Tea – the Wonder Beverage

Professor Siromi I Samarasinghe

Department of Chemistry, University of Sri Jayewardenepura, Gangodawila, Nugegoda

Tea is the most popular non-alcoholic beverage in many parts of the world. It is a valuable foreign exchange earning agricultural crop and is one of Sri Lanka's major export commodities.

The chemical composition, especially the polyphenolic compounds of the fresh tea leaves are responsible for the unique qualities of tea giving it its distinct aroma, superior flavor and therapeutic properties making it a wonder beverage indeed.

Tea is produced from the plant *Camellia sinensis (L) O.Kuntze* which belongs to the family Theacea. It is a native of South East Asian countries such as Tibet, western China and northern India and the three main varieties of tea are the China variety, Assam and the Cambodian variety. The tea plant is a small evergreen shrub; a vast number of hybrids have been developed to obtain the optimum quality parameters such as flavour, strength, colour and also adaptability to specific agro climatic factors.

History of Tea

Though Sri Lanka is world famous for tea, the beverage did not originate in Sri Lanka.

It was the Chinese Emperor Shen Nung, many centuries ago, who first introduced tea as a beverage to his subjects as having a 'fine flavour and a soothing sensation'. Ever since, the praises of tea have been sung by millions of others down the ages. The Chinese Historian Lu Yu wrote:in his classic work on tea, that "It is better to drink such a beverage than wine, which loosens the tongue".

The Birth of Ceylon Tea

Tea plants of the Assam variety and the Chinese variety were introduced to Sri Lanka in the early 19th century when the country was a British crown colony known as Ceylon. Tea plants were grown in the estates near Kandy and in Nuwara Eliya but tea cultivation remained a minor activity at the time because coffee was the country's main export crop.

In the 1870's however, a dreaded fungal disease known as the 'coffee blight' struck the coffee plantations. It destroyed the coffee plants and the entire coffee industry. The local economy then shifted to the 'new crop' - tea – within a few years.

The rapid substitution of tea for coffee was due to the initiative and untiring efforts of a Scotsman, James Taylor. In 1851, Taylor had signed on as an assistant supervisor on a coffee plantation in Ceylon and later his employers who were highly impressed with his work put him in charge of the Loolecondera estate to experiment with tea plants. The Peradeniya nursery supplied him with his first seeds around 1860.

By1867, he had planted tea in several hectares of forest land which had been originally cleared for coffee plantation and demonstrated the feasibility of tea as a plantation crop. A few years later he set up the first tea 'factory' in Ceylon.

In 1872, Taylor invented a machine for rolling the tea leaves, an important step in the process in which green leaves are converted to black tea.

Ceylon Tea became famous in the tea trade and its success led to the opening of an auction market in Colombo in 1883, and formation of the tea dealer's association some years later.

Today, there are many hybrids which have been developed for optimum quality and for adaptability to specific agro climatic conditions.

Different kinds of Tea

Tea is classified based on the agro climatic region in which it is grown, method of manufacture, and the different types of value added products.

Ceylon Tea which we are famous for is grown at three distinct elevations and are classified as the low growns, medium growns and the high growns. These in turn can be divided into the Westerns and the Easterns according to the location of the estates. The best tea comes from the Nuwara Eliya estates.

The Uva teas and the Dimbula teas are known as Seasonal teas.

Lemon tea, Peach tea and many other spiced and scented teas are some of the value added products.

It is said that like fine wine, fine tea is made under very difficult growing conditions. Each elevation, angle of slope, soil changes - all these affect the final quality attributes of the product.

Seasonal teas

Seasonal teas have a special superior quality in the flavour. In Sri Lanka there are two flavour seasons within the year,

Dimbula season (January – March)

Uva season (July – September)

During this period the prevailing weather conditions are very harsh and stressful to the tea plant. There is no rain, it is windy, and the days are clear with a lot of sunshine while the nights are cold. These conditions are needed to produce flavour compounds in the tea leaf which give the characteristic high quality flavour to the Dimbula and Uva teas.

Depending on how tea leaves are processed we get Black tea, Green tea or Oolong tea

The difference in these teas is in the manufacturing process and it is the fermentation of the tea leaves that makes all the difference.

Black tea is fermented, Green tea is not fermented, Oolong tea is partially fermented

Green tea is popular in South East Asia, mostly in China and Japan.

Among the green teas the following types are popular:
Japanese green tea (Sencha or steamed green tea) – this has a characteristically refreshing aroma with a green note.
Chinese green tea – (Lung Ching tea) – has an attractive flavour, characteristic floral, fruity and roasted aroma.
Roasted green tea (Hojicha) – low grade of sencha tea is often roasted to about 180 °C for a few minutes to enhance the aroma to give a more brisk or light taste.

There are many other varieties and value added products of green tea available in the market.

White tea
White tea has a color that varies from pale yellow or light red to clear white. The flavor is very delicate. White Tea undergoes a minimal amount of processing and is made from the new leaves and young buds of a special variety of the tea plant. The leaves are harvested when they still have a coating of white fuzzy hairs. 'Silver tips' and 'Silver needles' are some examples that are marketed at a very special price!

Chemistry

Tea chemistry is based on the reactions of its polyphenols. Therefore it is important to select the part of the tea plant which is most abundant with polyphenols, for further processing. The tea pluckers harvest the first two leaves and the bud of the tea plant for processing. These immature vegetative portions which are the rapidly growing shoot tips are collectively called the *tea flush*. When you compare the composition of the tea flush with that of other parts of the tea plant tea flush has the highest amount of polyphenols.

Plucking the tea flush fixes the chemical potential of the tea leaf, (which is the raw material which goes in to the manufacturing process), to make the tea product. Therefore the quality attributes of the final product depend largely on the chemical composition of the raw material, namely the fresh green tea leaf.

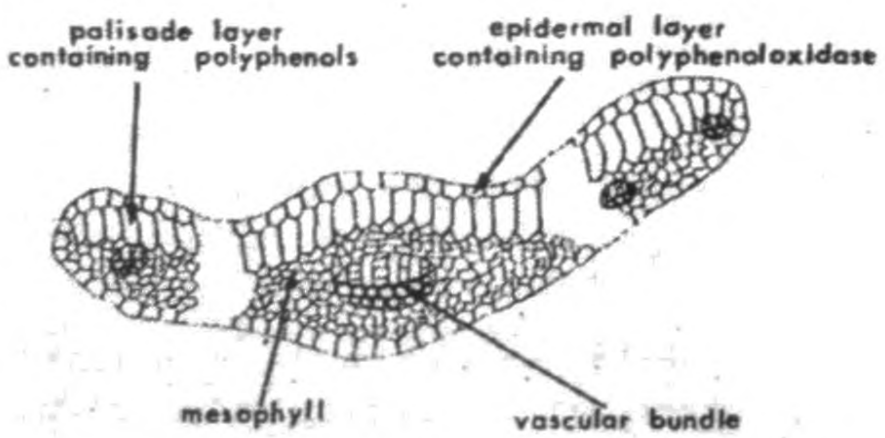


Table 1, gives the chemical composition of the tea flush. It is a general analysis and may differ with respect to the method and materials analysed. However, it is representative of the tea flush to illustrate the relative abundance of the chemical components and to understand the interaction between these components during the process of manufacture.

TABLE 1
Chemical composition of the tea flush (Assam variety)

Components	Amount in flush (% dry wt)
Substances soluble in hot water	
Flavanols	17 - 30
Flavonols and flavonol glycosides	3 - 4
Leucoanthocyanins	2 - 3
Polyphenolic acids and depsides	~ 5
Total polyphenols	~ 30
Caffein	3 - 4
Amino acids	~ 4
Simple carbohydrates	~ 4
Organic acids	~ 0.5
Substances partially soluble in hot water	
Polysaccharides	~13
Proteins	~15
Ash	~5
Substances insoluble in water	
Cellulose	~ 7
Lignin	~ 6
Lipids	~ 3
Pigments	~ 0.5
Volatile substances	0.01 – 0.02

*Adapted from Millin & Rustidge (1967)

Polyphenolic compounds
About 17 to 30 percent of the dry weight of the tissues consist of polyphenolic compounds, consisting of the following types of compounds:
Flavanols and their glycosides, flavonols and flavonol glycosides, leucoanthocyanins, phenolic acids and depsides.

Black tea manufacturing process

The conversion of fresh tea leaf to the black tea of commerce involves a series of transformations. The factory where tea processing takes place can be compared to a laboratory where fascinating chemical and biochemical reactions take place.

The manufacturing process of black tea consists of the following 5 stages after the leaves are plucked:

Harvesting, Withering, Rolling, Fermenting, Firing, Grading.

Harvesting: The slopes with closely cropped tea bushes are dotted with women in bright colourful clothing, carrying cane baskets on their backs, carefully picking the leaves. Experience is needed to handle this delicate job of plucking the tea leaves.

The most tender first two leaves and the unopened bud are selected by experienced hands. The chemical composition of this plucking unit of 2 leaves

and the bud is such that it gives the optimum quality to the processed beverage. If the process is mechanized, quality may be compromised for quantity.

Withering: The leaves are spread and warmed on wire or nylon racks . When they become limp and acquire a 'kid-glove' feel, they are ready for the next stage.

Rolling: can be done by hand or by machines. This process breaks up the cells and releases the natural juices of the leaf, where enzymes act upon polyphenolic compounds present in the leaf.

Rolling damages the tea leaves and initiates a chemical reaction between tea leaf polyphenols more specifically the catechins in tea, and an enzyme in the leaves known as tea polyphenol oxidase.

Fermentation: During fermentation this reaction is allowed to proceed. At the end of this process the leaves turn a copper colour. This is the crucial stage, because under fermenting makes the tea bitter, (green), over fermenting too results in inferior flavour.

Drying the leaves in hot air chambers stops the fermentation by inactivating the enzyme. The leaves then become dark brown.

The leaf is then sorted in sifting machines into Grades which are the Whole leaf grades and the Broken leaf grades.

Whole leaf grades:
Flowery Orange Pekoe (FOP)
Orange Pekoe (OP)
Pekoe (P)
Pekoe Souchong (PS)

Broken leaf grades :
Broken, Fannings and Dust.
Broken Orange Pekoe (BOP) larger particles than fannings or dust.
Fannings are used to fill tea bags.

It is important to be competitive in the global market, and the products should conform to Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP) and HACCP (safety standards). Every effort should be made in the tea trade, to keep up the good name of Ceylon tea.

It should be noted that leaf size is not an indication of tea quality.

Tea flavanols

From a chemist's point of view, the tea flavanols are fascinating compounds, not only because they contribute to the unique quality of tea but they are also proven to have health benefits.

The six major polyphenolic compounds in the tea leaf are the catechins. Catechins constitute about 25% of the dry weight of fresh tea leaf.

Total catechin content varies widely depending on clonal variation, growing location, seasonal/ light variation, and altitude.

TABLE 2
Phenolic compounds present in fresh green leaf (Tea Flush)

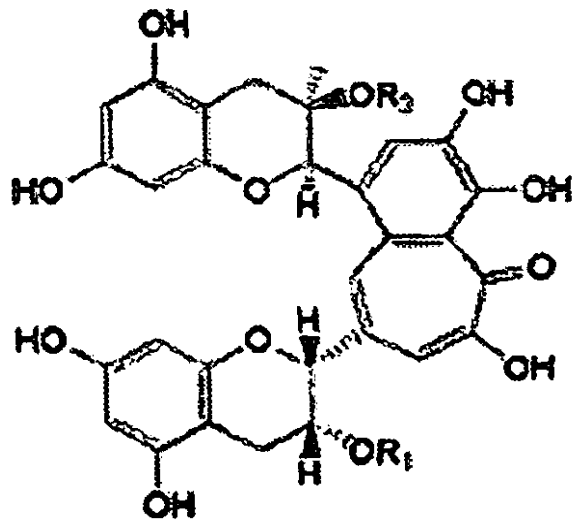
Phenolic compound	Reference to structure	Molecular formula	Molecular weight	% dry wt
Flavanols				
(-) Epicatechin	I	$C_{15}H_{14}O_6$	290	1 - 3
(-) Epicatechin gallate	II	$C_{22}H_{18}O_{10}$	442	3 – 6
(-) Epigallocatechin	III	$C_{15}H_{14}O_7$	306	3 – 6
(-) Epigallocatechin gallate	IV	$C_{22}H_{18}O_{11}$	458	9 – 13
(+) Catechin	V	$C_{15}H_{14}O_6$	290	1 – 2
(+) Gallocatechin	VI	$C_{15}H_{14}O_6$	306	3 - 4
Flavonol and flavonol glucosides				
Quercetin		$C_{15}H_{10}O_7$	302	**
Kaempferol		$C_{15}H_{10}O_6$	286	**
Quercetin 3- rhamnoglucoside		$C_{27}H_{30}O_{16}$	610	**
Kaempferol 3- rhamnoglucoside		$C_{27}H_{30}O_{15}$	594	**
Quercetin 3- rhamnodiglucoside		$C_{33}H_{40}O_{21}$	772	**
Kaempferol 3- rhamnodiglucoside		$C_{33}H_{40}O_{20}$	756	**
Leucoanthocyanins				2 - 3
Acids and Depsides				
Gallic acid		$C_7H_6O_5$	170	**
Chlorogenic acids (4 isomers)		$C_{16}H_{18}O_9$	354	**
p-Coumerylquinic (4 isomers)		$C_{22}H_{18}O_8$	338	**
Theogallin		$C_{14}H_{15}O_{10}$	343	~1
Ellagic acid		$C_{14}H_6O_8$	302	**
Total polyphenols				25 - 35

Fermentation

Fermentation is chemically, an oxidation process which takes place in the tea leaf when it is mechanically damaged during rolling.

Tea 'Catechins' are oxidized by the tea enzyme which is a polyphenoloxidase giving rise to astringent, orange and reddish brown compounds known as, Theaflavins (TF), and Thearubigins (TR).

The discovery of the structure of theaflavin was a major breakthrough in tea chemistry – the orange red colour is due to the presence of the benzotropolone ring system.



Theaflavin-1 $R_1 = R_2 = H$
Theaflavin-3-gallate-A R_1 = galloyl $R_2 = H$
Theaflavin-3'-gallate-B $R_1 = H$ R_2 = galloyl
Theaflavin-3,3'-digallate $R_1 = R_2$ = galloyl

Quality parameters for flavour, strength, colour, briskness, are determined by tea tasting which is a subjective evaluation.

Tea tasting is done by experts, and depends on their training and expertise rather than on a chemical evaluation based or instrumental analysis. Chemists have tried to relate the ratio of TR and TF to colour and other quality parameters, but the subjective

evaluation has proved to be superior.

Polyphenols are astringent. Theaflavin (orange red) and thearubigins (brown) contribute to taste and 'mouthfeel' of Black Tea.

Research on Black Tea (chemical and biochemical aspects only)

Early work in black tea was done to study the changes undergone by the polyphenols during manufacture and to understand the chemical properties of TF and TR in relation to quality of the beverage.

Roberts and co-workers[1] (mid 1950's and early 1960's) carried out the pioneering work on black tea liquors.

Takino et al [2] (1964) worked out the structure of TF

Brown et al[3] (1969) attempted to determine the chemical nature of the TR, and concluded that they were in fact a polymeric group of compounds – polymeric proanthocyanidins.

Sanderson[4] and co-workers (early 1970's) proposed a pathway for the formation of TF and TR during fermentation of black tea

Nursten & Cattell[5] (1977) Separation of TR's was carried out using new separation techniques (on Sephadex LH-20 using 60% acetone)

Leeds University group[6] (1977 – 1980) did further investigations to determine the chemical nature of thearubigins by carrying out invitro oxidation of tea leaf flavanols in model systems.

In later years, interest shifted to the aroma constituents, especially the Volatile Flavour Compounds (VFC's).

Aroma compounds

Work on aroma compounds has been done mainly by Japanese chemists[7] on green tea, correlating VFC's with quality.

Green tea aroma compounds have been isolated and aroma formation during BT manufacture has also been investigated.

Chemists at the TRI have done some very useful research on black tea aroma, relating aroma to quality.

Teesside University group (2002)[8,9]

Worked on the Fingerprinting of black teas of different origin based on the VFC's using GC + MS techniques. The tea samples were supplied by the Tea Research Institute of Sri Lanka.

It was observed that Ceylon tea had many more VFC's than either Kenya tea or Assam tea.

This method will be useful to identify the origin of Ceylon teas according to the different regions such as low country mid country and up country teas, and also the flavoury teas of Uva and Dimbulla.

Tea Aroma

Volatile compounds in tea aroma (Yamanishi 1999)[7] include the following:

Linalool, *cis* linalool oxide, *trans* linalool oxide, Methyl salicylate – (distinct Uva character)
Cis geraniol - (rose petal fragrance, High in NE teas), *trans* – 2-hexenal – (undesirable, 'greenish' note), Phenyl acetaldehyde, *cis*-jasmone

Aroma is described as

Fresh floral – due to the presence of Linalool, Jasmine lactone
Sweet floral – Phenylethanol, Jasmine lactone,
Sweet fruity- 2-phenylethanol
Citrus- Linalool oxide II,
Roasted- Pyrolle derivatives

Trends in tea research are moving towards the development of value added products and investigation of health benefits. In order to be productive and reap the maximum benefit from such research programmes a multidisciplinary approach to research should be adopted. There is a need for industry and researchers to collaborate and for scientists, industrialist, and policymakers to work together.

Adulteration of black tea should be prevented and every effort should be made to protect the good name of Ceylon Tea by devising quick, convenient and accurate methods to assess quality of tea samples.

Value addition

Value addition is important to be competitive in the tea trade. Many products are there in the market - such as Iced Lemon tea Green tea with added spices, fruit flavours or scented teas.

The Wonder Beverage

The health benefits of tea have been touted for infusions made from the plant *Camellia sinensis* for over 4700 years; ever since its discovery was attributed to the legendary emperor, Shen nong who claimed that its taste and stimulating properties were useful for treating tumors, abscesses, bladder ailments, lethargy, among other conditions

The vast majority of studies have been of Green tea, however some studies have been made of White tea, Oolong tea, and Black tea.

Green tea is ranked as a leading health-giving substance in traditional Chinese medicine.

Many studies on health benefits have been linked to the catechin content in tea, more specifically to epigallocatechingallate (EGCG). These have antioxidant properties.

The flavanoids found in both green and black teas are thought to be potent weapons in the fight against many diseases such as CHD (coronary heart disease), various types of cancers, liver diseases; they are even known to protect your teeth.

Some research findings

Lowers serum cholesterol

Human, animal and *in vitro* studies have suggested that green tea components can lower cholesterol levels. In one study carried out in Japan, an average decrease of

eight total cholesterol levels was found for men with the highest daily intake of green tea, compared to ones with the lowest.[10]

Protects teeth

Experiments with Green tea have shown promising results for oral health. Information from both human and animal studies have demonstrated how green tea works against bacteria that cause cavities in teeth.[11] Also, green tea naturally contains fluoride, which protects teeth from cavities.

Prevention and treatment of Cancers - Cancer research.

Esophageal Cancer: Reduced risk of esophageal cancer has been associated with green tea consumption. A lowered risk of esophageal cancer has been reported in those who drank green tea.[12] In this study, women who drank green tea were protected from esophageal cancer compared to women who did not drink green tea. Medical records of patients aged 30-74 years who were diagnosed with esophageal cancer were used for this study which was conducted in multiple locations.

Liver Cancer: In 1996, researchers at the Indiana University School of Medicine reported that green tea prevented liver tumors. The scientists studied the effects of green tea on mice that had been exposed to a known liver carcinogen.[13]

Prostate Cancer: Scientists at the Mayo Clinic in 1998 found that the active component in green tea, - epigallocatechin gallate (EGCG), triggered apoptosis (programmed cell death) in human prostate cancer cells.[14]

Plain *tea or milk tea?*

Does adding milk to tea reduce health benefits?

Protein in milk (casein) can bind to polyphenols (*e.g.* EGCG) in tea infusions to block the effect against cardio vascular diseases. However, the beneficial effects from black tea are not entirely attributed to its catechin content but to other physiologically active compounds present in black tea.

Green tea is not consumed with milk. In the above context, one cannot assume that adding milk to tea reduces its overall health benefits.

To summarise the health effects of tea:
It has long been felt that tea contains certain chemicals beneficial to health.

Although certain health claims need further investigation, tea is a good source of flavanoids which have antioxidant properties.
Traditionally black tea rather than green tea has been consumed in Sri Lanka – research in to the health aspects of black tea in its various forms needs to be carried out.

Tea, then, is truly a wonder beverage

The tired swear by its invigorating power on the system;
the sedate by its energizing properties;
the pessimist by its ability to cheer;
and the scientist by the immense potential of its constituents

So everytime you drink a cup of tea, you raise a toast to good health and well-being!

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