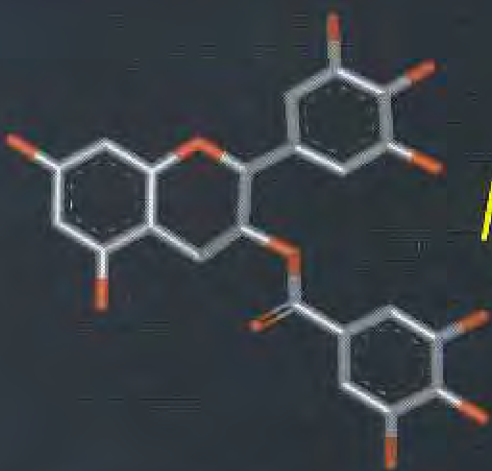

# Study to Promote the Industrial Exploitation of Green Tea Polyphenols in India

2003

Coverpage insets:
3D image of (-)- epigallocatechin-3-gallate
pictures of tea bud and flower

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# Study to Promote the Industrial Exploitation of Green Tea Polyphenols in India

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# Preface

In the recent years, there has been an increased interest in tea with a focus on its polyphenols, which have been demonstrated to prevent cancer development and metastasis. The tea polyphenols possess potent antioxidant properties, which safeguard the human body against a number of diseases including cardiovascular. The consumption of the required volume of tea beverage to obtain beneficial effects is not so feasible in those parts of the world where tea is not a common beverage. Developing non-conventional tea products with concentrated doses of polyphenols could be an option to overcome this problem which could benefit the society and the tea industry.

India is the largest producer of tea and it chiefly manufactures black tea. During the manufacture of black tea, the natural polyphenols of the tea are oxidized unlike in green tea. As a result, black tea possesses less health benefits than green tea.

India, traditionally home to black tea, has ignored the potential to produce and propagate green tea. With the increasing interest in green tea polyphenols all over the world, there is a potential for the Indian tea industry to enhance the green tea production and develop newer products based on natural tea polyphenols. To achieve this objective, it is important to identify the Indian tea cultivars with optimal content of tea polyphenols for industrial exploitation.

ICS took this initiative for the benefit of the tea industry in India and analyzed the samples of various cultivars with a view to identify the one containing the highest content of epigallocatechin gallate, the most active polyphenol in tea leaves. A large number of tea samples from different parts of the country were analyzed for their content of epigallocatechin gallate to provide a ready source of information to the Indian tea industry.

The results of the present study should help the Indian tea industry to focus on the production of green tea and develop non-conventional products to take advantage of the growing public interest in green tea polyphenols for health benefits.

Gennaro Longo
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# Contents

# 1. Introduction

Throughout the history of human civilization, man has selected three important non-alcoholic beverages from nature's resources, namely tea, coffee and cocoa. Among these, tea is the most widely consumed beverage. It is consumed by half of the world's population for its attractive aroma, taste and health benefits. It is a safe and easily affordable drink for all sections of society throughout the world and there is considerable evidence that consumption of tea is one of the most important ways to prevent a number of human ailments. It has evoked great interest in the medical community in the past few decades. Scientific research has validated the positive effects of tea on health, especially green tea, and shifted its reputation from being "the cup that cheers" to "the cup that heals".

Technically, tea is made from the top three leaves, a leaf bud and two tender leaves of the tea plant *Camellia sinensis* (L.) O. Kuntze (syn. *Thea sinensis* L.) family Theaceae (Figures 1-3).

The tea plant is native to Southeast Asia and is believed to have been discovered accidentally by the Chinese Emperor Shen Nung around 2737 B.C. Since then, its popularity has grown steadily to become China's most popular drink and its fame has spread to other parts of the world. In 1610 tea was taken by Dutch traders to Europe. In 1835 the East India Company established experimental tea plantations in the State of Assam in India. The first consignment of eight chests of Indian tea was auctioned in London in 1839, beginning the advent of Indian tea on the world market. Its cultivation then spread to Sri Lanka in 1857. Encouraged by this worldwide trend, Russia started tea cultivation with plantations in the Caucasus region in 1905. Tea cultivation in Indonesia started in 1910 and soon after the cultivation of tea was started in Kenya (1925) and other parts of Africa.[1]

## Types of Commercial Tea

Tea is commercially available in three types: green, black and the lesser-known oolong. These types vary in their method of manufacture and thereby in their chemical content. Black tea is widely used in India and green tea is popular in China, Japan and Taiwan. Oolong tea is mainly produced in China and Taiwan. Small quantities of green and oolong tea are also produced in India and Sri Lanka.  Worldwide, 80% of total production is  of black tea, 20% green and only 2% oolong tea.

## Green Tea

Green tea is unfermented and is the least processed of the three types of tea. In the manufacture of green tea, the freshly harvested leaves are steamed immediately to inactivate the enzymes, especially polyphenol oxidase (PPO), to prevent oxidation and polymerization of primary polyphenols.  In the cells primary polyphenols are located in the vacuoles and are kept separate from the enzymes that are present in the chloroplast. If the leaf is allowed to ferment the enzymes and polyphenols come in contact with each other resulting in oxidation and polymerization of polyphenols to form complex compounds.[2] Enzyme deactivation during the manufacturing process prevents polymerization of primary polyphenols, which pass as such into green tea.  Green tea infusion has a leafy taste, a smell of fresh vegetables, low caffeine content and no calories.[3]

*Figure 1:  Field view of a tea plantation*

*Figure 2: Growing tip of a tea plant*

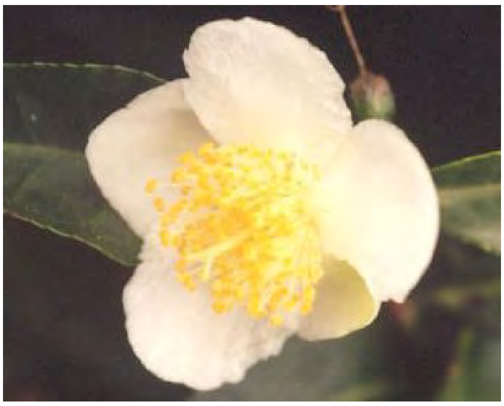


*Figure 3: Flower of a tea plant*

### Black Tea

Black tea is the most popular of the three varieties. It is a completely fermented type, prepared by keeping the leaves for fermentation after plucking. This process results in oxidation and polymerization of polyphenols, changing the nature of the chemical constituents of tea leaves and forming two groups of colouring polyphenols; the yellow group (theaflavins) and the red group (thearubigins).[3] These polyphenols are responsible for the briskness, strength, colour, taste, aroma and pungency associated with black tea. The infusion of black tea has a bright red or copper colour, astringent taste and characteristic aroma.[2]

### Oolong Tea

Oolong is a semi-fermented tea where primary polyphenols are allowed to partly oxidize. Oolong tea is not common and is intermediate in characteristics between green and black tea. Immediately after plucking, the tea leaves are partially fermented for about half the time of black tea. It has the colour of black tea and flavour of green tea.

## Cultivated Varieties of Tea

There are three cultivated varieties of tea: Cambodian, Chinese and Indian.[3] The different tea varieties hybridize freely. Varieties and their important characters are given in Table 1.

Table 1: Common cultivated varieties of tea

| Variety name | Taxonomic name | Important characteristics |
|---|---|---|
| Cambodian | *Camellia sinensis* var. *assamica* subsp. *lasiocalyx* | Grows to about 5 m in height. Used for hybridization with other varieties. |
| Chinese | *C. sinensis* var. *sinensis* | Grows up to 3 m. Small leaved, hardy plant able to withstand cold winters. |
| Indian | *C. sinensis* var. *assamica* | Grows from 3 to 18 m. Cultivated in India, mainly in Assam, Darjeeling and Nilgiris. |

## Tea Plucking Seasons

The flavour and the quality of tea are affected by the plucking season. During the first and second flush (Table 2), fine plucking of two leaves and a bud is made resulting in a high quality tea, whereas at other times three or even four leaves are plucked giving a lower quality. The tea plucking cycle is maintained at about 7 day intervals. The leaves are generally collected in bamboo baskets, taking particular care not to crush them. The plucking season of tea begins with the sprouting of plants towards the end of February and ceases in November as the plants are dormant in the winter period.

Table 2: Tea plucking periods

| Flush name | Period of year | Description |
|---|---|---|
| Easter or first flush | Late February–mid April | The leaves are tender and very light green in appearance. The infusion is light, clear, and bright, with a pleasant brisk flavour. |
| Spring or second flush | May–June | The spring flush is prominent in its quality. The leaves have a purplish bloom. The taste of the tea is full, with a fruity note. |
| Summer flush | July–September | Summer flush tea is stronger and bright. |
| Autumn flush | October–November | The leaves are large and give a round taste and coppery infusion. |

## Grading of Black Tea

The most distinguished tea comes from the first bud of the year, while twigs and other leaves down the stem tend to yield a poorer quality product. The best tea is hand-harvested.[4] The freshly gathered shoots are collected and subjected to withering, rolling, fermentation and drying. Black tea is sorted into various grades, mostly according to their leaf or particle size. The harvesting and manufacturing of tea has a considerable impact on the finished size of the leaf and tea grade. In the final sorting or grading, tea acquires the colourful names that are used in the tea trade. This nomenclature does not refer to the quality but to the size and appearance of the tea.

There are two main types of black tea, orthodox and CTC (crush, tear, curl), which fall into several grades. The manufacturing of orthodox black tea requires hand-plucking. This method yields all the possible leaf sizes and grades. CTC tea can be hand-plucked or machine-harvested. The leaves always break during manufacture. There are two broad categories of black tea grades: leaf (unbroken-leaf) and broken-leaf. The leaf grades have larger and intact leaves, greater visual appeal and fetch a higher price. Broken-leaf grades fetch a lower price, however they possess an excellent flavour and aroma, and give a stronger tea than the leaf grades.[5] The tea grades used in the tea trade are listed below in descending order of quality:[6]

- Supreme Finest Tippy Golden Flowery Orange Pekoe (SFTGFOP): the highest quality of FOP with plenty of golden tips. "S" stands for the supreme light coloured infusion of Darjeeling teas;
- Finest Tippy Golden Flowery Orange Pekoe (FTGFOP): high quality FOP;
- Tippy Golden Flowery Orange Pekoe (TGFOP): FOP with a greater proportion of golden tips than GFOP;
- Flowery Orange Pekoe (FOP): term used to describe the largest tea leaves;

- Orange Pekoe (OP): term often used to describe the largest leaf grade teas of Sri Lanka and occasionally of South India. The term "orange" is believed to have originated from the orange colour of tea leaves when they are plucked or from the Dutch House of Orange – the first importer of tea to Europe. The term "pekoe" is derived from a Chinese word referring to the tips of young tea buds;
- Broken Orange Pekoe (BOP): it is the highest of the broken-leaf grades;
- Broken Orange Pekoe Fannings (BOPF): tea leaves are smaller than BOP leaves and commonly used in tea bags;
- Golden Flowery Orange Pekoe (GFOP): similar to FOP, but with golden tips that are more delicate;
- Fannings: broken grade;
- Dust: broken grade and the lowest in quality.

These grades apply to black teas from India, Sri Lanka, Java, Sumatra, Africa and a few Chinese teas.

The grading of green and oolong teas is different. Green tea grades, unlike black tea, are related to quality and flavour. Green teas are priced according to variety, the province and estate where they are grown, and the flush or picking used.

# 2. Chemical Constituents of Tea

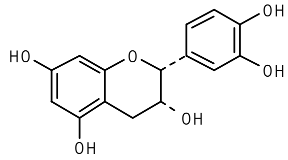
The constituents of green tea leaf include carbohydrates, proteins, polyphenols, caffeine, theanine, vitamins and minerals. Both commercially and biologically, polyphenols and caffeine are more important than the other constituents.

## Polyphenolic Constituents

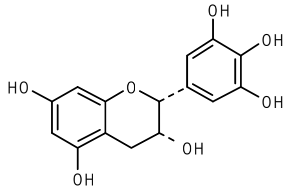
Green tea contains 30 to 42% polyphenols on a dry weight basis.[4] It contains predominantly flavanols, flavandiols and phenolic acids, such as gallic, coumaric or caffeic acid. The polyphenols are the derivatives of catechin and gallic acid.[7] Catechin is synthesized in tea leaves through mixed pathways of malonic and shikimic acid. Gallic acid is derived through shikimic acid pathway. The primary polyphenols of green tea are devoid of tanning properties and lack colour in tea infusions. They are bitter in taste and unique, as most of them are not found in other plants.[8]

Primary polyphenols are catechin derivatives and were first reported by Roberts and Woods in 1951 using paper chromatography.[9] The natural polyphenols in tea include (-)-epigallocatechin-3-gallate (EGCG), (-)-epigallocatechin (EGC), (-)-epicatechin-3-gallate (ECG), and epicatechin (EC). The highest concentration is of EGCG, followed by EGC, ECG and EC in decreasing order.[10-13] Other catechins including (+)-gallocatechin (GC), (-)-gallocatechin gallate (GCG), (-)-catechin gallate (CG) and (+)-catechin (C) are present in minor quantities.[2] A cup of green tea contains about 300 to 400 mg of polyphenols.[3]

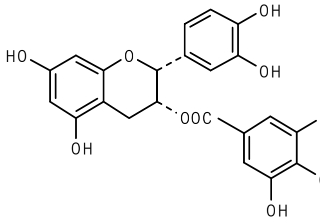
Primary polyphenols oxidize during the fermentation process of black tea and transform to compounds with tanning properties. Oxidized polyphenols are present up to 6%. Black tea polyphenols are divided into two groups: thearubigin and theaflavin (20 and 2 to 6%, respectively on a dry weight basis). Thearubigins have higher molecular weights and are chemically poorly characterized. They are partly polymeric proanthocyanidins, and impart colour to the tea infusions.[3, 14] Theaflavins in black tea are theaflavin 3-*O*-gallate, theaflavin 3′-*O*-gallate and theaflavin 3,3′-di-*O*-gallate.[3] They contribute to the briskness of the tea infusion. A good tea must contain a balanced quantity of these compounds.[4, 15]



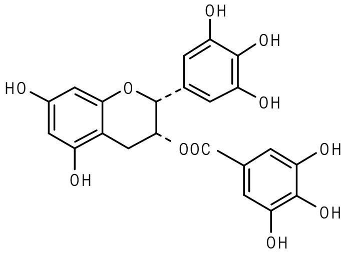
(-)-Epicatechin



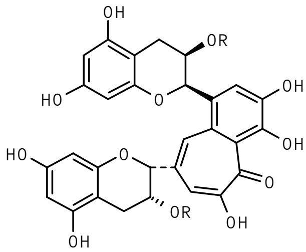
(-)-Epigallocatechin



(-)-Epicatechin-3-gallate

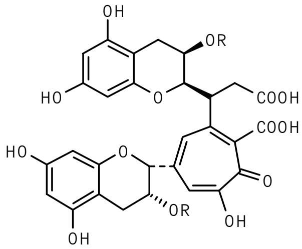


(-)-Epigallocatechin-3-gallate



Theaflavins

R=H or Galloyl



Thearubigins

A large number of dissimilar chemical reactions initiated by enzymes during fermentation are of practical use in the commercial manufacturing of black tea. The sequence of reactions in the process of tea fermentation is shown in Figure 4.[15]

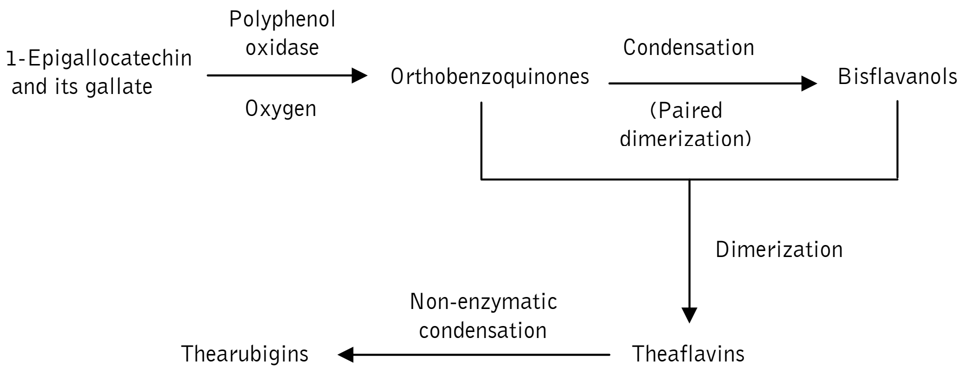



*Figure 4: Reactions involved in the process of tea fermentation*

The polyphenol oxidase of tea leaf works best at 28.3°C and the reaction slows down with an increase or decrease in temperature. Oxidation takes place more quickly in fresh leaf than in withered leaf.[16] The action of the oxidase converts 1-epigallocatechin and its gallate to corresponding orthoquinones, after which the enzyme action ceases. The changes that follow are non-enzymatic and the rate of reaction increases steadily with the rise in temperature. The four monomers of fresh tea leaves are epigallocatechin (EGC), epicatechin (EC) and their gallate esters namely epigallocatechin gallate (EGCG) and epicatechin gallate (ECG).[4, 16]

## Non-polyphenolic Constituents

### Caffeine

The presence of caffeine was first observed in tea in 1820.[8] A similar compound from tea was isolated and named theine, which was later identified to be the same as caffeine.[10] Caffeine content of tea leaves varies from 2 to 5%. Commercially, caffeine is prepared from tea leaves and tea wastes.[8, 17]

### Amino Acids and Other Nitrogenous Compounds

The content of total nitrogen in green tea extract ranges from 4.5 to 6%, and about half of it comes from free amino acids.[18] Theanine and glutamic acid are the major amino acids whereas aspartic acid and arginine are the minor amino acids present in tea.[19, 20] Theanine is a unique amino acid, produced by the tea plant and certain other species of *Camellia*. The rate of metabolism of theanine in tea leaves is slow but its transport from root to leaf is rapid, leading to its accumulation in the leaves. It is also one of the major components that gives green tea its specific taste and is antagonistic in action to caffeine.[21]

### Vitamins

Green tea contains about 0.3% of vitamin C, which is decomposed during manufacture of black and oolong tea. As a result, the vitamin C content of black and oolong tea is very low.[22]

### Inorganic Elements

Some specific inorganic elements present in tea are aluminium, fluorine and manganese.[10, 22] The level of aluminium and fluorine in tea leaves is higher than in other plants. It is presumed that the tea plant has a biochemical mechanism to neutralize the toxicity of aluminium. It has been observed that aluminium in tea leaf exists mainly in a chelated form, indicating that catechins prevent aluminium toxicity. These findings are important in the physiological significance of tea polyphenols.[23]

### Carbohydrates and Lipids

The carbohydrate content of green tea is about 40% and one third of it is cellulose. Starch is also present and affects the quality of green tea. Tea harvested in the morning has less starch and is of better quality in comparison to afternoon collections. Tea leaves also contain about 4.0% oil.[24]

# 3. Green Tea Polyphenols–Extraction and Estimation

## Extraction Methods

Polyphenols are extracted with water at boiling or near boiling temperature. A mixture of acetonitrile and water (1 : 1) has been used to extract tea polyphenols at room temperature. Different workers have used different ratios of tea leaves to solvent (1 : 40 to 1 : 500) and varying periods of extraction (3 to 60 min). The extract is filtered preferably through 0.45 μM membrane filter before being subjected to quantitative analysis in HPLC.[25-32]

## Estimation of Tea Polyphenols

A considerable amount of work has been done and reviewed on the quantitative estimation of green tea polyphenols.[33, 34] Tea polyphenols have been estimated by various methods, such as nuclear magnetic resonance,[35-37] near-infrared reflectance spectroscopy,[38] spectrophotometry,[39] column liquid chromatography,[30] thin layer chromatography and high performance thin layer chromatography (HPTLC),[40] liquid chromatography coupled with mass spectroscopy (LC-MS),[26] high performance capillary electrophoresis (HPCE)[31], and high performance liquid chromatography (HPLC).[41, 42] The HPLC is the most frequently used technique for estimating tea polyphenols. Many detection methods have been employed including a post-column reaction with 4-methylaminocinnamaldehyde and detection at 640 nm,[39] electrochemical detector,[43, 44] chemiluminiscent reaction[45] besides use of conventional UV-detectors.[29] In most cases reversed phase HPLC with UV-absorbance detection was the chosen method.[33] Separation is achieved using a C18 column. End capped, deactivated, monomeric C18 columns are preferred over non-deactivated or polymeric columns. Dalluge *et al.*[29] compared a variety of stationary phases and elution conditions. They observed that the stationary phases, with ultra pure silica and maximized coverage of the silica support, improved the separation. The presence of an acid in the mobile phase is essential for complete and efficient resolution of catechins, specifically for elimination of peak tailing and its detection at shorter wavelengths.[26, 46]

Liquid chromatography coupled with mass spectrophotometry provides a reliable approach to the analysis of catechins in pico-molar quantities in the complex matrices.

The first report on the use of LC-MS for the identification of catechins in tea appeared in 1993.[47] This report demonstrated the separation of a mixture of (-)-epigallocatechin-3-gallate (EGCG), (-)-epigallocatechin (EGC), (-)-epicatechin-3-gallate (ECG), and epicatechin (EC), employing thermo-spray ionization mass spectroscopy. Direct MS characterization of catechins in tea extracts without the use of LC has also been demonstrated. Electro-spray ionization, electron impact ionization, and fast atom bombardment mass spectroscopy have been employed to provide both molecular mass and structural information for catechins.[26, 48]

High Performance Capillary Electrophoresis (HPCE) is another technique that offers the advantage of short analysis time as compared to HPLC. Capillary zone electrophoresis (CZE) and micellar electro kinetic capillary chromatography (MEKC) with UV absorbance detection are the preferred capillary electrophoresis methods for the determination of catechins. In most cases, uncoated fused-silica capillaries have been used to effect the separations. In general, the MEKC methods provide better separation, resolution and quantification than CZE methods.[28, 31]

Gas chromatographic (GC) method utilizing glass columns or fused-silica capillary columns employing flame ionization detector (FID) has been developed for the estimation of catechins. As a prerequisite, a derivatization step is needed to convert catechins to trimethylsilyl (TMS) derivatives. Techniques of GC-MS and capillary column GC-FID were also used for the separation of catechins.[49, 50]

Thin layer chromatography of tea has been used for qualitative and quantitative determination of individual catechins. Zhu and Xiao[40] used silica gel plates and chloroform : ethyl formate : n-butanol : formic acid as a mobile phase to separate catechins and caffeine in green tea samples. The separated components were visualized under UV and the quantitative measurements were made based on the areas under the curve of the catechins spots. Four catechins, EC, EGC, ECG and EGCG were separated on silica plate using a mixture of chloroform, methanol and water. Detection of the catechins was done by colour formation with vanillin-hydrochloric acid reagent.

Singh *et al.*[39] have developed a simple method for separating, identifying and quantifying individual catechins based on two-dimensional paper chromatography. The catechins are identified as bright yellow spots on the chromatographic paper by spraying the paper with diazotized sulfanilamide, a reagent specific and selective for catechins. The sensitivity of visual detection is less than 1 μg of catechins.

The spectrophotomeric determinations of catechins are based on the formation of a green coloured complex with 4-dimethylaminocinnamaldehyde (DMACA), which is specific and selective for catechins.[39]

Total catechins have also been measured using biosensor.[51] Burdock tissue (*Arctium lappa* L., a biennial plant) contains polyphenol oxidase, which catalyses the oxidation of polyphenols. A catechin biosensor has been constructed that uses a slice of burdock tissue. As the catechins in a sample are oxidized, the oxygen electrode measures the amount of oxygen consumed. This biosensor was found to respond to various catechins namely, EC, EGC, ECG, EGCG and catechol. The biosensor has been applied for determination of total catechins in green tea infusions, but it is inadequate for accurate quantification because of the variability of response to the different catechins.

The quantitative determination of three catechins based on their chemiluminescent emission has also been reported. Catechins are reacted with hydrogen peroxide-acetaldehyde and horseradish peroxidase, which results in a distinct chemiluminescent emission at 630 nm.[45]

# 4. Biological Significance of Green Tea

The health benefits of tea have long been recognized in China and Japan. Scientific reports in the last two decades have validated many beneficial claims for tea. Understanding the mechanisms of the biological effects has interested scientists worldwide. The majority of beneficial effects have been attributed to the polyphenolic constituents.

Phenolic compounds are widely distributed in food of plant origin and are regarded as effective antioxidants. Several studies suggest that these components may be of importance in reducing the incidence of degenerative diseases such as cancer and arteriosclerosis. The most relevant compounds in dietary regimens are cinnamic acid derivatives and flavonoids. As natural polyphenols remain unchanged in green tea, it can be said that green tea is more beneficial than black tea, where fermentation during manufacture leads to the oxidation of primary polyphenols. The strong antioxidant potential of tea polyphenols is thought to mediate most of the beneficial effects of tea.52-55 Health benefits in relation to cancer, arthritis, cardiovascular diseases, diabetes, obesity and dental caries have been focused on scientific investigations in the recent past.

## Antioxidant Activity

The most potentially beneficial effects of tea catechins are attributed to their antioxidant properties that sequester metal ions, and scavenge oxygen species and free radicals.[54] The free radical scavenging property of catechins has been well studied particularly in the last decade. The early evidence of antioxidative property showed the EGCG-induced inhibition of soybean lipoxygenase ($IC_{50}$ = 10 to 20 μMm).[55] Later it was reported that EGCG inhibited TPA-induced oxidative DNA base modification in HeLa cells,[56] inhibited $Cu^{2+}$-mediated oxidation of low-density lipoprotein (LDL),[57] reduced *tert*-butyl hydroperoxide-induced lipid peroxidation,[58] and blocked the production of reactive oxygen species derived from NADPH,[59] cytochrome P-450 mediated oxidation of the cooked meat carcinogen and 2-amino-3-methylimidazo[4,5-f]quinoline.[60, 61] Low concentration of EGCG inhibited Jurkat T-cell DNA damage caused by hydrogen peroxide or 3-morpholinosydnonimine (a peroxynitrite generator) and at high concentration EGCG itself induced cellular DNA damage.[62] EGCG, the most abundant component present in tea extract, is also the most potent chemical of the epicatechin derivatives tested for biological activity. Along with other tea catechins and polyphenols, it is thought to prevent tumuorigenesis by protecting cellular components from oxidative damage through free radical scavenging. Indeed, a number of studies have demonstrated the free radical scavenging activity of EGCG[63-65] as well as its antimutagenic,[66, 67] antiangiogenic,[68, 69] antiproliferating and/or pro-apoptotic effects on mammalian cells both *in vitro* and *in vivo*.[70]

Tea catechins have been found to be better antioxidants than vitamin C, E, tocopherols and β-carotene.[71] The antioxidant property of the purified extract was less pronounced than the crude extract suggesting that many constituents contribute to the activity.[72] The polyphenols block free radical damage to lipids (found in cell membranes and serum lipids), nucleic acids and proteins (like those found as cellular enzymes and structural proteins). Damage to these cell components can lead to tumuor formation. The oxidative damage by oxygen free radicals of low-density lipoproteins (LDL) in serum leads to arteriosclerosis and coronary heart diseases. The oxidation of cell membranes and other cell components leads to ageing.[73]

The highest level of total catechins (72.9 mg/g of tea leaves) has been reported in samples of Chinese green tea and consequently showed the maximal antioxidant potential.[74] Oolong and black tea show weak protective action. The antioxidant activity of tea polyphenols is not only due to their ability to scavenge superoxides but also due to their ability to block xanthine oxidase and related transducers.[75] The polyphenols increased the activity of antioxidant enzymes e.g. glutathione peroxidase, glutathione reductase, glutathione-*S*-transferase, catalase and quinone reductase in the small intestine, liver and lungs which are the detoxifying enzymes of the body.[76] The antioxidant activity of tea is diminished by the addition of milk to the infusion, due to binding of tea polyphenols to milk proteins.

## Cardiovascular Activity

Several flavonoids and related phenolics have been reported to inhibit either enzymatic or non-enzymatic lipid peroxidation, an oxidative process implicated in several pathological conditions including atherosclerosis.[76] In particular, it has been suggested that tea polyphenols lower the oxidation of low-density lipoproteins (LDL) cholesterol, with a consequent decreased risk of heart diseases.[77] It has been observed that green tea polyphenols significantly reduce the levels of serum LDL, very low-density lipoproteins (VLDL) and triglycerides.[78] At the same time, they increase the levels of high-density lipoproteins (HDL).[79] A low ratio of triglycerides to HDL is an excellent marker for cardiovascular health.[80-82] In a cross-cultural correlation study of sixteen cohorts known as "The Seven Countries Study", the average flavanol intake was inversely correlated with mortality rates due to coronary heart disease after 25 years of follow-up.[83, 84] This observation has been strengthened by the finding that in hypercholesterolemic rats, green tea polyphenols lowered blood cholesterol levels and reduced blood pressure in spontaneously hypertensive animals.[85]

The quantities of antioxidants in the diet are inversely related to the risk of death from heart disease and of non-fatal heart attacks.[86] Green tea inhibits vascular smooth muscle proliferation, which is another factor contributing to the formation of arteriosclerotic plaque.[87] Tea polyphenols also interfere with the absorption of dietary fat and cholesterol.[88]

Green tea polyphenols have been found to play an important role in controlling essential hypertension by inhibiting angiotensin-I converting enzyme (ACE), which converts angiotensin-I to vasoconstrictive angiotensin-II.[2]

## Anticancer Activity

Experimental evidence points to the potential of green tea to protect against cancer at several stages of carcinogenesis, including cancer prevention,[89] endogenous carcinogen activation,[90] DNA damage and destabilization,[91] cell proliferation,[92] neoplastic growth and metastasis.[77, 89, 90, 93-97]

Tea, especially green tea, reduced the incidence of cancers of the stomach,[98, 99] small intestine,[98] pancreas,[100, 101] lung,[102] breast,[103] skin,[104] urinary bladder,[103] prostate,[105] oesophagus[98] and mouth.[106, 107] Also, it has been shown to reduce tumuor size and growth in cancer-bearing animals.[108, 109]

Green tea polyphenols directly inhibited the cytochrome P-450 enzyme systems (phase I enzyme) that play a pivotal role in carcinogen activation.[60] Concurrently, they boost the activity of phase II enzymes (e.g. glutathione transferase) that make xenobiotics hydrophilic for clearance from the body. The process is crucial for carcinogen detoxification.[93, 110] Recently, it was proposed to associate the anticancer activity of EGCG with the inhibition of urokinase, one of the most frequently expressed enzymes in human cancers.[111] However, the practicability of this study was later challenged due to the required dose levels.[110]

Green tea polyphenols also inhibited the reactions that give rise to nitrosamines both *in vitro* and *in vivo*.[112-114] Pretreatment with tea polyphenols resulted in substantial reduction of carcinogen binding to DNA.[115] The increased activity of glutathione peroxides and catalase in the intestine, liver and lungs of mice on pretreatment with tea polyphenols suggested that green tea polyphenols may suppress mutagenesis mediated by peroxides in the microenvironment of DNA.[95]

Tea polyphenols have also been shown to promote apoptosis of cancer cell lines such as prostate, lymphoma, colon and lung.[94] Modulating apoptosis is useful in the management, therapy and prevention of cancer. Reduction and inexpression of tumuor necrosis factor (TNF-α) may be the way polyphenols induce apoptosis. TNF-α is an endogenous tumuor promoter and a central mediator in chronic inflammatory diseases like rheumatoid arthritis and multiple sclerosis.[89, 108-110, 116, 117]

Green tea showed a protective effect against damage produced by UV radiation and reactive oxygen species to the dermis through apoptosis and inhibiting lipid peroxidation.[94] Topical application of EGCG decreased UV-induced erythema, edema and hypersensitivity.[110] Tea polyphenols also inhibited tumour promoters like okadaic acid and teleocidin in the skin.[117]

DNA-reactive genotoxic carcinogens, which affect the DNA of a normal cell, are responsible for the majority of human cancers. Polyphenols have been shown to stimulate the repair process of nucleotide excision by removing DNA-adducts produced by carcinogens.[95] The structure of tea polyphenols possesses strong nucleophilic centres that react with electrophilic carcinogens to form an adduct, which results in the prevention of cancer.[96]

Effects of polyphenols on nitric oxide (NO) induction have also been studied. EGCG inhibits the induction of NO synthase (NOS) via down regulation in the transcription nuclear factor, thus inhibiting induction of NOS. The NO is a bioactive molecule that plays an important role in inflammation and carcinogenesis.[110]

Green tea has been reported to be of great use in the modulation of cancer chemotherapy.[89, 97, 118] It enhances the effect of antitumuor drugs, which in many cases have resulted in serious complications as a result of effects on normal cells. Green tea has been reported to be beneficial as it increases the drug concentration (e.g. doxorubicin, sulindac) in the tumuor cells with no increase in normal cells. As it is a beverage, it reduces the burden on the patient of taking too many medicines.[97, 118, 119]

Bioavailability studies of polyphenols (especially EGCG) reported a wide distribution in multiple organs (digestive, liver, pancreas, mammary gland, and skin).[120] After intravenous administration of catechins in rats, it was seen that the half-life of EGCG, ECG and EC were 191, 362 and 45 min, respectively.[121] When pure EGCG was given, a shorter half-life was observed suggesting the effect of other components in the extract on the plasma concentration and the elimination of EGCG.[122-124]

Epidemiological studies in Japan and China suggest that the relatively high consumption of green tea (over 10 cups a day) is associated with substantial reduction in the risk of cancers of the skin, oesophagus, stomach, breast, lung and bladder.[117, 122, 124-127] Theaflavins are also reported to inhibit cancer of the lung and oesophagus.[89, 122] Thus therapeutic levels of polyphenols can exert important antimutagenic and anticarcinogenic effects in humans.

Most of the reports on cancer prevention came from Asians, who drink predominantly green tea, whereas studies involving black tea in Europeans observed infrequent protective effects.[122, 128]

## Antidiabetic Effect

The ability of polyphenols to lower blood glucose has been confirmed in diabetic rats. Both green tea and black tea were shown to possess antidiabetic activity and were effective in the prevention and treatment of diabetes.[129] Tea polyphenols lower the serum glucose by inhibiting the activity of the starch digesting enzyme, amylase. Tea inhibits both salivary and intestinal amylase. As a result, the starch is broken down more slowly and the sudden rise in serum glucose is minimized. In addition, tea also reduces the intestinal absorption of glucose.[129-131]

## Antiarthritic Activity

Polyphenols from green tea have demonstrated an exceptional protection against arthritis. The major polyphenols showing antiarthritic effect include epicatechin, epigallocatechin, epicatechin-3-gallate and epigallocatechin-3-gallate.

In a study conducted on mice, green tea polyphenols significantly reduced the incidence of arthritis (33 to 50%). Furthermore, the arthritic mice in the polyphenols fed group showed a less severe form of the disease. Histopathological examination of arthritic joints of mice from the control group revealed extensive cartilage and bone erosions with massive infiltration of mono-nuclear cells and fibroblasts, whereas the green tea polyphenols fed group showed a marked reduction in the number of infiltrating cells with no significant cartilage or bone erosions.[132]

Expression of cyclooxygenase-2 enzyme (COX-2) is upregulated in arthritis. It has been found that green tea polyphenols inhibit the production of COX-2 in arthritic joints.[132, 133] There was also a marked reduction in other inflammatory mediators such as

IFN-γ and TNF-α. The neutral endopeptidase activity is decreased on the administration of green tea polyphenols.[132] It was observed that total IgG and type II collagen specific IgG levels were lower in the serum and arthritic joints of mice fed with green tea polyphenols.[132] Catechins inhibited the release of lysosomal enzymes, the chemiluminescence response and the production of free radicals.[134, 135]

The studies suggested that a polyphenolic fraction of green tea rich in antioxidants might be useful in the prevention and severity of arthritis.[132] Since there is no cure for the rheumatoid and therapy aims at controlling the symptoms, a slight modification in lifestyle and the addition of green tea in the diet can reduce the risk of this disease. This has been demonstrated by a study conducted on mice, over a period of 85 days, which were administered an extract equivalent to a human drinking 4 cups of green tea per day.[2]

## Antiplaque Activity

In the discovery of antibacterial activities of green tea polyphenols, it was found that these compounds inhibit the growth and adherence of oral bacteria.[136, 137] Green tea extract acted in three ways. Firstly, it inhibited the growth of periodontal disease producing bacterium, *Porphyromonas gingivilis* and decay-causing bacteria such as *Streptococcus mutans*.[138, 139] Therefore, green tea as a mouth rinse resulted in less plaque and periodontal diseases. Secondly, it inhibited the enzyme amylase present in the saliva, and the starch in the mouth did not get converted into glucose and maltose.[130, 139] Less nutrition was thus available to decay-causing bacteria. Lastly, it increased the resistance of tooth enamel to acid-induced erosion.[140]

## Antiviral Activity

Tea extract has been shown to have virucidal activity against polio, influenza, vaccinia and herpes simplex virus.[141]

## Anti-AIDS Activity

The long-term efficacy of new combination drug therapies for HIV infection is limited by the tendency of transfected HIV to mutate and become drug resistant. Green tea polyphenols are antimutagenic and act as effective adjuvants to drug therapy.[94] It has been discovered that polyphenols from green tea and their oxidation products could inhibit the reverse transcriptase or polymerase of several types of viruses, including HIV-1 and herpes simplex-1.[130, 142, 143] However, research in this area is still in its initial stages.

## Anorectic Effect

The catechin polyphenols inhibit catechol-*O*-methyl transferase[144] and caffeine inhibits transcellular phosphodiesterase, thus stimulating thermogenesis and assisting the management of obesity.[145, 146] The release of glucose is slowed down by tea and thus harmful spiking of insulin is prevented. Since insulin is the most fattening hormone, fat burning overtakes fat storage.[130]

## Antimicrobial Activity

The crude catechins and theaflavins have been found to have an antibacterial activity. They are believed to damage bacterial cell membranes. Tea has been used in the treatment of diarrhoeal infections, cholera and typhus.[147] Polyphenols kill the spores of *Clostridium botulinum* and thus display antibacterial activity against food borne diseases and are also effective against heat-resistant bacilli like *Bacillus subtilis, B. cereus, Vibrio parahaemolyticus* and *Clostridium perfringens*.[148] Tea extracts also inhibited growth of *Staphylococcus aureus, S. epidemidis, Salmonella typhi, Shigella* spp., and *Streptococcus mutans*.[149] However, they show no activity against some common bacilli such as *Salmonella enteridis, Escherichia coli* or *Yersina enterocolitica*.[2, 149] Green tea also has protozoacidal properties.[2, 130]

## Other Biological Effects

Recently, reports have been published showing that green tea polyphenols exhibit neuromuscular, antiangiogenic, antihepatotoxic, antiproliferative/apoptotic and immuno-modulatory effects.[150]

In summary, it can be concluded that a number of diseases can be prevented by the incorporation of green tea into the diet. It has been seen that at least 10 cups a day of 100 ml each (3 to 4 g of polyphenols) are needed to have a significant beneficial effect. However, theories on this aspect vary.[108]

# 5. Experimental

## 5.1 Materials and Methods

### Tea Samples

Samples of different cultivated varieties of green tea were collected from three major tea-growing areas in India including Palampur (North India), Assam and Darjeeling (Northeast India), Coonoor and Ooty (South India). Samples of three main cultivated varieties, i.e. *C. sinensis* var*. cambodiensis*, *C. sinensis* var*. assamica* and *C. sinensis* var*. sinensis* and their hybrids presently under cultivation in India were collected from these areas. The collection from Palampur was done at three different times of the plucking season, first in April (beginning), then in September (mid-season-growing burst after rainy season) and finally in October and November (end of season). Darjeeling samples were collected in June and samples from Coonoor and Ooty were collected in October. Details of the collections are provided in Table 3. The collected samples were treated as in the manufacture of green tea by subjecting them to steam and drying under controlled conditions. In addition, some samples were sun-dried without steaming. The leaves were powdered prior to extraction.

### Solvents, Reagents and Chromatographic Plates

(-)-Epigallocatechin-3-gallate (EGCG) and (-)-epicatechin-3-gallate (ECG) were obtained from Sigma-Aldrich Chemicals. The solvents, chemicals and reagents were either obtained from E. Merck, or S. D. Fine Chemicals, India. Distilled water was used wherever water is mentioned. Laboratory-made TLC plates (silica gel G, 0.2 mm thickness) activated at 110°C for 30 min were used for qualitative work. For quantitative analysis, precoated silica gel G plates (20 x 20 cm, 0.2 mm thickness, plastic base, E. Merck) cut into desired size were used.

### Preparation of Tea Extract

The tea extracts were prepared by hot maceration of tea leaves with the appropriate solvent. At the end of the extraction, the material was filtered under reduced pressure and the marc was washed with a specified volume of fresh solvent while continuing filtration. The final volume of the filtrate was made to a specified volume before subjecting it to analysis. The quantity of tea leaves, its ratio to solvent, extraction period, temperature, volume of solvent used for washing the marc and the final volume of the extract were predetermined for each set of extraction. Initial experiments were conducted to optimize the extraction procedure with respect to the choice of solvent, temperature, period of extraction and particle size of tea leaves. The optimized extraction conditions were subsequently used to determine the amount of polyphenols in different varieties of tea.

Table 3: Collection details of tea samples

| Area | Place of collection | Clone/variety | Month and year of collection |
|---|---|---|---|
| North | Palampur | TV-23 | Sep. and Nov. 2001, Apr. 2002 |
| | | Kangra Asha | Nov. 2001, Apr. and Sep. 2002 |
| | | TV-1 | Nov. 2001 and Apr. 2002 |
| | | Kangra Jawala | Apr. and Sep. 2002 |
| Northeast | Darjeeling | P-126 | Jun. 2002 |
| | | Takda-7, 8 | Jun. 2002 |
| | | Tenali-17 | Jun. 2002 |
| | | TV-1 | Jun. 2002 |
| | | TV-9 | Jun. 2002 |
| | | TV-18 | Jun. 2002 |
| | | TV-20 | Jun. 2002 |
| | | TV-23 | Jun. 2002 |
| | | TV-26 | Jun. 2002 |
| | | China Bush + Clones | Jun. 2002 |
| South | Ooty | China Variety | Oct. 2002 |
| | | VP-Clones | Oct. 2002 |
| | | BSS-1 | Oct. 2002 |
| | | C-1 | Oct. 2002 |
| | | CR-6017 | Oct. 2002 |
| | Coonoor | UPASI-3 | Oct. 2002 |
| | | TRI-2024 | Oct. 2002 |
| | | TRI-2025 | Oct. 2002 |
| | | TRI-2026 | Oct. 2002 |
| | | UPASI-2 | Oct. 2002 |
| | | UPASI-3 | Oct. 2002 |
| | | UPASI-8 | Oct. 2002 |
| | | UPASI-9 | Oct. 2002 |
| | | UPASI-10 | Oct. 2002 |

### Quantitative Analysis

#### *TLC Method*

All quantitative estimations were made in triplicate, using a CAMAG TLC Scanner 3 and CATS software version 4.06. The known amount of tea extract was applied on a precoated TLC plate and the plate was developed in an appropriate solvent system. The plate was dried in a current of hot air and scanned in the TLC scanner at 280 nm. The area under the curve (AUC) for the peak corresponding to the spot of each polyphenol was noted and the concentration of different polyphenols in the extract was determined from their respective standard plots.

#### *HPLC Method*

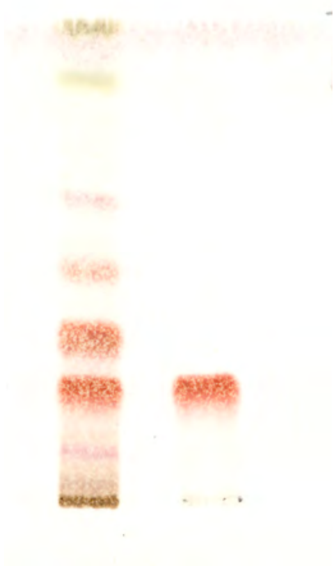
The analytical determinations of EGCG and ECG were carried out using reverse phase-HPLC at isocratic mode. The Waters HPLC system equipped with automated gradient controller, 510 pumps, U6K injector, 481 detector and 746 data module was used for the analysis. The Waters $\mu$-bondapak C18 (3.9 x 300 mm) column at ambient temperature 24 to 28°C, mobile phase water : methanol : acetic acid (70 : 30 : 0.5), flow rate 1.0 ml / min and UV detection at 280 nm were used in the HPLC analysis. All extracts were prepared and analyzed in triplicate. The extract was filtered through 0.45 $\mu$m filter before injecting 5 $\mu$L of the appropriately diluted sample.

### Stability Studies

The degradation pattern of EGCG was studied in buffers of pH 1.2, 2.0, 4.0, 6.0, 7.0 and 8.0 (Appendix 1) over a period of 48 h. The change in concentration of EGCG in buffered solution was monitored through quantitative TLC using CAMAG TLC Scanner.

## 5.2 Development of TLC Fingerprint Profile of Green Tea

A methanol extract of green tea was prepared by refluxing 2 g tea leaves in 50 ml methanol for 1 h in a water bath at 80°C. A variety of solvent systems were tried in order to obtain the best resolution. The spots were visualized by spraying the plate with 1% vanillin in sulphuric acid, followed by heating for 10 min at 110°C. A solvent system comprised of chloroform : acetone : formic acid (5 : 4 : 1) produced the most resoluted profile. The TLC fingerprint profiles of polyphenolic and non-polyphenolic constituents of tea are shown in Figure 5.



A.

B.

*Figure 5: TLC fingerprint profile of polyphenolic (A) and non-polyphenolic (B) constituents of tea*

## 5.3 Preparation of Standard Plots of EGCG and ECG

### Preparation of Standard Plots of EGCG

A standard solution of EGCG was prepared by dissolving 2.41 mg of EGCG in 25 ml methanol. The varying volumes of standard solution 0.5 to 16.0 µL in geometric progression were applied in triplicate on a precoated TLC plate. The plate was developed in chloroform : acetone : formic acid (5 : 4 : 1), dried and then scanned at 280 nm in the TLC scanner. The AUC for each quantity was noted (Table 4 and Figure 6) to construct the standard plot.

Table 4: Mean peak areas of EGCG in TLC analysis

| EGCG (µg) | [a]Mean AUC± SD |
|---|---|
| 0.0492 | 313 ± 5.90 |
| 0.0984 | 631 ± 26.71 |
| 0.1968 | 1219 ± 49.08 |
| 0.3936 | 2471 ± 23.61 |
| 0.7872 | 4808 ± 190.59 |
| 1.5744 | 8853[b] |

[a]n= 3, [b]n= 1

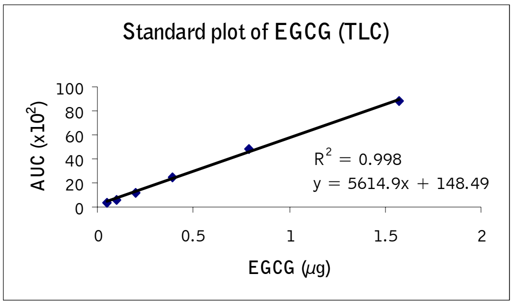



*Figure 6: Standard plot of EGCG in TLC analysis*

The standard plot for HPLC analysis was constructed by injecting in triplicate a constant volume of 5 μL of serially diluted concentrations and noting AUC corresponding to each concentration (Table 5 and Figure 7). Reverse phase C18 column and water : methanol : acetic acid (70 : 30 : 0.5) at 1 ml / min flow rate were used for the analysis.

Table 5: Mean peak areas of EGCG in HPLC analysis

| EGCG (ng) | [a]Mean AUC±SD |
|---|---|
| 9.85 | 23471 ± 19.0 |
| 19.70 | 46026 ± 855 |
| 39.35 | 88815 ± 36 |
| 78.50 | 175341 ± 2502 |
| 157.50 | 355954 ± 6708 |
| 283.20 | 635194 ± 3077 |

[a]n= 3

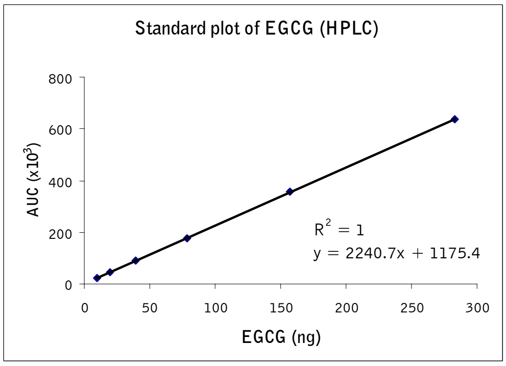



*Figure 7: Standard plot of EGCG in HPLC analysis*

## Preparation of Standard Plots for ECG

The standard plots of ECG for TLC and HPLC analysis were constructed similarly as described for EGCG, using the same conditions of the analysis in TLC and HPLC. The standard solution of ECG was prepared by dissolving 3.02 mg of ECG in 10 ml methanol. In TLC 0.5 to 2.5 μL of standard solution in increments of 0.5 μL was applied and AUC was noted (Table 6) to construct the standard plot (Figure 8).

Table 6: Mean peak areas of ECG in TLC analysis

| ECG(μg) | [a]Mean AUC±SD |
|---|---|
| 0.0302 | 211 ± 12.28 |
| 0.0604 | 411 ± 9.74 |
| 0.0906 | 571 ± 26.0 |
| 0.1208 | 761 ± 30.26 |
| 0.1510 | 953 ± 31.47 |

[a]n= 3

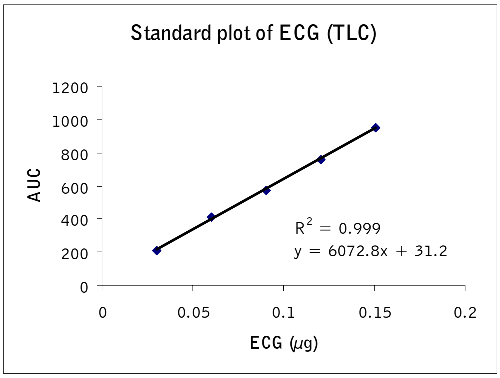



*Figure 8: Standard plot of ECG in TLC analysis*

In HPLC analysis, standard solution was diluted to inject a constant volume of 5 μL. The data and standard plot for HPLC are given in Table 7 and Figure 9, respectively.

Table 7: Mean paek areas of ECG in HPLC analysis

| ECG (ng) | [a]Mean AUC±SD |
|---|---|
| 09.40 | 26898 ± 736 |
| 18.85 | 48516 ± 1079 |
| 37.50 | 100503 ± 2205 |
| 75.50 | 188155 ± 2252 |
| 151.00 | 378395 ± 3563 |
| 302.00 | 761380 ± 5851 |

[a]n= 3

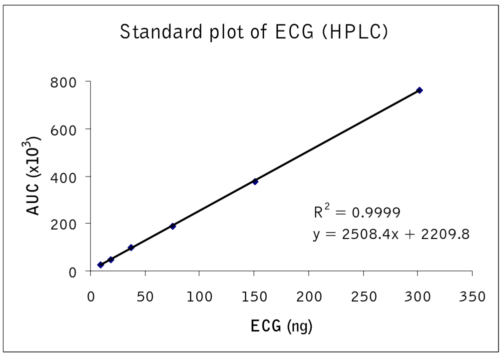



*Figure 9: Standard plot of ECG in HPLC analysis*

## 5.4 Optimization of Extraction Procedure for Tea Polyphenols

### Effect of Solvent on EGCG Extraction

The tea sample (2 g) was refluxed separately in 50 ml each of methanol, water and ethyl acetate for 30 min at 60°C. The extract was filtered under vacuum while hot. The marc was washed with 20 ml of additional extraction solvent while continuing filtration. The volume of the filtrate was made up to 100 ml. 1µL of this extract was applied on a precoated TLC plate, developed in a solvent system consisting of chloroform : acetone : formic acid (5 : 4 : 1) and scanned using TLC scanner. The AUC for peak corresponding to EGCG was noted and the concentration in the extract was calculated from the standard plot. The results are shown in Table 8 and Figure 10.

Table 8: Effect of solvent on extraction of EGCG

| Solvent | EGCG (mg/g) ± SD[a] |
|---|---|
| Methanol | 57.12 ± 0.68 |
| Water | 48.39 ± 0.20 |
| Ethyl acetate | 4.32 ± 0.30 |

[a]n= 3

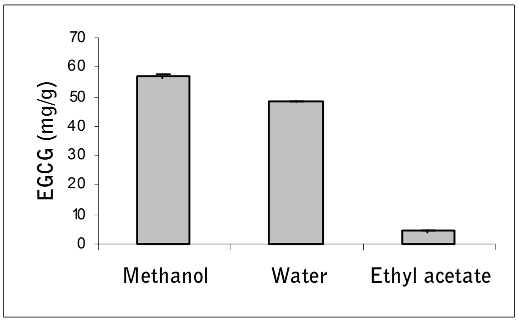



*Figure 10: Effect of solvent on extraction of EGCG*

### Effect of Time and Temperature on Extraction of EGCG

Tea leaf powder (2 g) was refluxed separately with 50 ml each of methanol and water at different temperatures (40, 60, 80 and 98°C) on a water bath for different time intervals (15, 30, 45, 60, 75 and 90 min). After completion of each extraction, the final volume of the extract was made to 100 ml. 1µL of this extract was applied on the TLC plate and the EGCG content was determined using the standard curve. Extractions were carried out in triplicate and each extract was applied in triplicate. Table 9 shows the extracted amount of EGCG. In one study the marc was re-extracted with fresh solvent to determine if the extraction was complete.

Table 9: Effect of time and temperature on extraction of EGCG

| Extraction time (min) | Solvent | EGCG (mg/g) ± SD[a] | | | |
|---|---|---|---|---|---|
| | | 40°C | 60°C | 80°C | 98°C |
| 15 | Methanol | 15.25 ± 0.37 | 54.12 ± 0.06 | 42.73 ± 1.08 | |
| | Water | 16.44 ± 0.63 | 40.65 ± 0.14 | 42.72 ± 1.09 | 53.60 ± 1.20 |
| 30 | Methanol | 20.55 ± 0.20 | 57.12 ± 0.68 | 47.55 ± 0.36 | |
| | Water | 21.42 ± 0.92 | 48.39 ± 0.20 | 53.51 ± 0.27 | 48.48 ± 0.62 |
| 45 | Methanol | 23.00 ± 1.16 | 58.24 ± 0.03 | 48.22 ± 0.59 | |
| | Water | 24.92 ± 0.62 | 46.09 ± 0.08 | 53.64 ± 0.36 | 49.55 ± 0.84 |
| 60 | Methanol | 29.98 ± 0.22 | 59.06 ± 0.26 | 48.68 ± 0.35 | |
| | Water | 23.82 ± 0.74 | 50.30 ± 1.19 | 54.02 ± 0.30 | 48.00 ± 0.96 |
| 75 | Methanol | 24.14 ± 0.31 | 58.74 ± 0.93 | 40.66 ± 0.65 | |
| | Water | 27.52 ± 0.30 | 49.18 ± 0.10 | 53.45 ± 0.13 | 49.45 ± 0.13 |
| 90 | Methanol | 26.52 ± 0.51 | 58.70 ± 0.52 | 39.96 ± 0.31 | |
| | Water | 23.90 ± 0.50 | 48.85 ± 0.47 | 53.40 ± 0.07 | 49.15 ± 0.13 |

[a]n= 3

## Effect of Time on Extraction of EGCG in Water

The tea leaf powder (2 g) was extracted with 50 ml of water at 98°C for varying period of extraction from 5 to 90 min. The amount of extracted EGCG was determined using the TLC method of analysis. The data are shown in Table 10 and Figure 11.

Table 10: Effect of time on extraction of EGCG in water

| Extraction time (min) | EGCG (mg/g) ± SD[a] |
|---|---|
| 5 | 54.30 ± 0.16 |
| 10 | 53.62 ± 0.07 |
| 15 | 53.60 ± 1.20 |
| 30 | 48.48 ± 0.62 |
| 45 | 49.55 ± 0.84 |
| 60 | 48.00 ± 0.96 |
| 75 | 49.45 ± 0.13 |
| 90 | 49.15 ± 0.13 |

[a]n= 3

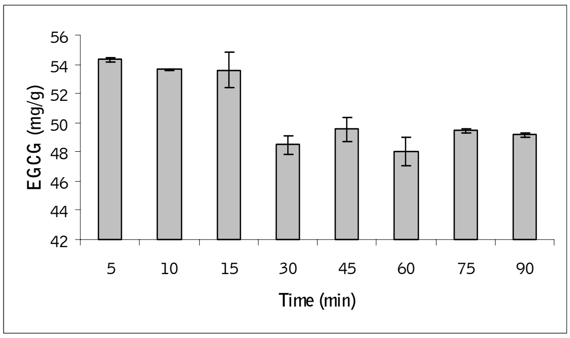



*Figure 11: Effect of time on extraction of EGCG in water*

## Effect of Sample to Solvent Ratio on Extraction of EGCG

Different ratios of sample to water were used to extract EGCG and the other parameters were kept constant as optimized for the extraction with water. After completion of each extraction, the quantity of EGCG in the extract was determined by TLC. The effect of volume of water on extraction is given in Table 11 and Figure 12.

Table 11: Effect of sample: water ratio on extraction of EGCG

| Sample : solvent (g : ml) | EGCG (mg/g) ± SD[a] |
|---|---|
| 1 : 10 | 40.21 ± 2.40 |
| 1 : 25 | 53.27 ± 0.58 |
| 1 : 50 | 54.58 ± 0.18 |
| 1 : 100 | 55.62 ± 0.67 |
| 1 : 150 | 61.01 ± 2.66 |
| 1 : 200 | 57.64 ± 0.60 |
| 1 : 400 | 24.98 ± 0.45 |

[a]n= 3

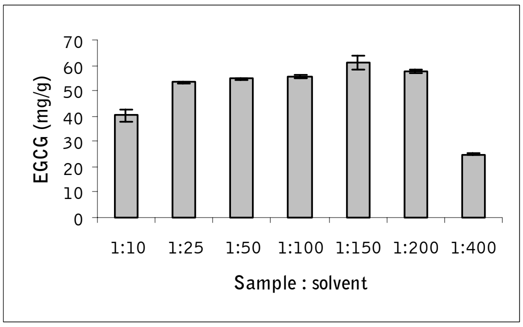



*Figure 12: Effect of sample: water ratio on extraction of EGCG*

## Effect of Shaking on Extraction of EGCG

Tea leaves (4 g) were extracted with water at 98°C for 5 min. The flasks were shaken continuously in a shaker. The extraction yield was compared with the control yield. The results are given in Table 12 and Figure 13.

Table 12: Effect of shaking on extraction of EGCG

| Treatment | EGCG (mg/g) ± SD[a] |
|---|---|
| Control | 14.80 ± 0.06 |
| Shaking | 21.16 ± 0.03 |

[a]n= 3

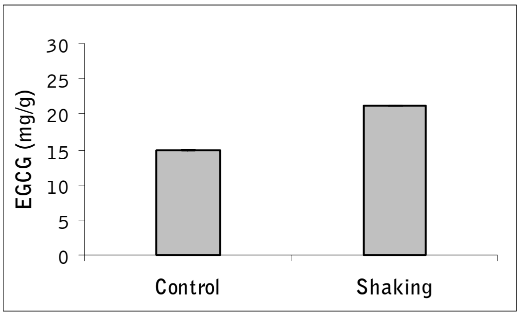



*Figure 13: Effect of shaking on extraction of EGCG*

## Effect of Particle Size on Extraction of EGCG

The tea leaves (2 g each) powdered into coarse, moderately coarse, moderately fine and fine powder (Appendix 2) were extracted in methanol using optimized conditions of time and temperature. The results are shown in Table 13 and Figure 14.

Table 13: Effect of particle size on extraction of EGCG

| Powder grade | EGCG (mg/g) ± SD[a] |
|---|---|
| Coarse | 55.88 ± 0.73 |
| Moderately coarse | 56.54 ± 0.80 |
| Moderately fine | 58.85 ± 0.49 |
| Fine | 56.34 ± 0.70 |

[a]n= 3

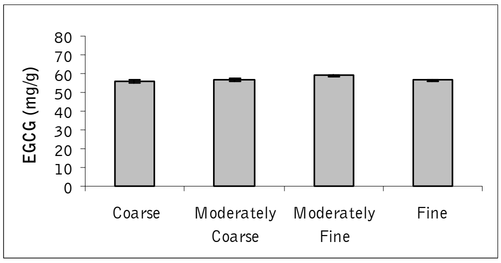



*Figure 14: Effect of particle size on extraction of EGCG*

## 5.5 Studies on Stability of Tea Polyphenols (EGCG)

### Effect of pH on Degradation of EGCG

The tea extract was prepared using the optimized method. Different aliquots of 10 ml each of this extract were concentrated to dryness and dissolved separately in 10 ml buffer of pH 1.2, 2, 4, 6, 7 and 8. The buffered extracts were stored at room temperature (26 to 28°C) and the EGCG content was monitored through quantitative TLC at different time intervals (Table 14). The control extract was concentrated to dryness and dissolved in 10 ml of distilled water. The percentage of degradation of EGCG at different time intervals is given in Table 15 and Figure 15.

Table 14: Effect of pH on EGCG degradation

| pH of solution | EGCG (mg/g) ± SD[a] at different time intervals (h) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 4 | 8 | 24 | 48 |
| Control | 40.86 ± 0.85 | 36.07 ± 0.43 | 32.63 ± 0.44 | 30.80 ± 0.10 | 29.98 ± 0.78 | 25.35 ± 0.18 | 23.18 ± 0.56 |
| 1.2 | 50.88 ± 0.88 | 49.55 ± 0.78 | 49.20 ± 0.53 | 49.18 ± 1.05 | 49.12 ± 0.44 | 49.14 ± 1.11 | 47.22 ± 0.84 |
| 2.0 | 44.84 ± 0.81 | 43.60 ± 0.52 | 43.44 ± 0.85 | 43.42 ± 0.96 | 43.44 ± 0.80 | 43.40 ± 1.10 | 41.96 ± 0.53 |
| 4.0 | 61.75 ± 0.53 | 60.01 ± 1.02 | 59.93 ± 0.95 | 59.96 ± 0.66 | 59.88 ± 0.89 | 59.86 ± 0.59 | 46.12 ± 0.82 |
| 6.0 | 50.65 ± 0.75 | 48.98 ± 0.96 | 48.98 ± 0.75 | 48.78 ± 1.05 | 48.75 ± 1.06 | 40.70 ± 1.02 | 39.54 ± 0.64 |
| 7.0 | 39.95 ± 0.37 | 35.62 ± 0.26 | 35.64 ± 0.77 | 35.58 ± 0.34 | 32.40 ± 0.54 | 25.19 ± 0.95 | 25.00 ± 0.46 |
| 8.0 | 28.15 ± 0.53 | 22.14 ± 0.84 | 19.95 ± 0.75 | 17.60 ± 0.46 | 16.65 ± 0.85 | 12.25 ± 0.52 | 09.64 ± 0.46 |

[a]n=3

Table 15: Per cent degradation of EGCG at different pH

| pH of solution | EGCG degradation (%) at time intervals (h) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 4 | 8 | 24 | 48 |
| Control | 0 | 11.6 | 19.9 | 24.3 | 26.3 | 37.5 | 42.8 |
| 1.2 | 0 | 2.6 | 3.2 | 3.3 | 3.4 | 3.4 | 7.1 |
| 2.0 | 0 | 2.7 | 3.0 | 3.1 | 3.1 | 3.2 | 6.3 |
| 4.0 | 0 | 2.7 | 2.9 | 2.9 | 3.0 | 3.0 | 25.1 |
| 6.0 | 0 | 3.1 | 3.1 | 3.5 | 3.6 | 19.3 | 21.6 |
| 7.0 | 0 | 10.7 | 10.7 | 10.8 | 18.6 | 36.5 | 37.0 |
| 8.0 | 0 | 21.0 | 28.6 | 36.8 | 40.2 | 55.6 | 64.7 |

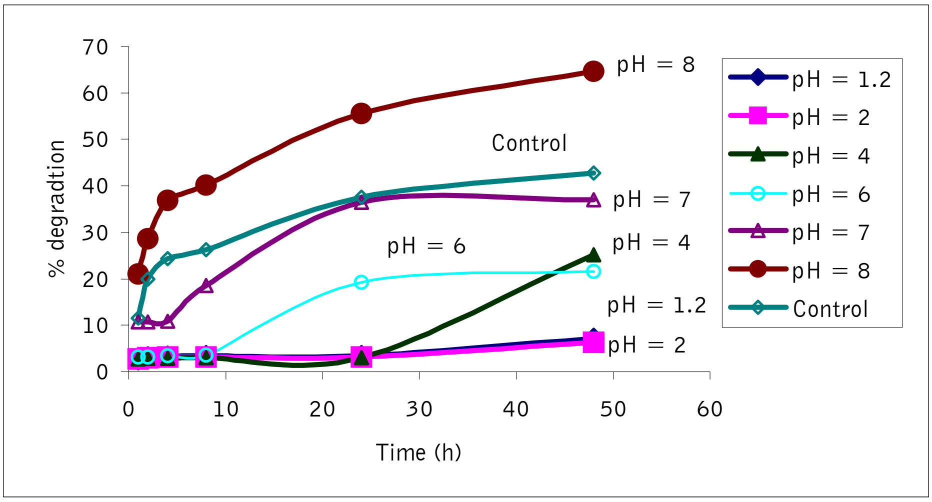



*Figure 15: Effect of pH on stability of EGCG*

## Stability of EGCG in Ethyl Acetate

The stability of EGCG in the tea extracts stored in ethyl acetate was monitored until 48 h (Table 16 and Figure 16).

Table 16: Stability of EGCG in ethyl acetate

| Time (h) | EGCG (mg/g) ± SD[a] | Degradation % |
|---|---|---|
| 0 | 14.66 ± 0.50 | 0 |
| 1 | 14.50 ± 0.56 | 1.1 |
| 2 | 14.48 ± 0.28 | 1.2 |
| 4 | 14.48 ± 0.17 | 1.2 |
| 8 | 14.48 ± 0.53 | 1.2 |
| 24 | 14.48 ± 0.38 | 1.2 |
| 48 | 14.43 ± 0.54 | 1.5 |

[a]n= 3

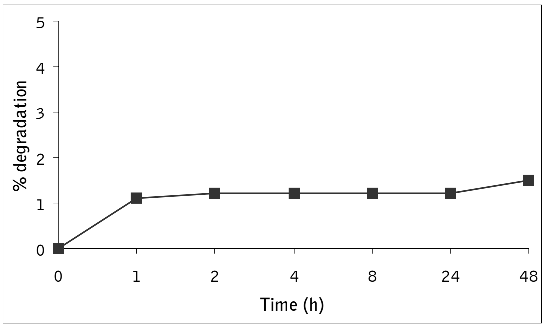



*Figure 16: Stability of EGCG in ethyl acetate extract*

## 5.6 Polyphenol Content in Cultivated Varieties of Indian Tea

The EGCG and ECG content was estimated by HPLC in the different samples of cultivated Indian varieties of tea using the optimized procedure of extraction and analysis developed in the laboratory. Accurately weighed (2 g) moderately fine powder of tea sample was put in a vacuum flask and 100 ml of boiling water was added to it. The flask was stoppered and shaken for 5 min. The extract was filtered while hot and the marc was washed with 10 ml of boiling water. The volume of extract was adjusted to 100 ml with refrigerated water. The extract was diluted (1 to 25) with a mobile phase of HPLC analysis (water : methanol : acetic acid 70 : 30 : 0.5). The diluted extract was filtered through a 0.45 $\mu$m filter and used for the HPLC analysis (Figure 17). The amount of EGCG and ECG in the extract was calculated from the area under the curve corresponding to the peaks of EGCG and ECG and using the standard plots (Table 17).

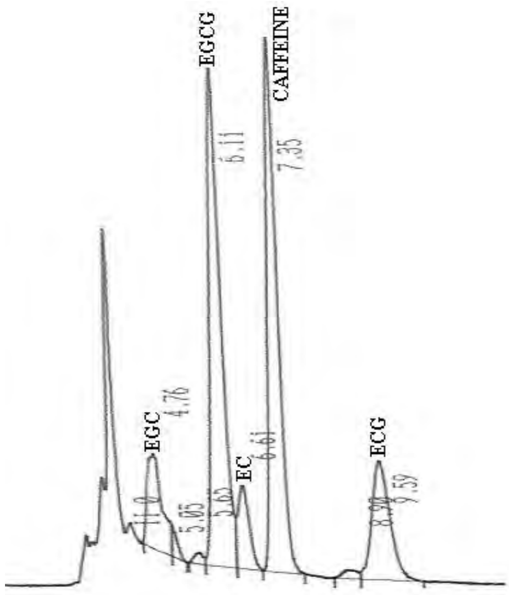



*Figure 17: A typical HPLC chromatogram of green tea extract*

Table 17: Polyphenol content of tea samples of different varieties cultivated in India

| Area | Clone/variety | Period of collection | Processing method | EGCG (mg/g) | ECG (mg/g) |
|---|---|---|---|---|---|
| **North** | TV-23 | Sep. 2001 | Sun drying | 2.70 ± 0.50 | Not detected |
| | | Sep. 2001 | Steam drying | 24.45 ± 2.48 | 6.36 ± 0.50 |
| | | Nov. 2001 | Sun drying | 19.82 ± 0.20 | 9.58 ± 0.11 |
| | | Nov. 2001 | Steam drying | 43.60 ± 0.25 | 16.40 ± 0.30 |
| | | Apr. 2002 | Sun drying | 31.87 ± 1.63 | 12.18 ± 0.22 |
| | | Apr. 2002 | Steam drying | 58.52 ± 1.34 | 18.95 ± 0.33 |

*Continued*

*Table 17 continued*

| | | | | | |
|---|---|---|---|---|---|
| | Kangra Asha | Nov. 2001 | Sun drying | 34.94 ± 0.23 | 8.13 ± 0.16 |
| | | Nov. 2001 | Steam drying | 32.00 ± 2.93 | 7.04 ± 0.51 |
| | | Apr. 2002 | Sun drying | 52.35 ± 1.41 | 10.62 ± 0.56 |
| | | Apr. 2002 | Steam drying | 45.61 ± 1.67 | 9.56 ± 0.32 |
| | | Sep. 2002 | Sun drying | 23.50 ± 0.85 | 11.39 ± 0.85 |
| | | Sep. 2002 | Steam drying | 64.38 ± 1.52 | 14.04 ± 0.90 |
| | Kangra Jawala | Apr. 2002 | Sun drying | 26.64 ± 2.52 | 6.37 ± 0.58 |
| | | Apr. 2002 | Steam drying | 68.89 ± 2.77 | 19.04 ± 0.35 |
| | | Sep. 2002 | Sun drying | 27.14 ± 2.07 | 10.88 ± 0.38 |
| | | Sep. 2002 | Steam drying | 62.01 ± 4.52 | 14.30 ± 1.15 |
| | TV-1 | Nov. 2001 | Sun drying | 29.61 ± 2.74 | 20.63 ± 2.63 |
| | | Nov. 2001 | Steam drying | 42.54 ± 0.43 | 25.36 ± 0.07 |
| | | Apr. 2002 | Sun drying | 22.16 ± 0.52 | 15.56 ± 0.67 |
| | | Apr. 2002 | Steam drying | 43.22 ± 2.80 | 27.39 ± 2.20 |
| **Northeast** | TV-1 | Jun. 2002 | Steam drying | 27.48 ± 2.32 | 19.64 ± 1.71 |
| | TV-9 | Jun. 2002 | Steam drying | 33.91 ± 3.67 | 10.72 ± 1.18 |
| | TV-18 | Jun. 2002 | Steam drying | 50.18 ± 1.61 | 16.22 ± 1.52 |
| | TV-20 | Jun. 2002 | Steam drying | 19.18 ± 0.82 | 6.60 ± 0.86 |
| | TV-23 | Jun. 2002 | Steam drying | 23.52 ± 0.61 | 13.71 ± 1.49 |
| | TV-26 | Jun. 2002 | Steam drying | 18.46 ± 1.40 | 7.33 ± 0.53 |
| | P-126 | Jun. 2002 | Steam drying | 12.89 ± 1.24 | 7.16 ± 0.71 |
| | Takda-7,8 | Jun. 2002 | Steam drying | 19.48 ± 0.59 | 6.45 ± 0.30 |
| | Tenali-17 | Jun. 2002 | Steam drying | 17.62 ± 1.48 | 5.63 ± 0.69 |
| | China Bush + Clones | Jun. 2002 | Steam drying | 30.36 ± 3.49 | 8.50 ± 0.85 |
| **South** | China Variety | Oct. 2002 | Sun drying | 1.65 ± 0.07 | 1.37 ± 0.04 |
| | UPASI-3 | Oct. 2002 | Sun drying | 1.36 ± 0.22 | 0.32 ± 0.00 |
| | VP-Clones | Oct. 2002 | Sun drying | 2.14 ± 0.50 | 0.71 ± 0.16 |
| | BSS-1 | Oct. 2002 | Steam drying | 24.32 ± 0.86 | 8.04 ± 0.56 |
| | C-1 | Oct. 2002 | Steam drying | 30.87 ± 0.89 | 10.54 ± 0.55 |
| | China Variety | Oct. 2002 | Steam drying | 38.12 ± 2.35 | 14.24 ± 1.08 |
| | CR-6017 | Oct. 2002 | Steam drying | 44.18 ± 3.58 | 11.60 ± 1.20 |
| | TRI-2024 | Oct. 2002 | Steam drying | 33.43 ± 3.60 | 12.76 ± 0.89 |
| | TRI-2025 | Oct. 2002 | Steam drying | 42.31 ± 5.09 | 10.29 ± 0.82 |
| | TRI-2026 | Oct. 2002 | Steam drying | 68.35 ± 5.21 | 22.20 ± 1.91 |
| | UPASI-2 | Oct. 2002 | Steam drying | 51.47 ± 0.74 | 12.15 ± 0.33 |
| | UPASI-3 | Oct. 2002 | Steam drying | 19.75 ± 6.99 | 5.53 ± 2.02 |
| | UPASI-8 | Oct. 2002 | Steam drying | 45.44 ± 3.09 | 14.68 ± 1.26 |
| | UPASI-9 | Oct. 2002 | Steam drying | 57.82 ± 1.62 | 14.24 ± 0.98 |
| | UPASI-10 | Oct. 2002 | Steam drying | 21.64 ± 2.24 | 8.33 ± 0.76 |

# 6. Survey Data

The tea producing areas in North, Northeast and South India were surveyed to collect information on the cultivated varieties of tea, the area under cultivation, the production, processing and marketing of green tea, and the problems of the green tea manufacturers. The information was procured from the Tea Board of India, the tea processing companies and other governmental and non-governmental organizations dealing with tea. The production data, including the total tea produced, the areas under tea cultivation, the tea yields, the monthly and annual tea sales at different auctions and the average prices of tea (Appendix 3) were provided by the Tea Board of India and J. Thomas and Private Company Limited, Kolkata. Various tea companies (Makaibari Tea Estates, Sannyasithan Tea Co. Pvt. Ltd., Maud Tea & Seed Co. Ltd., Tea Promoters-India Pvt. Ltd., Ambari Tea Co. Ltd., Sublime Agro Ltd., Sepoydhoorah Tea Co. Pvt. Ltd., Goodricke Group Ltd., Duncans Industries Ltd., United Planter's Association of Southern India, Indcoserve, The Peria Karamalai Tea & Produce Co. Ltd., and Mahalinga Indco Tea) and tea gardens were visited and surveyed using a questionnaire (Appendix 4) and to obtain processed green tea samples of different varieties for analysis. Information was gathered on marketing channels and problems in green tea processing and marketing (Appendix 5).

India is the world's largest producer and consumer of tea and is known to produce the finest qualities of tea.[150] It also produces the largest number of tea varieties. Indian tea is best known for its flavour, taste and colour. The three world famous types of Indian tea are Assam, Darjeeling and Nilgiri. According to an estimate, 673 thousand tonnes of tea were consumed in India in 2001, ranking it at the top of the tea consuming nations of the world. In India, the tea producing areas are located in the north, northeast and south (Figures 18-20). The largest producer is the northeastern area of India. The tea producing states and regions under each area are presented in Table 18.

## 6.1 Cultivated Varieties

In the north, Palampur in the Kangra Valley in the state of Himachal Pradesh, and Nainital in the state of Uttaranchal are engaged in tea production. The region largely cultivates the Chinese variety of tea (*Camellia sinensis* (L.) O. Kuntze *var. sinensis*), which is suited to the prevailing agro-climatic conditions of the area.

*Figure 18: A tea garden in Palampur (North India)*

*Figure 19: A tea garden in Darjeeling (Northeast India)*

*Figure 20: A tea garden in Ooty (South India)*

Table 18: Tea producing areas of India

| Area | State | District |
|---|---|---|
| North | Himachal Pradesh | Kangra |
| | Uttaranchal | Nainital |
| Northeast | Arunachal Pradesh | - |
| | Assam | Cachar |
| | | Darrang* |
| | | Dibrugarh* |
| | | Goalpara* |
| | | Kamrup* |
| | | Karbi Anlong |
| | | Lakhimpur* |
| | | North Cachar |
| | | Nowgong* |
| | | Sibsagar *[a] |
| | Bihar | Kisanganj |
| | Manipur | - |
| | Meghalaya | - |
| | Mizoram | - |
| | Nagaland | - |
| | Orissa | - |
| | Sikkim | - |
| | Tripura | - |
| | West Bengal | Darjeeling |
| | | Dooars [b] |
| | | Terai [c] |
| South | Tamilnadu | Coimbatore |
| | | Kanyakumari |
| | | Madurai |
| | | Nilgiris |
| | | Tirunelveli |
| | Kerala | Cannanore |
| | | Ernakulam |
| | | Idukki |
| | | Kottayam |
| | | Kozhikode |
| | | Malapuram |
| | | Palghat |
| | | Quilon |
| | | Trichur |
| | | Trivandrum |
| | | Wynaad |
| | Karnataka | Chikmagalur |
| | | Coorg |
| | | Hassan |

* Collectively known as Assam Valley
[a] Including Mikhir Hills and North Cachar
[b] Including Cooch Behar
[c] Including West Dinajpur

Assam and West Bengal are the main tea producing states in the northeast area (Table 18). In Assam, the Assam variety *(Camellia sinensis* (L.) O. Kuntze *var. assamica)* and its hybrids are cultivated, whereas in Darjeeling and the surrounding areas in West Bengal, the Chinese variety is cultivated. A number of clones and cultivars have been developed for cultivation in India (Table 19). The Department of Tea Husbandary and Technology of Himachal Pradesh Krishi Vishwa Vidhalaya in Palampur, the Tocklai Experimental Station in Jorhat, and the United Planters Association of South India (UPASI), and the Tea Research Institute in Coonoor have developed these clones.

Table 19: Important clones/cultivars of tea in different tea producing areas of India

| Area | Clone/cultivar | Area | Clone/cultivar |
|---|---|---|---|
| North | Kangra Asha | South | C-1 |
| | Kangra Jwala | | CR-6017 |
| | TV-1 | | TRI 2024 |
| | TV-23 | | TRI 2025 |
| Northeast | TV-1 | | TRI 2026 |
| | TV-9 | | UPASI-1 |
| | TV-18 | | UPASI-2 |
| | TV-19 | | UPASI-3 |
| | TV-20 | | UPASI-4 |
| | TV-23 | | UPASI-5 |
| | TV-26 | | UPASI-6 |
| | TV-27 | | UPASI-7 |
| | TV-29 | | UPASI-8 |
| | TV-30 | | UPASI-9 |
| | Takda-7-8 | | UPASI-10 |
| | Tenali-17 | | UPASI-15 |
| South | BSS-1 | | UPASI-20 |

## 6.2 Tea Production and Area Under Tea Cultivation in India

### North and Northeast India

The zone under tea production in the north and northeast areas from 1998 to 2000 is presented in Table 20.[151] No change in the area under tea cultivation was observed in the northern zone during this period. However, tea production decreased by 529 tonnes (25.6%) in 1999 while in 2000 a decrease of 20 tonnes (1.30%) was observed.

Table 20: Production and area under tea cultivation in North and Northeast India

| Area | State | 1998 | | 1999 | | 2000 | |
|---|---|---|---|---|---|---|---|
| | District | Area (ha) | Quantity (tonnes) | Area (ha) | Quantity (tonnes) | Area (ha) | Quantity (tonnes) |
| North | **Himachal Pradesh** | | | | | | |
| | Kangra | 2,325 | 1,711 | 2,325 | 1,222 | 2,325 | 1,247 |
| | **Uttaranchal** | | | | | | |
| | Nainital | 1,068 | 349 | 1,068 | 309 | 1,068 | 264 |
| | Total North | 3,393 | 2,060 | 3,393 | 1,531 | 3,393 | 1,511 |
| Northeast | **Arunachal Pradesh** | 1,953 | 965 | 2,179 | 1,063 | 2,176 | 993 |
| | **Assam** | | | | | | |
| | Cachar | 30,565 | 51,850 | 30,938 | 49,119 | 31,116 | 53,722 |
| | Darrang | 40,950 | 86,942 | 41,393 | 78,501 | 41,968 | 80,227 |
| | Dibrugarh | 83,380 | 164,463 | 88,291 | 150,469 | 93,138 | 155,932 |
| | Goalpara | 3,338 | 6,099 | 3,357 | 5,436 | 3,522 | 5,855 |
| | Kamrup | 3,307 | 5,146 | 3,289 | 4,941 | 3,300 | 5,003 |
| | Karbi Anlong | 1,652 | 1,375 | 1,781 | 1,301 | 2,005 | 1,878 |
| | Lakhimpur | 4,809 | 9,995 | 5,046 | 9,413 | 5,230 | 9,701 |
| | North Cachar | 4,516 | 6,743 | 4,523 | 6,367 | 4,524 | 6,521 |
| | Nowgong | 7,746 | 14,684 | 7,850 | 13,559 | 8,014 | 14,073 |
| | Sibsagar | 71,362 | 119,749 | 71,267 | 113,819 | 74,575 | 118,324 |
| | Total Assam | 251,625 | 467,046 | 257,735 | 432,925 | 267,392 | 451,236 |
| | **Bihar** | 762 | 138 | 1,348 | 473 | 1,350 | 538 |
| | **Manipur** | 536 | 76 | 746 | 97 | 907 | 96 |
| | **Meghalaya** | 145 | 127 | 215 | 135 | 351 | 140 |
| | **Mizoram** | 350 | 23 | 360 | 35 | 391 | 39 |
| | **Nagaland** | 472 | 29 | 1,012 | 39 | 1,214 | 43 |
| | **Orissa** | 214 | 94 | 214 | 100 | 214 | 105 |
| | **Sikkim** | 202 | 112 | 296 | 102 | 296 | 105 |
| | **Tripura** | 6,355 | 6,099 | 6,482 | 6,385 | 6,623 | 6,431 |
| | **West Bengal** | | | | | | |
| | Darjeeling | 17,830 | 10,253 | 17,968 | 9,294 | 18,109 | 9,814 |
| | Dooars | 70,479 | 147,133 | 70,996 | 133,803 | 71,225 | 135,963 |
| | Terai | 17,315 | 36,403 | 19,790 | 37,115 | 20,356 | 34,947 |
| | Total West Bengal | 105,624 | 193,789 | 108,754 | 180,212 | 109,690 | 180,724 |
| | Total Northeast | 368,238 | 668,598 | 379,341 | 631,566 | 390,604 | 640,450 |
| North and Northeast | | 371,631 | 670,658 | 382,734 | 623,097 | 393,997 | 641,961 |

In the northeast, the area under tea cultivation in 1998 ranged up to 368,238 hectares, it increased by 11,103 hectares (3.0%) in 1999, and 11,263 hectares (2.96%) in 2000. In Assam, the area under tea cultivation increased by 6,110 hectares (2.42%) in 1999, and 9,657 hectares in 2000, whereas in West Bengal an increase of 936 hectares (0.8%) was observed in 2000 as compared to 3,130 hectares (2.96%) in 1999. Except for the state of Orrisa (for which no change was registered), all the other states in the northeast observed an increase in the areas under cultivation.

All the tea producing districts in West Bengal with the exception of Terai, the states of Manipur and Arunachal Pradesh recorded a higher crop production. In 2000, the maximum increase was recorded in Assam (4.22%) and the minimum in West Bengal (0.284%) (Table 20).[151] Production in the northeast declined from 668,598 tonnes in 1998 to 621,566 tonnes (7.0%) in 1999; whereas an increase of 18,884 tonnes (3.04%) in production was witnessed in 2000 over the level of the previous year.

A decrease of 9.8% in yield was observed in North India (north and northeast) in 1998, while a negligible change (increase of 0.06%) was observed in 2000 (Table 21).[151]

## South India

The state of Tamilnadu witnessed the maximum increase in the area under tea cultivation, 5,612 hectares in 1999 and 5,176 hectares in 2000 (Table 22).[152] In Kerala, a marginal increase of 0.04% was observed from 1998 to 2000 and no change was observed in Karnataka. Tea production in South India increased by 1.59% in 1999–2000 and stood at 204,522 tonnes in 2000. The higher increase was reported in Kerala with marginal contribution from other tea producing states of South India. The average tea production and yield of South India are given in Table 22 and 23, respectively.[151]

## Total Tea Production in India

The total area under tea cultivation increased from 490,747 hectares in 1999 to 507,196 hectares in 2000. Area-wise production of tea in India is given in Figure 21. Tea production increased by 2.67% in 2000 over the previous year and reached 846,483 tonnes in 2000, although the yield of tea recorded a negligible growth during the same period. Only the state of Kerala recorded an increase (5.18%) in yield in 2000.

Table 21: Average tea yield in North and Northeast India

| Area | State<br>District | Average yield (kg/ha)<br>1998 | 1999 | 2000 |
|---|---|---|---|---|
| North | **Himachal Pradesh** | | | |
| | Kangra | 736 | 526 | 536 |
| | **Uttaranchal** | | | |
| | Nainital | 327 | 289 | 247 |
| Northeast | **Arunachal Pradesh** | 494 | 488 | 456 |
| | **Assam** | | | |
| | Cachar | 1,696 | 1,588 | 1,727 |
| | Darrang | 2,123 | 1,896 | 1,912 |
| | Dibrugarh | 1,972 | 1,704 | 1,674 |
| | Goalpara | 1,827 | 1,619 | 1,662 |
| | Kamrup | 1,556 | 1,502 | 1,516 |
| | Karbi Anlong | 832 | 730 | 937 |
| | Lakhimpur | 2,078 | 1,865 | 1,855 |
| | North Cachar | 1,493 | 1,408 | 1,441 |
| | Nowgong | 1,896 | 1,727 | 1,756 |
| | Sibsagar | 1,678 | 1,597 | 1,587 |
| | Average Assam | 1,856 | 1,680 | 1,688 |
| | **Bihar** | 181 | 351 | 399 |
| | **Manipur** | 142 | 130 | 106 |
| | **Meghalaya** | 876 | 628 | 399 |
| | **Mizoram** | 66 | 97 | 100 |
| | **Nagaland** | 61 | 39 | 35 |
| | **Orissa** | 439 | 467 | 491 |
| | **Sikkim** | 554 | 345 | 355 |
| | **Tripura** | 975 | 985 | 971 |
| | **West Bengal** | | | |
| | Darjeeling | 575 | 517 | 542 |
| | Dooars | 2,088 | 1,885 | 1,909 |
| | Terai | 2,102 | 1,875 | 1,717 |
| | Average W. Bengal | 1,835 | 1,657 | 1,648 |
| North and Northeast | | 1,805 | 1,628 | 1,629 |

Table 22: Tea production in South India

| **State** | **1998** | | **1999** | | **2000** | |
|---|---|---|---|---|---|---|
| District | **Area (ha)** | **Quantity (tonnes)** | **Area (ha)** | **Quantity (tonnes)** | **Area (ha)** | **Quantity (tonnes)** |
| **Tamilnadu** | | | | | | |
| Coimbatore | 11,609 | 32,997 | 11,650 | 32,000 | 11,650 | 32,100 |
| Kanyakumari | 434 | 119 | 434 | 101 | 434 | 120 |
| Madurai | 941 | 3,075 | 941 | 3,600 | 941 | 3,650 |
| Nilgiris | 49,759 | 93,972 | 55,330 | 90,375 | 60,506 | 90,729 |
| Tiruneveli | 800 | 1,883 | 800 | 2,012 | 800 | 2,100 |
| Total Tamilnadu | 63,543 | 132,046 | 69,155 | 128,088 | 74,331 | 129,699 |
| **Kerala** | | | | | | |
| Cannanore | - | - | - | - | - | - |
| Ernakulam | 2 | - | 2 | - | 2 | - |
| Idukki | 26,608 | 48,254 | 26,610 | 51,200 | 26,615 | 52,000 |
| Kottayam | 840 | 244 | 840 | 300 | 840 | 320 |
| Kozhikode | | - | | | | 1,420 |
| Malapuram | | | 174 | | 174 | 5,468 |
| Malapuram | 174 | - | 174 | - | 174 | - |
| Palghat | 841 | 2,398 | 841 | 1,800 | 841 | 1,950 |
| Quilon | 1,348 | 366 | 1,348 | 360 | 1,348 | 375 |
| Trichur | 523 | 1,951 | 523 | 1,500 | 523 | 1,650 |
| Trivendrum | 965 | 582 | 965 | 440 | 965 | 475 |
| Wynaad | 5,447 | 12,148 | 5,449 | 12,196 | 5,454 | 12,585 |
| Total Kerala | 36,748 | 65,943 | 36,752 | 67,796 | 36,762 | 69,355 |
| **Karnataka** | | | | | | |
| Chikmagalur | 1,420 | 3,484 | 1,421 | 3,269 | 1,421 | 3,288 |
| Coorg | 290 | 768 | 290 | 750 | 290 | 760 |
| Hassan | 395 | 1,209 | 395 | 1,408 | 395 | 1,420 |
| Total Karnataka | 2,105 | 5,461 | 2,106 | 5,427 | 2,106 | 5,468 |
| Total South India | 102,396 | 203,450 | 108,013 | 201,311 | 113,199 | 204,522 |

Table 23: Average tea yield in South India

| State<br>District | Average yield (kg/ha)<br>1998 | <br>1999 | <br>2000 |
|---|---|---|---|
| **Tamilnadu** | | | |
| Coimbatore | 2,842 | 2,747 | 2,755 |
| Kanyakumari | 274 | 233 | 276 |
| Madurai | 3,268 | 3,826 | 3,879 |
| Nilgiris | 1,889 | 1,633 | 1,516 |
| Tiruneveli | 2,354 | 2,515 | 2,625 |
| Average Tamilnadu | 2,078 | 1,852 | 1,745 |
| **Kerala** | | | |
| Cannanore | - | - | - |
| Ernakulam | - | - | - |
| Idukki | 1,814 | 1,924 | 1,954 |
| Kottayam | 290 | 357 | 381 |
| Kozhikode | - | - | - |
| Malapuram | - | - | - |
| Palghat | 2,851 | 2,140 | 2,319 |
| Quilon | 272 | 267 | 278 |
| Trichur | 3,730 | 2,868 | 3,155 |
| Trivendrum | 603 | 456 | 492 |
| Wynaad | 2,230 | 2,238 | 2,307 |
| AverageKerala | 1,794 | 1,845 | 1,887 |
| **Karnataka** | | | |
| Chikmagalur | 2,454 | 2,300 | 2,314 |
| Coorg | 2,648 | 2,586 | 2,621 |
| Hassan | 3,061 | 3,565 | 3,595 |
| Average Karnataka | 2,594 | 2,577 | 2,596 |
| **South India** | 1,987 | 1,864 | 1,807 |

## 6.3 Production Trends of Different Types of Indian Tea

Production of cut tear curl (CTC) black tea in North India decreased by 35,514 tonnes (5.99%) in 1999 and increased by 34,024 tonnes (5.75%) in 2000 (Table 24).[151, 152] In South India however, a reverse trend was observed as CTC tea production increased by 3,815 (2.30%) in 1999 and decreased by 1,871 tonnes (1.10%) in 2000. In India as a whole, production of CTC tea decreased by 31,699 tonnes (4.18%) in 1999 and increased by 32,153 tonnes (4.4%) in 2000. Orthodox tea manufacture of black tea in North India decreased by 28,788 tonnes (41.21%) in 1999 and increased by 39,370 tonnes (9.6%) in 2000. Similar trends were observed in the south and for the country as a whole.

A continuous decrease in green tea production since 1998 was observed in North India, (6.3%) in 1999 and (5.27%) in 2000. In South India, the production of green tea stayed nearly static between 1998 and 2000 and stood at 1,819 tonnes in 2000.

Table 24: Production of different types of tea in India

| Area<br>Tea type | 1998<br>Tonnes | <br>% share | 1999<br>Tonnes | <br>% share | 2000<br>Tonnes | <br>% share |
|---|---|---|---|---|---|---|
| **North** | | | | | | |
| CTC black | 592,421 | 88.5 | 556,907 | 92.2 | 590,931 | 92.1 |
| Orthodox black | 69,845 | 10.5 | 41,057 | 6.8 | 45,027 | 7.0 |
| Green tea | 6,764 | 1.0 | 6,337 | 1.0 | 6,003 | 0.9 |
| Total | 669,030 | 100.0 | 604,301 | 100.0 | 641,961 | 100.0 |
| **South** | | | | | | |
| CTC black | 165,737 | 82.3 | 169,552 | 84.2 | 167,681 | 82.0 |
| Orthodox black | 33,786 | 16.8 | 29,905 | 14.9 | 35,022 | 17.1 |
| Green tea | 1,852 | 0.9 | 1,854 | 0.9 | 1,819 | 0.9 |
| Total | 201,375 | 100.0 | 201,311 | 100.0 | 204,522 | 100.0 |
| **All India** | | | | | | |
| CTC black | 758,158 | 87.1 | 726,459 | 90.2 | 758,612 | 89.6 |
| Orthodox black | 103,631 | 11.9 | 70,962 | 8.8 | 80,049 | 9.5 |
| Green tea | 8,616 | 1.0 | 8,191 | 1.0 | 7,822 | 0.9 |
| Total | 870,405 | 100.0 | 805,612 | 100.0 | 846,483 | 100.0 |

Amritsar in Panjab, Kolkata and Siliguri in West Bengal, Guwahati in Assam, Cochin in Kerala and Coonoor and Coimbatore in Tamil Nadu are the Indian trading centres of tea, where tea is sold at open auctions. The sale of tea has decreased in Amritsar auctions since 1998. The tea sale price has also followed a similar trend. The different kinds of tea at other markets followed a variable trend both for sale and average price. Orthodox and all leaf tea generally fetched a higher price compared to other grades (Table 25 and Figure 22).[151, 152] Sale and average price trends were variable at south Indian tea auctions (Figure 23).[151, 152] At all the auctions, orthodox tea's average sale price was the highest.

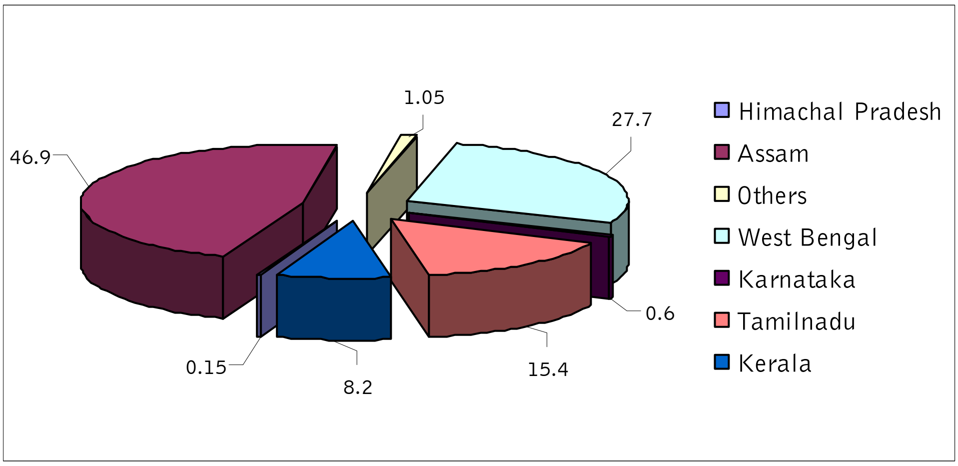



*Figure 21: State-wise production share of tea in India (2000)*

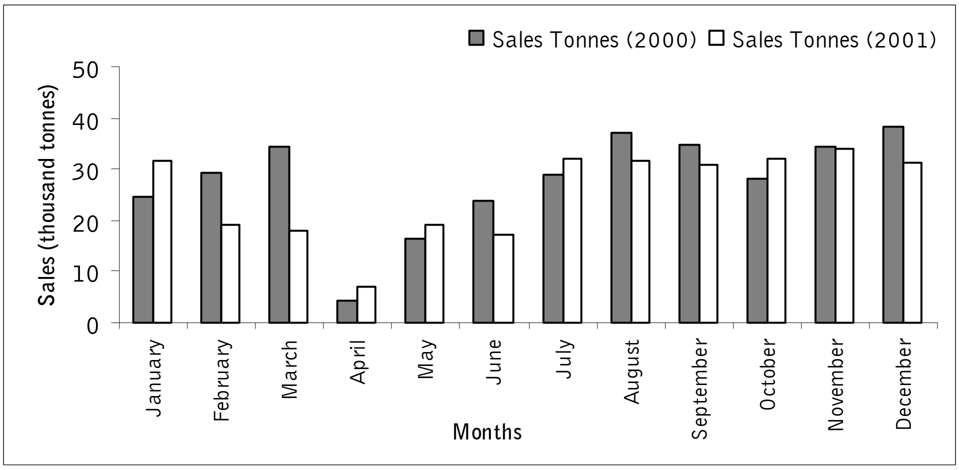



*Figure 22: Month-wise sales of tea at North Indian auctions*

## 6.4 Green Tea Production in India

In South India, green tea is produced only in the state of Tamilnadu. In India as a whole, a 19.39% decrease in green tea production was observed during the period 1997 to 1999 (Table 26).[151]

The state of Himachal Pradesh and Uttaranchal in the north and the state of Assam, West Bengal and Tripura in the northeastern zone are engaged in production of green tea. West Bengal is the largest producer of green tea. The production of green tea has declined in North India since 1997.

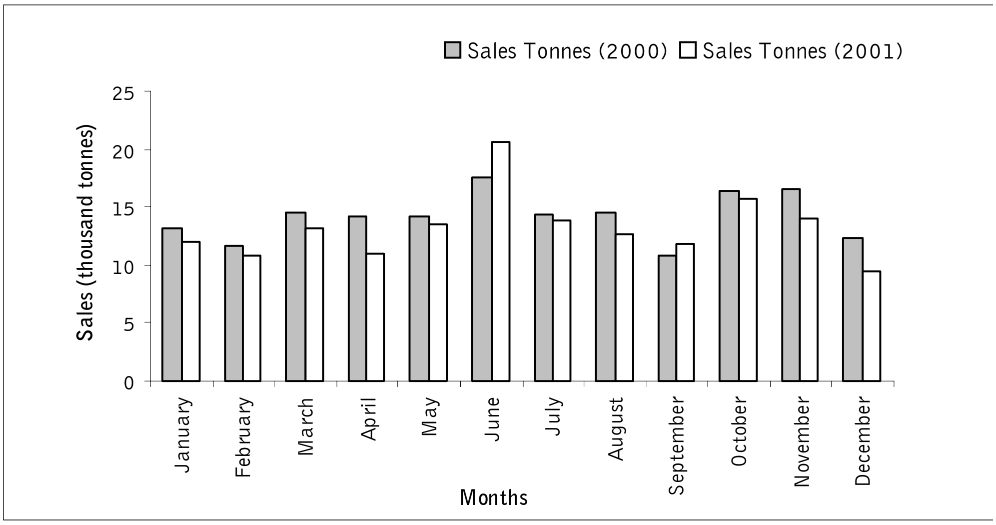



*Figure 23: Month-wise sales of tea at South Indian auctions*

Table 25: Sales of different kinds of black tea through auctions in India

| Market | Type of tea | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Quantity (tonnes) | Price (INR/kg) | Quantity (tonnes) | Price (INR/kg) | Quantity (tonnes) | Price (INR/kg) | Quantity (tonnes) | Price (INR/kg) |
| Amritsar | All types of tea | 718 | 50.83 | 472 | 49.31 | 405 | 48.56 | 319 | 43.05 |
| Kolkata | Orthodox | 24,469 | 85.48 | 11,669 | 94.57 | 18,330 | 95.77 | 19,277 | 79.80 |
| | CTC | 34,792 | 84.81 | 49,881 | 83.98 | 52,147 | 71.74 | 47,635 | 73.69 |
| | All leaf | 67,560 | 91.56 | 67,146 | 93.51 | 75,674 | 84.93 | 71,563 | 81.56 |
| | All dust | 18,058 | 79.61 | 22,026 | 79.86 | 22,439 | 70.08 | 23,213 | 66.48 |
| Guwahati | CTC | 92,377 | 79.98 | 98,618 | 82.35 | 101,196 | 69.99 | 94,368 | 71.47 |
| | All leaf | 93,222 | 79.94 | 99,044 | 82.24 | 111,797 | 70.08 | 94,995 | 71.47 |
| Silliguri | All leaf | 58,192 | 77.29 | 71,630 | 74.82 | 64,977 | 63.37 | 58,449 | 66.71 |
| | All dust | 14,164 | 69.56 | 15,163 | 65.09 | 13,859 | 53.93 | 13,342 | 57.55 |
| Cochin | Orthodox | 14,100 | 80.42 | 14,855 | 68.03 | 17,664 | 58.10 | 13,935 | 56.67 |
| | CTC | 9,607 | 64.94 | 7,791 | 52.81 | 5,966 | 38.09 | 4,845 | 40.98 |
| | All leaf | 23,707 | 74.22 | 22,646 | 62.80 | 23,633 | 52.87 | 18,780 | 52.59 |
| Coonoor | Orthodox | 2,110 | 69.08 | 1,720 | 59.75 | 1,882 | 49.89 | 1,663 | 47.62 |
| | CTC | 56,384 | 64.78 | 68,366 | 53.98 | 57,187 | 39.12 | 57,351 | 42.25 |
| Coimbatore | Orthodox | 4,038 | 75.87 | 4,555 | 64.54 | 6,678 | 56.32 | 4,023 | 54.75 |
| | CTC | 7,449 | 65.72 | 9,566 | 53.71 | 15,834 | 38.16 | 11,978 | 40.79 |
| | All dust | 5,759 | 67.76 | 6,141 | 56.84 | 10,763 | 43.64 | 9,117 | 47.39 |

## 6.5 Problems and Prospects of Green Tea Production

Indian green tea had a good market in Afghanistan and Morocco and 50% of green tea production in India was exported to these two countries. Exports to Afghanistan suffered a major setback following political disturbances in that country. Some other potential markets for Indian green tea are Germany, France, USA, Tunisia, Algeria and Middle East countries. Initiatives need to be taken to promote the production and export of green tea. In India, green tea is mainly produced by small tea companies, which are financially weak. As a result, it is not possible for them to undertake R&D to improve the quality or technique of green tea manufacture. Old methods of manufacture are used. Green tea is manufactured by steaming, followed by rolling. A substantial amount of components are lost from the leaf during the process leading to lower quality, which is the major drawback of this process. Other methods such as frying or panning and devising sophisticated sorting machines to remove both smaller and bigger stalks can produce better grades of tea.

Table 26: Green tea production in India

| Area | State<br>District | Production (Tonnes)<br>1997 | <br>1998 | <br>1999 |
|---|---|---|---|---|
| North | **Himachal Pradesh** | | | |
| | Kangra | 755 | 648 | 600 |
| | **Uttaranchal** | 260 | 210 | 175 |
| Northeast | **Assam** | | | |
| | Cachar | 212 | 178 | 160 |
| | Darrang | 289 | 243 | 233 |
| | Dibrugarh | 407 | 342 | 325 |
| | Goalpara | 218 | 185 | 175 |
| | Kamrup | 12 | 10 | 7 |
| | Sibsagar | 506 | 437 | 415 |
| | Total Assam | 1,644 | 1,395 | 1,315 |
| | **West Bengal** | | | |
| | Dooars | 1,926 | 2,755 | 2,221 |
| | Terai | 3,282 | 1,658 | 1,600 |
| | Total W. Bengal | 5,208 | 4,413 | 3,821 |
| South | **Tamilnadu** | | | |
| | Madurai | 45 | 43 | 47 |
| | Nilgiris | 455 | 482 | 453 |
| | Total Tamilandu | 500 | 525 | 500 |
| Total | | 500 | 525 | 500 |

The lack of proper auction centres for green tea, the low consumption of green tea on the domestic market, the lack of knowledge regarding the technical aspects of green tea manufacture, and the lack of R&D facilities for the upgrading of manufacturing processes are some of the main problems faced by the green tea industry in India. In order to overcome these problems and to increase green tea production, there is a need to identify potential areas for green tea production in each region and to cultivate the best variety of tea. At present, Kashmir Valley has an annual domestic market of about 500 tonnes. Other markets in the country should be developed through promotional campaigns to increase domestic consumption of green tea and make people aware of its health benefits. R&D activities are urgently required to develop cultivars suited to green tea production and to improve the existing manufacturing process of green tea.

# 7. Conclusions

Samples of different cultivated varieties of tea were collected from all tea growing areas of the country. In one case, collection was repeated at the beginning, in the middle and at the end of the plucking season. The hand-picked tea leaves were processed for sample preparation following the usual manufacturing procedure of green tea. The leaves were steamed for 5 min and then dried in an oven at a temperature not exceeding 65°C. Samples were also prepared by directly drying the leaves in the sun immediately after plucking to compare their polyphenol profile.

Quantitative TLC was used for standardizing the extraction procedure and the HPLC method was used for estimating the polyphenol content of tea samples. The TLC solvent system for the best resolution of polyphenols in tea was developed in the laboratory. The best results were obtained using a mixture of chloroform : acetone : formic acid (5 : 4 : 1), which gave Rf values of 0.22 for EGCG, 0.32 for ECG, 0.27 for EGC and 0.46 for caffeine. In HPLC analysis, the mixture of water : methanol : acetic acid (70 : 30 : 0.5) as mobile phase gave a good separation of tea polyphenols in a 15 min run. It was observed that presence of acid in the solvent system of TLC and in the mobile phase of HPLC was essential for obtaining good chromatograms.

All analyses were performed in triplicate. The standard plots were constructed using reference samples of EGCG and ECG obtained from Sigma-Aldrich Chemicals. The estimations of EGCG and ECG in standard solutions showed an excellent coefficient of correlation both in TLC ($R^2$ = 0.9998 and 0.999 for EGCG and ECG respectively) and HPLC ($R^2$ = 1.0 and 0.9999 for EGCG and ECG respectively) over a wide range of concentration. It was therefore satisfactory to use the standard curve to determine the amount of EGCG and ECG in tea extracts. The concentration of extract was adjusted to fall in the middle range of the standard plot for carrying out the analysis.

In the initial experiments to optimize the extraction procedure, the EGCG extraction from tea samples was tried using methanol, water and ethyl acetate. It was observed (Table 8 and Figure 10) that methanol was the most suitable for extraction of tea polyphenols followed by water, whereas ethyl acetate proved to be a very poor solvent.

Therefore, water and methanol were further compared and investigated to optimize the period and temperature of extraction.

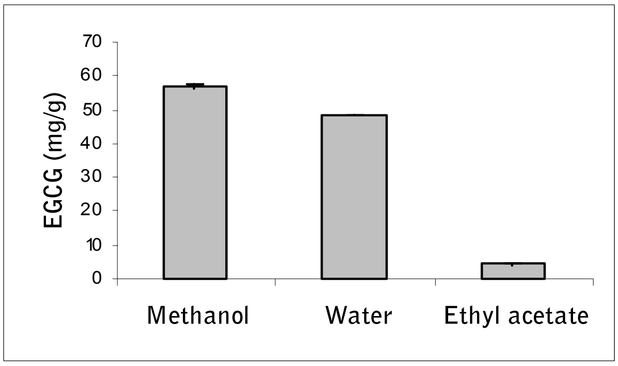



*Figure 10: Effect of solvent on extraction of EGCG*

The extractions in these two solvents were done at different temperatures (40, 60, 80 and 98°C) and time periods (15, 30, 45, 60, 75 and 90 min). In the case of methanol, there was a sharp rise in the EGCG extraction as the temperature was increased from 40 to 60°C and the maximum extraction was achieved in 60 min before it started declining. In the case of water, a similar trend was noticed as the temperature was increased from 40 to 98°C. The maximum extraction was achieved at 98°C in 15 min and thereafter it remained more or less static. However, in the case of methanol it started declining after attaining the maxima. These observations indicate different rates of EGCG degradation in water and methanol. The maximum EGCG extracted in methanol was slightly higher than the one obtained in water but it required 60 min extraction as compared to water which produced the maximum extraction in a short period of 5 min. Safety, acceptability and economical parameters of water off set the small advantage of a slightly higher extraction in methanol. Therefore, water became the logical choice as an extraction solvent.

The extraction of EGCG in water for time periods of 5, 10 and 15 min showed that the amount of EGCG obtained in 5 min did not improve further as the extraction time was increased to 15 min. Therefore, extraction in boiling water for 5 min was selected to extract and compare the polyphenols content of different tea samples.

The sample to water ratio of 1 : 50 was found the most appropriate to extract EGCG. No significant increase was observed in increasing the water proportion, although at a lower proportion it resulted in incomplete extraction (Table 11 and Figure 12).

Shaking during extraction resulted in a highly significant increase of 43% in EGCG extraction in comparison to still extraction (Table 12 and Figure 13).

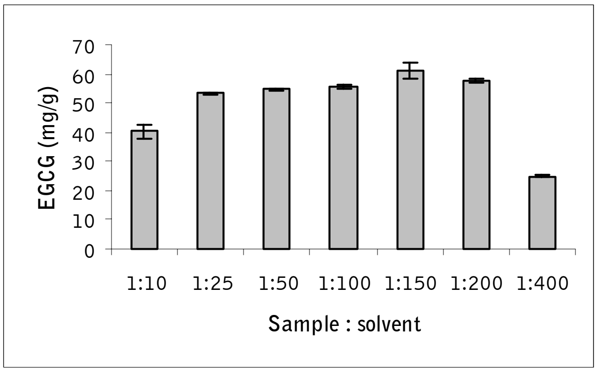



*Figure 12: Effect of sample: solvent ratio on extraction of EGCG*

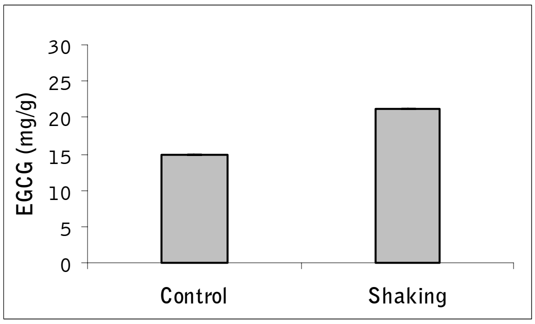



*Figure 13: Effect of shaking on extraction of EGCG*

The extraction of EGCG was also affected by the particle size of the powder (Table 13 and Figure 14). Fine powder gave a better extraction and moderately fine powder gave the maximum yield. Further reduction in the particle size of the powder adversely affected the extraction. These observations indicate that the solvent, the temperature, the duration of extraction, the particle size and shaking during extraction are critical for extraction of EGCG from tea leaves. The preliminary experiments established that boiling water, 1 : 50 sample to water ratio, 5 min extraction time, and moderately fine powder were the most appropriate for extracting EGCG from tea leaves.

Stability of EGCG as mixture of polyphenols in tea extract was monitored using buffers of different pH. The results indicated that there was marginal (3%) degradation of EGCG at pH 4 or below during the first 24 h, which increased to around 7% in the next 24 h at pH 1.2 and 2.0 but increased to 25% at pH 4 (Table 15 and Figure 15). The degradation was faster in alkaline pH and 65% of EGCG degraded during the first 48 h at pH 8. In water extract, pH 5.5, 43% degradation was observed after 48 h.

The EGCG in ethyl acetate extract of tea was stable and it was found that only 1.5% of it degraded during the first 48 h (Table 16 and Figure 16). Therefore, although ethyl acetate is not a good solvent for extraction, it can be used as a solvent for short storage of the EGCG solution.

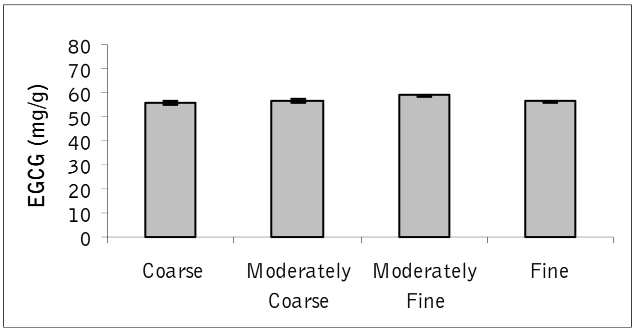



*Figure 14: Effect of particle size on extraction of EGCG*

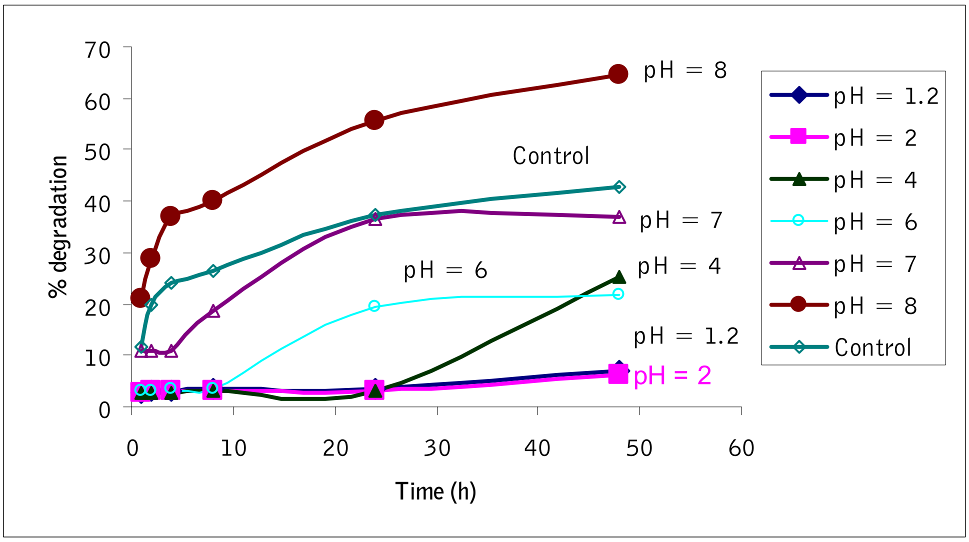



*Figure 15: Effect of pH on stability of EGCG*

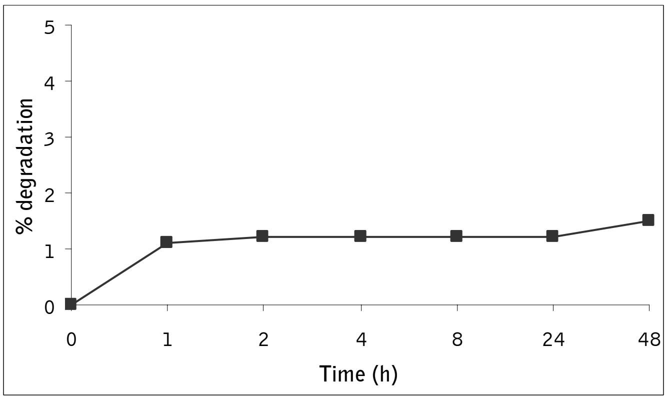



*Figure 16: Stability of EGCG in ethyl acetate extract*

The EGCG and ECG content of different cultivars were determined using optimized conditions of extraction and analysis developed in the laboratory. The content of EGCG and ECG in analyzed samples varied over a wide range (0.14 to 6.88% for EGCG and 0.03 to 2.74% for ECG). In general, samples prepared by the method of steaming and drying under controlled temperature showed a higher content of these two polyphenols. In samples collected from North India, the content of EGCG and ECG varied from 0.27 to 6.88% and 0.64 to 2.73% respectively. The comparison of EGCG and ECG content in tea samples collected at the beginning and at the end of the plucking season showed that the polyphenol content was higher in samples collected at the beginning of the plucking season. The EGCG and ECG content of samples from the northeast ranged from 1.28 to 5.01% and 0.56 to 1.96% respectively, whereas it ranged from 0.14 to 6.83% and 0.03 to 2.22% in samples from South India.

Among different cultivars, steamed samples of Kangra Jawala, a cultivar developed at the Department of Tea Husbandry and Technology, Himachal Pradesh Krishi Vishvavidalya, Palampur, North India, and TRI-2026 developed at the United Planters Association of South India, showed the highest content of EGCG (6.88 and 6.83% respectively). The TV-1 cultivar from Palampur showed the highest content of ECG (2.74%) among all the samples analyzed. The EGCG and ECG content of TV-1 and TV-23 in samples from Palampur was marginally higher than the content of samples from the northeast.

# 8. Summary

There are three areas of cultivation and production of tea in India. In the year 2000, black tea constituted 99.07% of the total production of tea. The bulk of green tea is produced in the northeast (West Bengal and Assam), followed by the northern area (Himachal Pradesh), and very small quantities are produced in the southern area (Tamilnadu). The production figures from 1998 to 2000 are compiled in this report along with the auction prices. In this period, the production of green tea decreased from 8,616 to 7,822 tonnes. Various factors responsible for low production of green tea in India have been highlighted and the comments of some of the companies visited are available in Appendix 5.

The extraction procedure of EGCG from green tea leaves was optimized with respect to solvent, time, temperature, particle size and sample to solvent ratio. EGCG can be extracted with boiling methanol or water. The extraction is quicker in water. The maximum amount of EGCG is extracted in 50 times by weight of water in 5 min using moderately fine powder of tea leaves. The ethyl acetate has proved to be a poor solvent for extraction of polyphenols. These constituents were found to degrade rapidly in weakly acidic to alkaline solution.

A large number of cultivars of tea have been developed in India. In the present study, 26 prominent cultivars were analyzed. Region-wise, Kangra Jawala grown in Palampur (North India) showed the highest content of EGCG (6.8%), followed by TRI-2026 (6.83%) grown in Coonor (South India), and Kangra Asha (6.4%) grown in Palampur. The lowest content of EGCG was recorded in P-126 (1.29%), Tenali-17 (1.76%) and TV-20 (1.92%) grown in Darjeeling. The samples of two cultivars, TV-1 and TV-23 were collected from two regions, north (Palampur) and northeast (Darjeeling). The content of EGCG was lower in northeast samples, suggesting the possible role of agro-climatic conditions. The deactivation of enzymes by steaming immediately after plucking is essential as observed from the very low content of EGCG in sun dried samples.

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# APPENDIX 1

## BUFFERS USED IN STABILITY STUDIES OF EGCG

| | |
|---|---|
| **Hydrochloric acid buffer pH 1.2** | Add 85 ml of 0.2 M hydrochloric acid to 50 ml of 0.2 M potassium chloride solution. Make the volume up to 200 ml with water. |
| **Hydrochloric acid buffer pH 2.0** | Add 13 ml of 0.2 M hydrochloric acid to 50 ml of 0.2 M potassium chloride solution. Make the volume up to 200 ml with water. |
| **Phosphate buffer pH 4.0** | Dissolve 6.8 g of potassium dihydrogen orthophosphate in 700 ml of water. Adjust the pH with 10% v/v orthophosphoric acid. Add water to make 1,000 ml. |
| **Phosphate buffer pH 6.0** | Dissolve 5.6 ml of 0.2 M NaOH solution to 50 ml monobasic potassium phosphate. Add water to make 200 ml. |
| **Phosphate buffer pH 7.0** | Add 29.1 ml of 0.2 M NaOH solution to 50 ml monobasic potassium phosphate. Add water to make 200 ml. |
| **Phosphate buffer pH 8.0** | Add 46.1 ml of 0.2 M NaOH solution to 50 ml monobasic potassium phosphate. Add water to make 200 ml. |

# APPENDIX 2

## PARTICLE SIZE DESCRIPTION OF POWDER USED IN EXTRACTION

| | |
|---|---|
| **Coarse powder** | All passes through 2,000 $\mu$ sieve and not more than 40% passes through 350 $\mu$ sieve. |
| **Moderately coarse powder** | All passes through 710 $\mu$ sieve and not more than 40% passes through 250 $\mu$ sieve. |
| **Moderately fine powder** | All passes through 355 $\mu$ sieve and not more than 40% passes through 180 $\mu$ sieve. |
| **Fine powder** | All passes through 180 $\mu$ sieve. |

# APPENDIX 3

## MONTHLY SALES OF ORTHODOX, CTC, ALL LEAF AND ALL DUST TEA AT AUCTION MARKETS IN THE NORTHEAST (KOLKATA, GUWAHATI AND SILIGURI)[152]

### Monthly sales of orthodox tea at Kolkata auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 3,232 | 91.48 | 1,672 | 67.63 | 1,314 | 84.50 | 2,328 | 66.05 |
| February | 2,296 | 89.02 | 1,571 | 65.02 | 765 | 78.30 | 2,379 | 58.23 |
| March | 822 | 76.94 | 789 | 64.74 | 358 | 83.10 | 851 | 57.33 |
| April | 592 | 93.39 | 372 | 62.28 | 178 | 101.32 | 244 | 75.64 |
| May | 1,526 | 80.23 | 486 | 96.84 | 1,246 | 99.65 | 719 | 83.46 |
| June | 2,468 | 85.16 | 373 | 106.74 | 1,192 | 99.41 | 874 | 108.59 |
| July | 2,779 | 95.12 | 602 | 133.74 | 2,227 | 121.77 | 1,845 | 104.18 |
| August | 3,110 | 96.37 | 1,086 | 116.79 | 2,110 | 111.98 | 1,905 | 95.79 |
| September | 1,692 | 84.81 | 764 | 115.89 | 2,423 | 104.55 | 2,224 | 91.02 |
| October | 1,315 | 80.08 | 871 | 112.48 | 2,065 | 100.37 | 2,053 | 77.14 |
| November | 2,484 | 80.24 | 1,644 | 102.90 | 2,148 | 87.11 | 1,719 | 70.88 |
| December | 2,153 | 72.98 | 1,439 | 89.88 | 2,304 | 77.24 | 2,136 | 68.12 |

### Monthly sales of CTC tea at Kolkata auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 2,970 | 101.41 | 5,116 | 74.46 | 5,588 | 77.74 | 5,684 | 88.80 |
| February | 1,668 | 95.29 | 5,134 | 72.01 | 5,666 | 64.27 | 4,588 | 82.13 |
| March | 1,511 | 83.95 | 3,401 | 63.63 | 3,480 | 57.79 | 3,998 | 63.51 |
| April | 1,502 | 90.06 | 832 | 80.58 | 703 | 60.61 | 1,070 | 72.69 |
| May | 2,585 | 83.47 | 1,857 | 99.74 | 2,544 | 78.26 | 2,846 | 79.54 |
| June | 3,185 | 87.47 | 3,834 | 91.20 | 2,966 | 77.23 | 2,350 | 84.75 |
| July | 3,025 | 80.92 | 4,413 | 88.73 | 4,978 | 82.13 | 4,228 | 80.33 |
| August | 4,140 | 80.41 | 6,311 | 83.90 | 4,503 | 75.33 | 3,887 | 70.90 |
| September | 2,722 | 81.51 | 3,798 | 88.08 | 4,544 | 74.83 | 4,154 | 66.51 |
| October | 2,007 | 81.20 | 4,134 | 93.34 | 5,064 | 74.58 | 4,861 | 59.85 |
| November | 4,915 | 79.13 | 6,095 | 91.01 | 5,874 | 67.40 | 4,529 | 64.56 |
| December | 4,562 | 73.97 | 5,356 | 81.09 | 6,237 | 70.82 | 5,440 | 70.73 |

## Monthly sales of all leaf tea at Kolkata auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 6,551 | 98.54 | 7,261 | 73.73 | 7,313 | 80.93 | 8,400 | 84.26 |
| February | 4,136 | 92.86 | 7,011 | 70.75 | 6,648 | 66.54 | 7,143 | 74.60 |
| March | 2,400 | 83.53 | 4,358 | 65.06 | 3,990 | 60.72 | 4,957 | 64.11 |
| April | 2,284 | 111.62 | 1,310 | 98.39 | 957 | 95.21 | 1,497 | 96.85 |
| May | 4,619 | 95.57 | 2,567 | 117.39 | 4,169 | 99.16 | 3,904 | 91.28 |
| June | 6,201 | 93.67 | 4,613 | 106.41 | 4,590 | 92.85 | 3,532 | 98.29 |
| July | 6,415 | 99.34 | 5,589 | 110.30 | 7,933 | 106.77 | 6,818 | 99.27 |
| August | 7,939 | 92.10 | 8,095 | 95.49 | 7,187 | 92.66 | 6,338 | 85.14 |
| September | 4,798 | 87.46 | 5,048 | 98.39 | 7,614 | 88.63 | 6,833 | 77.57 |
| October | 3,714 | 85.88 | 5,535 | 101.69 | 7,678 | 84.28 | 7,331 | 67.09 |
| November | 8,012 | 82.45 | 8,358 | 96.96 | 8,555 | 75.85 | 6,635 | 68.12 |
| December | 7,254 | 75.76 | 7,401 | 87.63 | 9,040 | 75.61 | 8,175 | 72.24 |

## Monthly sales of all dust tea at Kolkata auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 1,561 | 97.19 | 2,314 | 65.35 | 2,522 | 74.09 | 3,081 | 86.47 |
| February | 1,457 | 90.67 | 2,091 | 58.20 | 2,347 | 59.63 | 2,368 | 74.67 |
| March | 775 | 75.00 | 1,753 | 51.26 | 2,056 | 50.28 | 2,346 | 50.21 |
| April | 322 | 86.06 | 231 | 63.47 | 324 | 50.27 | 486 | 47.26 |
| May | 938 | 78.62 | 536 | 100.61 | 658 | 83.93 | 855 | 77.89 |
| June | 1,270 | 82.97 | 1,319 | 93.51 | 1,039 | 76.80 | 1,049 | 86.16 |
| July | 1,524 | 76.86 | 1,817 | 91.93 | 1,985 | 82.56 | 2,183 | 77.45 |
| August | 2,441 | 73.52 | 2,974 | 83.99 | 2,024 | 72.22 | 1,764 | 66.77 |
| September | 1,728 | 76.40 | 1,969 | 89.99 | 2,550 | 75.63 | 1,839 | 62.40 |
| October | 767 | 77.67 | 2,006 | 92.58 | 1,751 | 73.98 | 2,116 | 56.84 |
| November | 3,157 | 72.94 | 2,767 | 88.45 | 2,300 | 70.86 | 2,147 | 55.50 |
| December | 2,118 | 67.73 | 2,249 | 79.06 | 2,883 | 70.80 | 2,979 | 56.22 |

## Monthly sales of CTC leaf tea at Guwahati auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 8,509 | 98.33 | 8,292 | 70.90 | 8,279 | 75.73 | 9,322 | 87.27 |
| February | 6,477 | 93.87 | 8,014 | 68.67 | 9,882 | 66.05 | 4,323 | 76.60 |
| March | 4,114 | 75.64 | 7,076 | 63.41 | 13,036 | 55.12 | 3,960 | 56.79 |
| April | 4,035 | 82.97 | 1,070 | 85.32 | 1,246 | 68.07 | 2,081 | 79.02 |
| May | 7,758 | 77.50 | 2,964 | 99.12 | 6,767 | 76.95 | 6,704 | 78.16 |
| June | 9,240 | 81.71 | 8,960 | 89.59 | 7,598 | 76.13 | 6,262 | 83.18 |
| July | 8,457 | 76.11 | 9,711 | 82.31 | 9,118 | 80.39 | 11,403 | 75.73 |
| August | 8,885 | 76.06 | 14,802 | 80.42 | 12,787 | 71.40 | 9,343 | 68.40 |
| September | 9,131 | 74.44 | 9,496 | 89.17 | 10,960 | 69.31 | 9,947 | 64.27 |
| October | 8,529 | 76.69 | 7,499 | 92.42 | 9,738 | 68.07 | 11,132 | 59.36 |
| November | 8,513 | 75.63 | 10,770 | 88.20 | 10,674 | 63.71 | 10,493 | 62.34 |
| December | 8,729 | 70.82 | 9,964 | 78.68 | 10,981 | 69.00 | 9,398 | 66.53 |

## Monthly sales of all leaf tea at Guwahati auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 8,597 | 98.30 | 8,333 | 70.94 | 8,313 | 75.69 | 9,405 | 86.99 |
| February | 6,495 | 93.67 | 8,057 | 68.50 | 9,905 | 66.04 | 4,391 | 75.97 |
| March | 4,114 | 75.74 | 7,093 | 63.43 | 13,063 | 55.14 | 3,982 | 56.70 |
| April | 4,092 | 82.99 | 1,095 | 84.14 | 1,257 | 67.98 | 2,091 | 78.90 |
| May | 7,809 | 77.44 | 2,973 | 99.04 | 6,817 | 76.96 | 6,718 | 78.17 |
| June | 9,377 | 81.55 | 8,999 | 89.50 | 7,632 | 76.13 | 6,292 | 83.13 |
| July | 8,545 | 76.13 | 9,727 | 82.32 | 9,187 | 80.39 | 11,478 | 75.66 |
| August | 8,937 | 76.12 | 14,859 | 80.43 | 12,859 | 71.48 | 9,416 | 68.37 |
| September | 9,172 | 74.46 | 9,555 | 89.16 | 11,035 | 69.34 | 10,015 | 64.27 |
| October | 8,679 | 76.63 | 7,526 | 92.48 | 9,857 | 69.17 | 11,179 | 59.37 |
| November | 8,568 | 75.61 | 10,825 | 88.22 | 10,803 | 63.72 | 10,560 | 62.36 |
| December | 8,837 | 70.64 | 10,002 | 78.72 | 11,069 | 68.96 | 9,468 | 66.47 |

## Monthly sales of all leaf tea at Siliguri auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 5,760 | 91.86 | 5,740 | 70.72 | 4,926 | 69.76 | 5,092 | 78.01 |
| February | 3,142 | 83.87 | 5,213 | 65.73 | 5,724 | 59.52 | 2,246 | 75.04 |
| March | 1,532 | 72.01 | 4,893 | 57.88 | 6,752 | 50.57 | 3,016 | 59.74 |
| April | 2,009 | 86.79 | 2,286 | 79.76 | 891 | 71.08 | 1,866 | 71.78 |
| May | 4,952 | 77.94 | 2,670 | 86.96 | 2,433 | 70.36 | 4,705 | 72.96 |
| June | 3,593 | 82.07 | 5,182 | 82.19 | 6,061 | 70.64 | 3,218 | 77.73 |
| July | 6,300 | 74.54 | 7,968 | 75.95 | 4,650 | 68.58 | 5,549 | 69.43 |
| August | 5,741 | 72.78 | 7,094 | 71.29 | 7,567 | 62.83 | 7,354 | 63.73 |
| September | 6,007 | 72.23 | 10,228 | 75.77 | 6,937 | 60.22 | 6,234 | 56.94 |
| October | 6,179 | 72.89 | 5,928 | 82.21 | 3,554 | 61.41 | 5,909 | 54.63 |
| November | 6,601 | 70.77 | 6,634 | 78.15 | 6,647 | 55.90 | 7,983 | 59.93 |
| December | 6,376 | 69.75 | 7,794 | 71.26 | 8,835 | 59.57 | 5,277 | 60.86 |

## Monthly sales of all dust tea at Siliguri auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 1,500 | 88.02 | 1,110 | 56.99 | 846 | 66.91 | 1,260 | 66.11 |
| February | 827 | 78.31 | 1,273 | 48.22 | 955 | 55.24 | 625 | 64.69 |
| March | 421 | 67.78 | 1,413 | 43.3 | 1,612 | 39.82 | 718 | 49.53 |
| April | 238 | 82.50 | 376 | 60.87 | 150 | 49.42 | 350 | 57.94 |
| May | 1,000 | 70.80 | 401 | 80.94 | 375 | 64.82 | 812 | 66.38 |
| June | 888 | 70.22 | 894 | 76.07 | 1,215 | 64.08 | 723 | 71.91 |
| July | 2,025 | 61.23 | 1,815 | 70.47 | 1,168 | 60.85 | 1,232 | 62.33 |
| August | 1,746 | 60.95 | 1,281 | 64.59 | 1,873 | 52.23 | 2,017 | 53.70 |
| September | 1,570 | 63.95 | 2,446 | 66.61 | 1,626 | 47.62 | 1,514 | 49.94 |
| October | 1,365 | 65.75 | 1,475 | 72.98 | 833 | 49.30 | 1,198 | 45.65 |
| November | 1,393 | 63.38 | 1,304 | 72.52 | 1,576 | 45.49 | 1,835 | 49.19 |
| December | 1,191 | 61.83 | 1,375 | 67.53 | 1,630 | 51.39 | 1,058 | 53.30 |

## MONTHLY SALES OF ALL TEA (BLACK AND GREEN) AT AUCTION MARKET IN THE NORTH (AMRITSAR)[152]

### Monthly sales of all tea at Amritsar auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 45 | 32.36 | 21 | 36.18 | 38 | 40.26 | 14 | 24.53 |
| February | 54 | 29.54 | 10 | 32.44 | 11 | 34.68 | 14 | 26.49 |
| March | 46 | 17.52 | 30 | 23.41 | 8 | 23.64 | 7 | 26.56 |
| April | 30 | 89.25 | 4 | 111.29 | 9 | 111.05 | 3 | 82.34 |
| May | 89 | 65.09 | 22 | 69.74 | 79 | 71.39 | 38 | 64.62 |
| June | 101 | 60.41 | 34 | 57.43 | 87 | 50.38 | 31 | 59.39 |
| July | 66 | 60.10 | 51 | 66.64 | 47 | 58.94 | 33 | 53.28 |
| August | 52 | 56.81 | 31 | 64.85 | 27 | 52.69 | 45 | 44.89 |
| September | 77 | 58.19 | 90 | 47.84 | 28 | 45.41 | 32 | 50.25 |
| October | 64 | 54.11 | 65 | 49.34 | 27 | 44.69 | 36 | 39.18 |
| November | 36 | 46.33 | 78 | 44.84 | 21 | 25.66 | 38 | 25.38 |
| December | 58 | 40.26 | 36 | 37.05 | 23 | 24.02 | 28 | 19.76 |

### Total sales of different types of tea at Amritsar auctions

| Year | Quantity (tonnes) | | | Average price (INR/kg) | | |
|---|---|---|---|---|---|---|
| | Black tea | Green tea | Total | Black tea | Green tea | Total |
| 1997 | 23 | 721 | 744 | 18.24 | 42.65 | 60.89 |
| 1998 | 55 | 662 | 717 | 18.42 | 54.74 | 73.16 |
| 1999 | 10 | 546 | 556 | 47.31 | 12.48 | 59.79 |

Monthly sales of different types of tea at Amritsar auctions

| BLACK TEA | | | | | | |
|---|---|---|---|---|---|---|
| Months | Quantity (tonnes) | | | Average price (INR/kg) | | |
| | 1997 | 1998 | 1999 | 1997 | 1998 | 1999 |
| January | 9 | 18 | 2.70 | 23.91 | 24.88 | 36.64 |
| February | 8 | - | - | 12.60 | - | 31.06 |
| March | 5 | 32 | 5.70 | 12.01 | 13.76 | 25.64 |
| April | - | - | - | - | - | 111.29 |
| May | - | - | - | - | - | 69.74 |
| June | - | - | - | - | - | 57.42 |
| July | 1 | - | - | - | - | 66.64 |
| August | - | 3 | - | 28.02 | 27.95 | 64.89 |
| September | 0 | - | - | 37.04 | - | 38.80 |
| October | - | 1 | - | - | 23.36 | 49.20 |
| November | - | - | 2.00 | - | - | 44.78 |
| December | - | 1 | - | - | 17.62 | 42.98 |
| GREEN TEA | | | | | | |
| January | 44 | 27 | 36.20 | 22.10 | 37.36 | 12.50 |
| February | 17 | 54 | 15.10 | 29.65 | 29.58 | - |
| March | 24 | 14 | 24.90 | 25.25 | 26.32 | 12.35 |
| April | 11 | 30 | 3.40 | 73.87 | 89.24 | - |
| May | 62 | 89 | 22.10 | 59.01 | 65.09 | - |
| June | 79 | 102 | 34.00 | 45.98 | 60.42 | - |
| July | 80 | 65 | 51.50 | 39.21 | 60.10 | - |
| August | 49 | 49 | 31.10 | 41.31 | 58.64 | - |
| September | 60 | 77 | 143.20 | 41.32 | 58.18 | - |
| October | 137 | 63 | 65.40 | 42.43 | 54.35 | - |
| November | 83 | 36 | 100.50 | 40.88 | 46.41 | 12.48 |
| December | 75 | 56 | 18.50 | 49.62 | 40.64 | - |

## MONTHLY SALES OF ORTHODOX, CTC, ALL LEAF AND ALL DUST TEA AT AUCTION MARKETS IN THE SOUTH (COCHIN, COONOOR AND COIMBTORE)[152]

### Monthly sales of CTC leaf tea at Cochin auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 1,376 | 82.42 | 651 | 58.64 | 542 | 43.99 | 595 | 45.25 |
| February | 927 | 83.26 | 837 | 59.17 | 642 | 41.48 | 473 | 49.11 |
| March | 837 | 82.46 | 716 | 55.03 | 402 | 40.9 | 398 | 49.21 |
| April | 864 | 69.1 | 664 | 51.58 | 329 | 38.11 | 365 | 44.16 |
| May | 602 | 56.89 | 539 | 51.46 | 653 | 36.36 | 676 | 38.92 |
| June | 660 | 55.76 | 550 | 47.59 | 462 | 37.11 | 537 | 37.37 |
| July | 946 | 55.03 | 588 | 49.14 | 417 | 37.48 | 350 | 38.98 |
| August | 667 | 64.2 | 607 | 53.8 | 640 | 38.3 | 301 | 40.16 |
| September | 884 | 52.62 | 562 | 56.88 | 341 | 38.62 | 315 | 37.66 |
| October | 647 | 53.55 | 549 | 50.28 | 582 | 36.98 | 362 | 35.2 |
| November | 571 | 63.1 | 857 | 54.46 | 500 | 33.56 | 264 | 36.65 |
| December | 626 | 60.94 | 671 | 45.79 | 458 | 34.3 | 209 | 38.2 |

### Monthly sales of orthodox leaf tea at Cochin auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 1,535 | 87.89 | 1,062 | 69.57 | 1,285 | 61.54 | 1,922 | 53.49 |
| February | 1,135 | 92.2 | 1,094 | 71.38 | 1,110 | 69.37 | 1,229 | 56.87 |
| March | 1,062 | 93.62 | 1,043 | 67.79 | 1,411 | 63.55 | 1,101 | 58.79 |
| April | 1,082 | 87.49 | 1,002 | 67.81 | 1,909 | 54.6 | 1,055 | 57.45 |
| May | 746 | 80.54 | 911 | 63.63 | 1,997 | 54.44 | 1,303 | 55.35 |
| June | 1,197 | 80.17 | 1,364 | 57.08 | 1,490 | 54.23 | 1,835 | 49.79 |
| July | 1,640 | 81.23 | 1,058 | 65.99 | 1,407 | 56.74 | 856 | 50.52 |
| August | 1,093 | 84.35 | 1,083 | 76.3 | 1,533 | 58.22 | 530 | 59.65 |
| September | 1,271 | 71.15 | 1,278 | 78.33 | 813 | 61.07 | 975 | 62.98 |
| October | 1,342 | 62.05 | 1,546 | 72.47 | 2,040 | 60.37 | 1,068 | 59.66 |
| November | 825 | 71.51 | 1,798 | 67.81 | 1,411 | 51.81 | 1,194 | 55.49 |
| December | 1,172 | 72.51 | 1,616 | 58.3 | 1,258 | 51.30 | 867 | 60.03 |

## Monthly sales of all leaf tea at Cochin auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 2,912 | 85.3 | 1,712 | 65.42 | 1,827 | 56.34 | 2,517 | 51.54 |
| February | 2,061 | 88.2 | 1,932 | 66.09 | 1,752 | 59.15 | 1,702 | 54.71 |
| March | 1,899 | 88.71 | 1,760 | 62.6 | 1,814 | 58.52 | 1,499 | 56.25 |
| April | 1,946 | 79.32 | 1,665 | 61.34 | 2,238 | 52.18 | 1,420 | 54.04 |
| May | 1,348 | 69.93 | 1,450 | 59.06 | 2,649 | 49.99 | 1,979 | 49.74 |
| June | 2,455 | 71.72 | 1,914 | 54.39 | 1,952 | 50.17 | 2,372 | 46.98 |
| July | 1,989 | 71.46 | 1,646 | 59.97 | 1,824 | 52.34 | 1,206 | 47.17 |
| August | 1,759 | 76.7 | 1,690 | 68.23 | 2,173 | 52.35 | 831 | 52.58 |
| September | 2,155 | 63.54 | 1,840 | 71.74 | 1,154 | 54.44 | 1,290 | 56.79 |
| October | 1,989 | 59.23 | 2,095 | 66.66 | 2,621 | 55.18 | 1,430 | 53.47 |
| November | 1,396 | 68.12 | 2,655 | 63.53 | 1,912 | 47.03 | 1,458 | 52.08 |
| December | 1,798 | 68.46 | 2,287 | 54.63 | 1,717 | 46.76 | 1,076 | 55.8 |

## Monthly sales of CTC leaf tea at Coonoor auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 6,445 | 82.37 | 5,381 | 61.89 | 4,705 | 45.47 | 2,945 | 46.21 |
| February | 4,276 | 84.35 | 4,015 | 62.45 | 2,785 | 44.07 | 3,284 | 51.73 |
| March | 3,919 | 82.82 | 5,321 | 56.24 | 4,644 | 42.18 | 4,740 | 52.08 |
| April | 4,597 | 70.14 | 4,969 | 52.75 | 5,021 | 36.68 | 3,996 | 47.63 |
| May | 3,140 | 57.32 | 4,909 | 51.96 | 3,835 | 38.44 | 4,611 | 42.23 |
| June | 4,063 | 59.49 | 5,759 | 47.97 | 6,749 | 37.55 | 8,571 | 39.41 |
| July | 5,514 | 58.84 | 8,108 | 51.44 | 5,132 | 37.66 | 5,772 | 40.21 |
| August | 4,664 | 61.69 | 5,957 | 55.1 | 4,377 | 40.48 | 5,244 | 40.64 |
| September | 4,983 | 53.64 | 6,763 | 57.77 | 3,969 | 38.91 | 4,321 | 38.91 |
| October | 5,784 | 53.92 | 6,613 | 53.64 | 5,443 | 38.83 | 5,731 | 34.25 |
| November | 4,575 | 50.46 | 3,667 | 52.29 | 6,165 | 33.26 | 4,974 | 36.49 |
| December | 4,424 | 62.39 | 6,904 | 44.35 | 4,362 | 35.95 | 3,162 | 37.3 |

## Monthly sales of orthodox leaf tea at Coonoor auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 200 | 81.07 | 130 | 60.78 | 134 | 56.35 | 114 | 46.39 |
| February | 109 | 84.77 | 62 | 64.12 | 79 | 63.44 | 82 | 45.69 |
| March | 188 | 79.18 | 140 | 60.15 | 169 | 55.11 | 146 | 49.84 |
| April | 276 | 69.97 | 164 | 56.97 | 225 | 45.89 | 102 | 46.00 |
| May | 128 | 65.83 | 158 | 55.58 | 102 | 50.69 | 122 | 47.31 |
| June | 167 | 67.28 | 137 | 49.63 | 180 | 48.65 | 263 | 44.22 |
| July | 192 | 69.22 | 182 | 57.65 | 135 | 48.08 | 128 | 44.01 |
| August | 118 | 76.77 | 118 | 66.16 | 148 | 46.81 | 104 | 46.83 |
| September | 173 | 61.81 | 147 | 70.95 | 134 | 52.47 | 98 | 52.13 |
| October | 291 | 55.40 | 156 | 63.85 | 162 | 47.28 | 125 | 50.49 |
| November | 163 | 58.55 | 109 | 59.23 | 240 | 43.79 | 220 | 47.95 |
| December | 105 | 59.19 | 217 | 51.97 | 174 | 40.12 | 159 | 50.58 |

## Monthly sales of CTC leaf tea at Coimbatore auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 1,193 | 83.06 | 899 | 61.37 | 1,026 | 45.49 | 785 | 44.86 |
| February | 318 | 85.67 | 703 | 61.71 | 1,146 | 42.87 | 692 | 50.35 |
| March | 634 | 82.66 | 628 | 56.72 | 1,498 | 41.17 | 1,155 | 50.23 |
| April | 530 | 70.81 | 722 | 53.14 | 1,055 | 35.84 | 845 | 46.43 |
| May | 423 | 57.05 | 416 | 50.27 | 1,143 | 37.02 | 1,069 | 39.60 |
| June | 261 | 56.62 | 373 | 47.12 | 1,822 | 36.06 | 1,449 | 37.30 |
| July | 634 | 58.15 | 638 | 51.19 | 1,514 | 36.89 | 1,173 | 39.33 |
| August | 493 | 61.67 | 549 | 54.57 | 1,479 | 38.66 | 1,262 | 38.40 |
| September | 645 | 53.90 | 816 | 57.36 | 1,078 | 38.10 | 930 | 37.67 |
| October | 895 | 52.79 | 1,336 | 52.72 | 1,262 | 38.68 | 1,110 | 33.53 |
| November | 588 | 64.65 | 1,558 | 52.33 | 1,494 | 32.94 | 897 | 35.80 |
| December | 835 | 61.64 | 928 | 46.13 | 1,317 | 34.29 | 611 | 36.00 |

## Monthly sales of orthodox leaf tea at Coimbatore auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 683 | 85.68 | 384 | 64.20 | 389 | 61.73 | 212 | 50.42 |
| February | 228 | 89.64 | 173 | 64.91 | 494 | 68.69 | 352 | 52.47 |
| March | 441 | 87.56 | 353 | 60.42 | 736 | 61.52 | 480 | 57.13 |
| April | 250 | 81.58 | 325 | 59.87 | 526 | 51.89 | 304 | 54.47 |
| May | 222 | 76.51 | 305 | 59.25 | 587 | 54.14 | 283 | 55.29 |
| June | 325 | 75.16 | 215 | 55.23 | 704 | 52.82 | 771 | 49.85 |
| July | 391 | 77.95 | 197 | 64.52 | 612 | 55.88 | 407 | 50.74 |
| August | 214 | 81.08 | 165 | 74.98 | 430 | 58.04 | 238 | 57.75 |
| September | 340 | 64.48 | 506 | 76.99 | 519 | 58.34 | 199 | 63.62 |
| October | 400 | 56.76 | 472 | 72.72 | 620 | 57.28 | 235 | 58.70 |
| November | 238 | 66.98 | 854 | 65.91 | 614 | 49.34 | 304 | 52.86 |
| December | 306 | 67.08 | 606 | 58.49 | 447 | 46.18 | 238 | 53.72 |

## Monthly sales of all dust tea at Coimbatore auctions

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 595 | 81.38 | 597 | 61.76 | 799 | 50.93 | 622 | 52.09 |
| February | 276 | 85.32 | 377 | 58.22 | 697 | 50.18 | 605 | 54.96 |
| March | 416 | 78.58 | 350 | 58.88 | 1,039 | 44.72 | 902 | 48.16 |
| April | 412 | 74.52 | 465 | 57.88 | 615 | 40.75 | 529 | 46.00 |
| May | 439 | 68.71 | 459 | 55.13 | 662 | 43.74 | 502 | 47.00 |
| June | 497 | 57.54 | 514 | 51.22 | 1,131 | 41.23 | 971 | 42.25 |
| July | 676 | 55.06 | 590 | 53.21 | 1,075 | 39.47 | 706 | 46.11 |
| August | 349 | 65.36 | 417 | 53.96 | 1,030 | 42.58 | 763 | 49.47 |
| September | 487 | 61.01 | 386 | 62.35 | 918 | 42.81 | 764 | 49.27 |
| October | 676 | 59.39 | 659 | 56.20 | 877 | 41.71 | 932 | 44.21 |
| November | 432 | 63.17 | 666 | 59.17 | 1,086 | 39.87 | 1,231 | 44.60 |
| December | 504 | 63.19 | 661 | 54.21 | 833 | 45.71 | 590 | 44.59 |

## Monthly sales of North Indian tea at auctions (all tea)

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 28,084 | 96.58 | 28,494 | 69.34 | 27,429 | 75.39 | 31,820 | 83.33 |
| February | 19,432 | 90.09 | 27,891 | 64.68 | 29,382 | 63.49 | 19,034 | 73.85 |
| March | 11,496 | 76.14 | 23,543 | 58.91 | 34,201 | 52.25 | 17,908 | 56.57 |
| April | 10,023 | 90.29 | 5,961 | 80.78 | 4,219 | 70.45 | 7,176 | 75.61 |
| May | 22,915 | 80.05 | 10,149 | 99.53 | 16,559 | 81.47 | 19,221 | 78.49 |
| June | 25,908 | 83.29 | 24,468 | 91.11 | 23,636 | 77.53 | 17,325 | 85.19 |
| July | 29,776 | 78.95 | 31,140 | 86.38 | 28,948 | 84.87 | 32,121 | 78.77 |
| August | 32,203 | 77.49 | 41,462 | 81.65 | 37,032 | 72.54 | 31,617 | 68.97 |
| September | 28,771 | 75.54 | 33,923 | 84.91 | 34,621 | 71.10 | 30,982 | 64.45 |
| October | 25,406 | 76.53 | 26,273 | 91.06 | 28,125 | 72.61 | 32,225 | 58.73 |
| November | 32,189 | 75.52 | 34,812 | 87.90 | 34,299 | 65.48 | 34,037 | 60.54 |
| December | 29,478 | 70.85 | 33,393 | 78.08 | 38,331 | 67.66 | 31,214 | 64.36 |

## Monthly sales of South Indian tea at auctions (all tea)

| Months | 1998 | | 1999 | | 2000 | | 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) | Tonnes | Price (INR) |
| January | 16,397 | 83.71 | 12,321 | 63.26 | 13,147 | 51.26 | 12,040 | 51.31 |
| February | 10,883 | 85.55 | 10,559 | 63.13 | 11,714 | 52.07 | 10,879 | 53.69 |
| March | 10,952 | 83.06 | 12,235 | 58.61 | 14,527 | 47.74 | 13,193 | 52.54 |
| April | 11,671 | 75.07 | 11,753 | 57.00 | 14,238 | 42.70 | 11,003 | 49.62 |
| May | 9,109 | 63.81 | 11,508 | 54.92 | 14,199 | 44.58 | 13,528 | 46.13 |
| June | 12,952 | 61.66 | 13,841 | 51.39 | 17,602 | 41.53 | 20,536 | 41.92 |
| July | 13,681 | 60.54 | 15,581 | 53.77 | 14,299 | 42.25 | 13,775 | 43.61 |
| August | 10,701 | 66.18 | 12,472 | 57.99 | 14,602 | 45.43 | 12,753 | 45.39 |
| September | 12,375 | 59.29 | 13,829 | 61.77 | 10,733 | 45.40 | 11,789 | 46.35 |
| October | 14,518 | 57.41 | 15,363 | 58.09 | 16,443 | 42.00 | 15,653 | 41.27 |
| November | 11,344 | 64.99 | 13,243 | 58.78 | 16,599 | 40.90 | 14,007 | 41.81 |
| December | 12,097 | 64.45 | 16,474 | 50.15 | 12,270 | 43.35 | 9,512 | 43.87 |

# APPENDIX 4

## SURVEY QUESTIONNAIRE

1) **Name of the company/firm**

2) **Tea brands marketed:**
   Green Tea
   Black Tea

3) **Total tea production:**
   Type of Tea (green/black)
   Production (tonnes)
   Year

4) **Tea varieties cultivated:**
   Variety/clone
   Area under cultivation (ha)

5) **Total area (ha) under tea cultivation**

6) **Tea consumption in the market:**
   National
   International
   Countries to which tea is exported

7) **Production processes for green tea**

8) **Problems related to green tea**

9) **Additional information, if any**

10) **Contact address**

# APPENDIX 5

| | | |
|---|---|---|
| 1. | **Name of the firm:** | Makaibari Tea Estates. |
| | **Tea brands marketed:** | Makaibari tea (for both green and black tea). |
| | **Total tea production during (2001):** | 110 tonnes of which 40% is green tea. |
| | **Tea varieties cultivated:** | Chinese type, Assam type and their clones. |
| | **Area under cultivation (ha):** | 570.12 ha |
| | **Tea consumption in the market (national and international):** | 80% of the total green tea production is exported to Japan, USA, UK and Germany; only 20% is consumed on the domestic market. |
| | **Production processes for green tea:** | Steaming is the basic step in green tea manufacturing. |
| | **Problems related to green tea production, plucking, packing and marketing:** | Green tea is produced against order; the main importer is Japan. |
| | **Additional information:** | Major green tea grades produced by the company are: Tips Golden Flowery Orange Pekoe (TGFOP), Golden Flowery Orange Pekoe (GFOP), Broken Orange Pekoe (BOP), Orange Fanning (OF), and dust; TGFOP is the most expensive grade while dust is the cheapest. |
| | **Contact address:** | Mr. P. N. Banerjee<br>Director<br>Makaibari Tea Estates<br>Flat No. 7, 184, Lenin Sarani<br>Kolkata 700013 |
| 2. | **Name of the firm:** | Sannyasithan Tea Co. Pvt. Ltd. |
| | **Tea brands marketed:** | Hind tea. |
| | **Total tea production during (2001):** | 300 tonnes per year of green tea. |
| | **Tea varieties cultivated:** | Chinese seed, clones developed by Tocklai Research Association. |
| | **Area under cultivation (ha):** | 125 ha |

**Tea consumption in the market (national and international):** Almost all green tea produced by the company is auctioned at Amritsar market; Kashmir is the main domestic market for the product; small quantities are also exported to Europe.

**Production processes for green tea:** Steaming is the basic step in green tea manufacturing.

**Problems related to green tea production, plucking, packing and marketing:** Lack of awareness of the health benefits among the consumers, organized marketing, auction centres and market statistics for green tea; manufacturing is costly; sale price is lower than manufacturing price.

**Additional information:** -

**Contact address:**
Mr. P. Bhartia
C. F. A.
Sannyasithan Tea Co. Pvt. Ltd.
B- ½, Gillanders House, 1st Floor
8, Netaji Subhas Road
Kolkata 700001

3. **Name of the firm:** Maud Tea & Seed Co. Ltd. (also known as Biotea Estates Ltd.).

**Tea brands marketed:** Directly sell tea in bulk from the gardens.

**Total tea production during (2001):** 2,500 tonnes, including 30 tonnes of green tea.

**Tea varieties cultivated:** China variety in Darjeeling gardens and Assam variety in Assam gardens.

**Area under cultivation (ha):** 1,700 ha

**Tea consumption in the market (national and international):** 80% of the production is exported: Germany (50%), USA (20-30%), UK, Japan and Australia.

**Production processes for green tea:** Steaming is the basic step in green tea manufacturing.

**Problems related to green tea production, plucking, packing and marketing:** Green tea is produced against order; production is costly; crop losses are high; green tea is not advertised properly; people are not used to the taste of green tea.

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|---|---|---|
| | **Additional information:** | Green tea is made from leaves plucked just before the "Banji period". |
| | **Contact address:** | Mr. S. Lohia and Y. Lohia<br>Maud Tea & Seed Co. Ltd.<br>1 & 2, Old Court House Corner<br>Kolkata 700001 |
| **4.** | **Name of the firm:** | Tea Promoters (India) Pvt. Ltd. |
| | **Tea brands marketed:** | Bulk green tea. |
| | **Total tea production during (2001):** | 100 tonnes, which includes 55 tonnes of green tea. |
| | **Tea varieties cultivated:** | China type in Darjeeling gardens and Assam type and its hybrids in Assam gardens. |
| | **Area under cultivation (ha):** | 900 ha |
| | **Tea consumption in the market (national and international):** | All tea production is exported to Europe, mainly Germany, Italy, Switzerland and UK. |
| | **Production processes for green tea:** | Steaming or roasting are the basic steps used in green tea manufacturing. |
| | **Problems related to green tea production, plucking, packing and marketing:** | No market for green tea. |
| | **Additional information:** | Started green tea production in 1988; since then production has increased significantly; almost all (99.9%) green tea production is exported to Europe and the rest is auctioned at Amritsar market; selling price is INR 300 per kg for leaf grade and INR 150 per kg for Fannings; green tea is mainly produced in July; the company also produces organic tea made from plants that are cultivated without fertilizers. |
| | **Contact address:** | Mr. Binod. K. Mohan<br>Director<br>Tea Promoters (India) Pvt. Ltd.<br>17, Chowringhee Mansions<br>30, Jawaharlal Nehru Road<br>Kolkata 700016 |

5. **Name of the firm:** Ambari Tea Co. Ltd.

**Tea brands marketed:** Cooch Behar green tea, Long view/Snow view green tea.

**Total tea production during (2001):** 380 tonnes (300 tonnes green tea and 80 tonnes black tea) from Cooch Behar Tea Estates, 710 tonnes (300 tonnes green tea and 410 tonnes black tea) from Longview Tea Estates.

**Tea varieties cultivated:** Assam type and its hybrids developed by Tocklai Research Association.

**Area under cultivation (ha):** 700 ha (both the gardens)

**Tea consumption in the market (national and international):** 90% of total production (green and black tea) is consumed locally and the rest is exported to Germany and Japan.

**Production processes for green tea:** Steaming is the basic step used in green tea manufacturing.

**Problems related to green tea production, plucking, packing and marketing:** Costly production processes, sorting of green tea is slow and expensive; high stocks of green tea are held due to lack of market; from a given quantity of tea leaves 45% of black tea can be made; however, only 21% of green tea is produced resulting in considerable crop losses due to loss of water; steaming and firing are also costly.

**Additional information:** Green tea is sold at INR 80 per kg.

**Contact address:**
Mr. S. Agarwal
Director
Ambari Tea Co. Ltd.
5/2, Garstian Place
Kolkata 700001

6. **Name of the firm:** Sublime Agro. Ltd.

**Tea brands marketed:** Bulk producer of tea.

**Total tea production during (2001):** 250 tonnes green tea and 100 tonnes black tea.

**Tea varieties cultivated:** Assam type, China type, and clones (TV1-30, Tenali-17).

**Area under cultivation (ha):** 300 ha

| | | |
|---|---|---|
| | **Tea consumption in the market (national and international):** | Exported directly to Germany (about 3 tonnes of green tea), USA, Japan. |
| | **Production processes for green tea:** | Steaming. |
| | **Problems related to green tea production, plucking, packing and marketing:** | - |
| | **Additional information:** | - |
| | **Contact address:** | Mr. Raja Ram Upadhyay<br>Supervisor<br>Dagapur Tea Estate<br>Siliguri |
| **7.** | **Name of the firm:** | Sepoydhoorah Tea Co. Pvt. Ltd. |
| | **Tea brands marketed:** | Chamling for both green and black tea. |
| | **Total tea production during (2001):** | 100 tonnes and small quantity of green tea. |
| | **Tea varieties cultivated:** | Assam type (14%), China type (32.3%), hybrids (53%) and clones (TV-9, TV-29). |
| | **Area under cultivation (ha):** | - |
| | **Tea consumption in the market (national and international):** | Auctioned on Amritsar market. |
| | **Production processes for green tea:** | Steaming. |
| | **Problems related to green tea production, plucking, packing and marketing:** | Low market demand. |
| | **Additional information:** | Started green tea production in 1998 but it has been abandoned in the last three years. |
| **8.** | **Name of the firm:** | Goodricke Group Ltd. |
| | **Tea brands marketed:** | Goodricke tea. |
| | **Total tea production during (2001):** | 27,830 tonnes. |
| | **Tea varieties cultivated:** | - |

| | |
|---|---|
| Area under cultivation (ha): | - |
| Tea consumption in the market (national and international): | Green tea is produced against order. |
| Production processes for green tea: | Steaming, panning, roasting. |
| Problems related to green tea production, plucking, packing and marketing: | Limited market for green tea. |
| Additional information: | - |
| Contact address: | Mr. A. N. Singh<br>14, Gurusadaya Road<br>Kolkata 700001 |

9\. 

| | |
|---|---|
| Name of the firm: | Duncans Industries Ltd. |
| Tea brands marketed: | Duncans tea, Sargam, Shakti, etc. |
| Total tea production during (2001): | 17,000 tonnes. |
| Tea varieties cultivated: | TV-1, TV-20, TV-27, TV-19. |
| Area under cultivation (ha): | 7,000 ha |
| Tea consumption in the market (national and international): | Domestic market. |
| Production processes for green tea: | - |
| Problems related to green tea production, plucking, packing and marketing: | Do not produce green tea. |
| Additional information: | - |
| Contact address: | Mr. M. Gurbaxani<br>31, Netaji Subash Road<br>Kolkata 700001 |

| | | |
|---|---|---|
| 10. | **Name of the firm:** | The Peria Karamalai Tea & Produce Co. Ltd. |
| | **Tea brands marketed:** | CTC. |
| | **Total tea production during (2001):** | 4,500 tonnes per year. |
| | **Tea varieties cultivated:** | Assam light leaf, Vetjan- khorijan, UPASI-clones, Akamalai clones. |
| | **Area under cultivation (ha):** | Approx. 1600 ha in Anmalai hills. |
| | **Tea consumption in the market (national and international):** | Local consumption and export to Russia. |
| | **Production processes for green tea:** | Do not produce green tea. |
| | **Problems related to green tea production, plucking, packing and marketing:** | Crop loss and marketing problems due to fine plucking. |
| | **Additional information:** | - |
| | **Contact address:** | Mr. Prakash Prashar<br>Vice President<br>Cowcoody Chambers<br>234-A, Race Cource Road<br>Coimbatore 641018 |
| 11. | **Name of the firm:** | United Planter's Association of Southern India (UPASI). |
| | **Tea brands marketed:** | - |
| | **Total tea production during (2001):** | - |
| | **Tea varieties cultivated:** | 32 cultivars have been recommended for cultivation in South India.<br>UPASI-02, 03, 08, 09, 10; TRI- 2024, 2025, 2026; CR-6017 and Sri Lankan clones. |
| | **Area under cultivation (ha):** | - |
| | **Tea consumption in the market (national and international):** | - |
| | **Production processes for green tea:** | - |
| | **Problems related to green tea production, plucking, packing and marketing:** | Lack of market and technical know-how for green tea production. |

| | | |
|---|---|---|
| | **Additional information:** | - |
| | **Contact address:** | Mr. J. D. Hudson<br>Assistant Director<br>UPASI Tea Research Foundation<br>Regional Centre<br>Glenview<br>Coonoor 643101 |
| **12.** | **Name of the firm:** | The IndcoServe. |
| | **Tea brands marketed:** | CTC and Orthodox. |
| | **Total tea production during (2001):** | Data provided and included in Table 22. |
| | **Tea varieties cultivated:** | UPASI varieties. |
| | **Area under cultivation (ha):** | - |
| | **Tea consumption in the market (national and international):** | Most of green tea production is exported to Russia. |
| | **Production processes for green tea:** | Roasting and steaming; Roasting is preferred over steaming. |
| | **Problems related to green tea production, plucking, packing and marketing:** | Lack of basic knowledge of green tea production technology. |
| | **Additional information:** | Different grades of tea have been provided for analysis. |
| | **Contact address:** | Mr. K. Swaminaathan<br>General Manager<br>The Indcoserve<br>Church Road<br>Coonoor 643101 |
| **13.** | **Name of the firm:** | Mahalinga Indco Tea. |
| | **Tea brands marketed:** | CTC and Orthodox. |
| | **Total tea production during (2001):** | 700 tonnes. |
| | **Tea varieties cultivated:** | China bush and VP-clones. |

| | |
|---|---|
| **Area under cultivation (ha):** | 1.22 ha |
| **Tea consumption in the market (national and international):** | Produces green tea by order. |
| **Production processes for green tea:** | Steaming. |
| **Problems related to green tea production, plucking, packing and marketing:** | Lack of market. |
| **Additional information:** | - |
| **Contact address:** | Mr. Pitchai Pillai<br>Special Officer<br>Mahalinga Ind. Co. Tea<br>Coonoor 643101 |