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Influence of climatic seasons on quality of south Indian black teas

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ABSTRACT

The climatic seasons prevailed in Anamallais region of south India significantly affected the quality of CTC (Crush, Tear & Curl) black teas produced in that region. The changes in biochemical composition of green tea leaves and black tea quality were monitored. The changes with respect to different climatic seasons revealed that theaflavins (TF) and aroma composition are more in black teas manufactured during the summer season (January to April) of the year. The south-west monsoon season of the year (May to August) resulted in black teas of poor quality. The black teas manufactured while the north-east monsoon (September to December) in operation stood amidst both the extremes.

Key words: Black tea, catechins, theaflavins, aroma, EGCG, seasons, crude fibre, quality

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INTRODUCTION

Tea is manufactured from the tender leaves and buds of the evergreen shrub *Camellia sinensis* (L.) O Kuntze. The yield of harvestable shoots is affected mainly by the environmental factors. Due to the perennial nature of tea plant, leaves are harvested almost throughout the year. In some parts of the world, tea plants experiences dormancy during winter seasons, there the harvesting is affected for certain periods of the year. In such places, tea cultivation may be regarded as seasonal. The biochemical characters are either inherent nature of the raw material used or formed/changed during the course of tea manufacture. Catechins are the well known quality precursors present in tea leaves. The changes in the levels of catechins with respect to the climatic seasons revealed that the tea plant accumulate more catechins during summer seasons under south Indian conditions [1]. Thus it was expected that the teas produced during the summer season would be of higher quality than those produced during rest of the year. Since catechins are also involved in the development of aroma, there is a possibility for the development of more aroma compounds in teas manufactured during summer season [2].

The increase or decrease of aroma during different seasons is the consequence of enzymic reactions controlling the dynamic metabolic systems in tea leaves. Most of the aroma compounds are present in large quantities in north-east Indian teas manufactured during summer, which is often referred as flavoury tea in the market [3]. Higher amounts of mono terpene alcohols present in this tea making it as superior tea. Seasonal variations in infusion quality of orthodox Kangra tea over various seasons are reported by Gulati and Ravindranath [4]. TFs, TR and caffeine are maximum during early season and gradual decline with progress in season, showing a minimum during main growing season and slight improvement through backend yield season. Flavour profile analysis also revealed qualitative and quantitative seasonal variations in aroma complex under Kangra conditions. Higher proportions of aroma compounds recorded during early flush exhibited comparatively lower contents or even total loss through main growing season. The chemical composition viz., TFs, TR and caffeine content of Darjeeling teas during first and second flush period did not vary significantly [5].

In contrast to the observations from both south and north-east India, the content of total polyphenols showed wide variations with time of a year under Kenyan conditions, also correlated significantly with black tea quality parameters [6] and used as a parameter for identifying potential high quality clonal tea plants [7]. The seasonal changes in chemical composition of black tea with the environmental conditions in Kenyan tea growing conditions were studied by Owuor [8].

The present investigation was carried out to study the influence of climatic seasons on the quality precursors in the green leaves and quality and aroma components of CTC black tea manufactured at Anamallais of southern India.

MATERIALS AND METHODS

Three elite tea cultivars (UPASI-3, UPASI-9 and CR-6017) of south India and Assam seedlings were selected to study the quality fluctuations with respect to altitude. The experimental plots comprising of 100 bushes of same age from pruning were laid out at UPASI Tea Research Foundation Experimental Farm, Valparai, situated at 1150 meters above mean sea level. The cultural practices and pest, disease and nutrient management practices are kept similar as suggested by UPASI (*5*). In Anamallais of south India, there exists three different climatic seasons in the year viz., summer (January-April), south-west monsoon season (May-August) and north –east monsoon season (September – December). The sampling were done during these climatic seasons are in operation.

Experimental CTC black tea manufacture

About 2 kg green leaves (2 leaves and a bud) of respective cultivars were collected from the fields and spread on the withering troughs at the rate of 3 kg per square foot. Ambient air was passed with the velocity of 45 cfm (cubic feet per meter) through the leaves for a period of 16 hours to bring about adequate physical and chemical wither. The withered leaves were passed through miniature CTC machine for five times to get adequate maceration. The *cut dhool* was allowed to ferment in a chamber maintained at 25 °C and 95 percent relative humidity for a definite period. The fermented *dhool* was dried in a miniature fluid bed drier with a blast of hot air of inlet temperature 120 °C, to get the black tea. The tea samples thus manufactured were sorted and the pekoe fannings (PF) grade was selected for the study.

Estimation of TF and TR (Thanaraj and Seshadri, 1990)

The estimation of TF and TR was performed by following the methodology proposed by Thanaraj and Seshadri [9]. Briefly, to two gram of black tea sample (PF grade) taken in a 250 ml conical flask, 100 ml of freshly boiled water was added and the contents were infused over the boiling water bath for 10 minutes with intermittent shaking. The contents were filtered through cotton wool and the analyses were made as per the scheme in Figure 1. From the absorbance values, TF and TR were calculated using the following formulae,

$$\text{TF (\%)} = 4.313 \times C$$
$$\text{TR (\%)} = 13.643 \times (B-C+D)$$

Estimation of catechin fractions using HPLC

The estimation of individual catechins was done as per the international standard method [10]. Briefly, the green leaves were dried in a hot air oven maintained at 70 ±2 °C for 12 hours. The dried leaves were ground and passed through 30 mesh sieve to get particles of uniform size. About 0.2 g of powdered tea leaves was extracted using 10 ml of 70 percent methanol maintained at 70 °C. One ml of the extract was diluted to five ml with stabilizing solution (0.25 percent each of EDTA and ascorbic acid in 10 percent acetonitrile) and was filtered through 0.45 µm nylon membrane filter, and used for HPLC analyses.

The analyses were performed in Agilent 1100 series HPLC with diode array detector. Phenomenex Luna 5 µm phenyl-hexyl column (250 mm length x 4.6 mm internal diameter) fitted with a Phenomenex Security Guard (4 mm length x 3 mm diameter phenyl hexyl bonded) cartridge was used for the analyses. The column was maintained at 35 ± 0.5 °C. The absorbance of compounds measured at the wave length of 278 nm. Mobile phase A was 2 percent acetic acid in 9 percent acetonitrile and mobile phase B was 80 percent acetonitrile. The gradient programme is as follows: 100 percent mobile phase A for 10 minutes, then over 15 minutes a linear gradient of 68 percent mobile phase A, 32 percent mobile phase B and hold at this condition for 10 minutes. Then reset to 100 percent mobile phase A and allowed to equilibrate for 10 minutes before next injection. The integration and data handling were performed using HP Chemstation software. The retention time of the compounds were compared with those of authentic standards from Sigma Chemical Limited.

Estimation of theaflavin fractions using HPLC

The individual theaflavins were analysed as stated by Bailey et al. [11] with slight modifications. Briefly, the standard tea brew (2 %) was prepared and filtered through 0.45 µ membrane filter and 10 µl portion was injected to HPLC.

Agilent 1100 series HPLC equipped with photo diode array detector was used for the determination. A Hypersil ODS column (250 mm length x 4.6 mm internal diameter) was used for the analyses. The absorbance of compounds measured at the wave length of 280 nm. The mobile phase A is 100 % acetonitrile and the mobile phase B is 2% acetic acid in water. The gradient programme is given as below.

100 percent mobile phase B for first 3 minutes, followed by a linear gradient of 31 percent mobile phase A up to 15 minutes and reset to 100 percent mobile phase B till 17 minutes and allowed to equilibrate for another 10 minutes before next injection. The integration and data handling were performed using HP Chemstation software.

Estimation of volatile flavour compounds using gas chromatograph with head space sampler (GC-HS)

Two grams of black tea samples along with 2 ml of internal standard (50 ppm of ethyl caproate in 5% ethyl alcohol) are taken in the headspace vial. The aroma profile of black teas (from the head space volatiles) was assessed using PerkinElmer Autosystem XL GC with Turbomatrix 16 head space sampler. The analyses are made using HP-Innowax column (60 meters length, 0.25 mm internal diameter and 0.25 µm film thickness). At the head space sampler, the oven, needle and transfer line were maintained at 95, 100 and 105 °C respectively. The GC conditions are, initial temperature of the column is 50 °C for 2 minutes and increased at the rate of 5 °C per minute to 180 °C, thereafter maintained at the same temperature for 15 minutes. The injector was maintained at 200 °C, while the flame ionization detector at 250 °C. Nitrogen was employed as the carrier gas with the flow rate of 1 ml per minute. The signals were analysed using Totalchrom software.

The presence of individual component was expressed as percentage relative distribution of peak areas to that of internal standard. The aroma compounds are classified in to two groups. Group I consisted of hexanal, 1-penten-3-ol, trans-2-hexenal, 2-hexanol, 1-pentanol, 6-methyl-5-hepten-2-one, cis-3-hexenol and 1-octen-3-ol. Compounds fall in group II are α-pinene, linalool oxide I, linalool oxide II, citronellal, benzaldehyde, linalool, phenyl acetaldehyde, geranyl acetate, methyl salicylate, nerol, geraniol, α-ionone, benzyl alcohol, phenyl ethanol, β-ionone, cis-nerolidol and methyl jasmonate. The ratio between group II and group I compounds were worked out and expressed as flavour index.

$$Flavour index = \frac{Sum\ of\ percent\ relative\ distribution\ of\ group\ II\ compounds}{Sum\ of\ relative\ distribution\ of\ group\ I\ compounds}$$

Determination of water extract (IS 13862: 1998)

Two hundred ml of hot water was added to two gram of tea sample taken in a 1 L conical flask fitted with an air condenser. The contents were boiled gently on a hot plate for exactly one hour with intermittent shaking. The contents were cooled and filtered through pre weighed sintered glass crucible. The residue was washed with hot water. The crucible with contents was dried in the oven at 103 ± 2 °C overnight. Cooled and weighed. From the weight of dried residue left after extraction, the amount of water extract was calculated and expressed on dry matter basis.

Determination of crude fibre content (IS 16041: 2012)

About 2.5 gram of the tea sample was digested with 200 ml of hot 5.5 % (v/v) sulphuric acid for 30 minutes. The contents were filtered using Whatman No. 41 filter paper under suction and transferred to 200 ml of hot 10 % (w/v) sodium hydroxide. Few drops of anti-pumping agent (octanol) were added and the contents were again digested for another 30 minutes. Filtered through sintered glass crucible, the residue was washed with hot water, 1 % (v/v) hydrochloric acid, hot water, twice with alcohol and thrice with acetone. The contents were dried in the oven maintained at 103 ± 2 °C for three hours. Cooled and weighed, the residue was ashed by keeping the crucible in a muffle furnace at 525 ± 25 °C for three hours. Cooled and weighed again. From the difference in weights of crucible with residue and crucible with ash, the crude fibre content of black tea sample was calculated.

RESULTS AND DISCUSSION

Influence of climatic seasons on Theaflavin content of black teas of various cultivars

The seasonal changes in TF levels of CTC black teas of various cultivars are given in Table 1. Irrespective of the cultivars, the CTC black teas manufactured during the season between January to April had higher TFs followed by that manufactured between September and December and lowest TF was obtained for CTC black tea manufactured between May to August. Apart from the changes in climatic seasons, the CTC black tea manufactured from the cultivar UPASI-3 had higher levels of TF and rest of the cultivars is at par with each other with respect to their TFs. For the same cultivar at different climatic seasons, the cultivar UPASI-3 had higher TFs during January to April and its performance was similar during the seasons May to August and September to December. The cultivar UPASI-9 also had higher TFs during January to April and its performance was similar during the seasons May to August and September to December.

The cultivar CR-6017 and Assam seedlings resulted in CTC black teas with lower TF during May to August and its performance was found to be at par for the seasons January to April and September to December. When comparing the performance of cultivars at the same climatic conditions, all the four cultivars at par with each other during January to April and September to December. But, the cultivar UPASI-3 resulted in CTC black teas of comparatively higher TF, when manufactured between May and August, while UPASI-9, CR-6017 and Assam seedlings were found at par of TF content during May to August.

Black teas manufactured during the season between January to April had higher TFs followed by that manufactured between September and December. This is mainly due to the fact that, during the summer season, the days will be bright and hot followed by cold nights. Under these climatic conditions, the tea plant accumulates the bio-chemicals necessary for the synthesis of TF. Black tea manufactured from the cultivar UPASI-3 had higher levels and rest of the cultivars had similar levels of TF. This is due to the proper balance of essential biochemical constituents in the leaves of the respective cultivars. When comparing the performance of cultivars at the same climatic conditions, all the four cultivars at par with each other with respect to their TF content. This implies that the cultivars acquainted with the climatic conditions prevailed and are producing similar levels of TFs during the particular season. During rainy seasons, the tea plants exposed to cloudy and rainy days which affected the synthesis of major bio-constituents in the leaf [12]. Also, in the factories, it becomes difficult to give adequate withering, which could affect the TFs composition in resultant black tea [4].

Impact of climatic seasons on thearubigin content of clonal black teas

The results on the seasonal variations of TR in CTC black teas of different cultivars are given in the Table 2. Irrespective of the cultivars, the CTC black teas manufactured between January and April had higher TR followed by September to December and the lowest was obtained during May to August. All the four cultivars are at par with each other in their TR content when comparing them beyond the seasonal changes. While comparing the performance of the individual cultivars at different climatic seasons, UPASI-3 had lower TR during May to August and its performance was similar at the other two seasons. Similar result was observed in case of Assam seedlings also. The cultivars CR-6017 and UPASI-9 resulted in black teas of higher TR during January to April followed by September to December and lowest was obtained during May to August. At the same season, during January to April, the cultivar UPASI-3 resulted in lowest TR while the rest of the cultivars tested are at par with each other. During May to August and September to December, the performances of these cultivars are at par with each other in the respective seasons.

The climatic seasons had a little impact on the TR content of black teas of various cultivars (Table 2). Black teas manufactured between May and August had lower TR followed by that manufactured during September to December. During these seasons, the tea plantations of south India are under north-east and south-west monsoons and receive showers. Highest TR during January to April followed by September to December and the lowest was obtained during May to August. It is demonstrated that the rain flush teas have lower TR content under north Indian conditions [4]. All the four cultivars are at par with each other in their TR content when comparing them beyond the seasonal changes. This may be due to the fact that, the formation of TR is related to the biochemical composition of green leaves and also with the TF oxidized during the fermentation phase of black tea processing. During May to August season, activity of the enzyme peroxidase, the enzyme responsible for the formation of TR in black tea was found to be lower [13]. This lower activity of peroxidase could also be the reason for lower TR in black teas manufactured during May to August.

Water extract of black teas of various cultivars as influenced by climatic seasons

The changes in the water extract of clonal black teas with climatic seasons were analysed and are presented in the Table 3. Irrespective of the cultivars, the black teas manufactured during January to April had higher water extract. Black teas manufactured during May to August and September to December are at par with each other. Irrespective of the climatic seasons, the performances of the individual cultivars are similar to each other. The cultivar UPASI-3 had higher water extract during January to April and at par with May to August and the lowest during September to December. UPASI-9 resulted in black teas of higher water extract during January to April and at par with September to December and the lowest water extract was obtained during May to August. Similar results were also observed with the cultivar CR-6017 and Assam seedlings. During January to April and September to December, the performance of individual cultivars is on par with each other. During May to August, the cultivar UPASI-3 had higher water extract and all other are at par with each other.

Black teas manufactured during January to April had higher water extract (Table 3). During this season, the growth of tea plant is restricted and the availability of compounds for the formation of soluble solids is more [14]. Black teas manufactured during May to August and September to December are at par with each other, since more soluble solids are transferred to the actively growing parts and are involved in the production of biomass [5]. Irrespective of the climatic seasons, the performances of the individual cultivars are similar to each other. During January to April and September to December, the temperature is relatively higher and lead to the formation of more water extractives and hence the performance of individual cultivars is on par with each other.

Changes in crude fibre content of black teas of various cultivars with respect to the climatic seasons

The results on the crude fibre content of clonal black teas with respect to climatic seasons are presented in Table 4. Irrespective of the cultivars, the CTC black teas manufactured during January to April had lower crude fibre content and those manufactured during May to August and September to December are at par with each other. Irrespective of the climatic conditions prevailed, the cultivar UPASI-3 resulted in black teas with higher crude fibre content and rest of the cultivars is at par with each other. While comparing the performance of individual cultivars at various climatic seasons, the cultivar UPASI-3 performed similarly throughout the year.

The cultivars UPASI-9 and Assam seedlings had highest crude fibre content during May to August followed by September to December and January to April and both were found at par. The cultivar CR-6017 had lower crude fibre content during January to April, and at par with May to August, while higher during September to December. However, the values are well within the limits prescribed by Prevention of Food Adulteration (PFA) Act.

Irrespective of the cultivars, the black teas manufactured during January to April had lower crude fibre content and those manufactured during May to August and September to December are at par with each other (Table 4). This could be due to favourable growing conditions and leaves becoming coarser quickly during May to August. Also the lignification of plant tissues to form more crude fibre increases at high humid conditions during May to August. These results are in line with the reports for Darjeeling teas [15]. But are contrast to studies made by Wood and Roberts [16], they reported that there is no effect of climatic seasons on the crude fibre content of black tea. When the cultivar UPASI-3 resulted in black teas with higher crude fibre content and rest of the cultivars is at par with each other. This could be due to the genetic character of the cultivar.

Theaflavin fractions and Digallate equivalent of theaflavins of clonal black teas as influenced by climatic seasons

The seasonal variations in the individual TFs were analysed using HPLC, the DGETF values were worked out and are presented in Table 5. During January to April, considering the DGETF values, the black CTC teas manufactured from the cultivars Assam seedlings and UPASI-9 are at par with each other. The CTC black tea of UPASI-3 is superior with respect to its DGETF value. The cultivar CR-6017 produced the CTC black tea with intermittent values of DGETF.

During May to August, the CTC black tea manufactured from Assam seedlings is inferior in their DGETF values. The cultivars UPASI-9 and CR-6017 are at par with each other. The cultivar UPASI-3 resulted in CTC black tea of higher DGETF value. During the season between September and December, the cultivars UPASI-9, CR-6017 and Assam seedlings are at par with each other. The CTC black tea of the cultivar UPASI-3 possessed higher DGETF value.

The seasonal variations in DGETF values showed that, during January to April, black tea of the cultivar UPASI-3 is superior followed by CR-6017 (Table 5). The cultivars Assam seedlings and UPASI-9 are at par with each other. During May to August, the black tea of Assam seedlings is inferior. The cultivars UPASI-9 and CR-6017 are at par with each other. The cultivar UPASI-3 resulted in black tea of higher DGETF. During the season between

September and December, the cultivars UPASI-9, CR-6017 and Assam seedlings are at par with each other. The black tea of the cultivar UPASI-3 possessed higher DGETF value. In general, the black teas manufactured during January to April had higher DGETF than others. This could be due to the fermenting potential of the cultivar tested and the environmental factors which influence the manufacturing conditions and also the accumulation of essential biochemical compounds in the green leaves. The accumulation of catechins and its gallates during the summer seasons resulted in teas of higher DGETF [17].

Changes in flavour Index of clonal black teas with respect to the climatic seasons

Flavour index of clonal black teas as affected by the seasons are illustrated in Table 6 after statistical analyses. Irrespective of the cultivars taken for the study, the CTC black teas manufactured during January to April had higher flavour index followed by those manufactured between September to December and May to August. Apart from the changes in the climatic seasons, the CTC black teas of the cultivar UPASI-3 had higher flavour index followed by CR-6017 and UPASI-9. The cultivar Assam seedlings resulted in black teas of poor aroma character *i.e.* lower flavour index. When comparing the performance of individual cultivars at various climatic seasons, all the four cultivars had higher flavour indices when manufactured during January to April. The flavour index values of CTC black teas from all the cultivars are lower during May to August. Intermittent values of flavour index were resulted in black teas manufactured between September and December. When comparing the performance of cultivars at the same season, irrespective of the seasons the cultivar UPASI-3 resulted in black teas of higher flavour index, which is followed by CR-6017, UPASI-9 and Assam seedlings.

Black teas manufactured during January to April had higher flavour index followed by those manufactured between September to December and May to August (Table 6). All the four cultivars had higher flavour indices when manufactured during January to April. The flavour index values of black teas from all the cultivars are lower during May to August. This is due to the accumulation of high levels of chlorophyll in tea leaves during the rainy seasons [18]. The black teas of cultivar UPASI-3 had higher flavour index followed by CR-6017, UPASI-9 and Assam seedlings. Intermittent values of flavour index were resulted in black teas manufactured between September and December.

The delicate and economically valuable aroma of tea is a seasonal characteristic and the reasons for its ephemeral nature have long been sought to under stand. The essential climatic condition for the production of flavoury teas was identified for Sri Lankan teas [19]. A cool, dry and cloudless days followed by cold and clear nights could lead to the accumulation of compounds necessary for the flavour production. Further, in these climatic conditions, the growth is slow and two consecutive weeks of such weather are generally necessary before flavor becomes manifest. Study made by Herath et al [20] revealed the fact that the desirable volatiles accumulate during the dry weather conditions of Sri Lanka. The major compounds responsible for the tea aroma declined with the rain. But higher levels of compounds responsible for aroma were observed during the dry periods of the year.

The increase or decrease of flavour constituents during different seasons is the consequence of enzymic reactions controlling the dynamic metabolic systems in tea leaves. The group II volatiles are synthesized in more, during the summer seasons, while the flavanol glycosides and essential aroma precursors are accumulated. The changes in group II volatiles with the climate under Sri Lankan conditions also found to be in the same line [21].

Changes in individual catechins in different cultivars with respect to climatic seasons

The leaves of different cultivars were analysed for individual catechins using HPLC and the results are presented in Table 7. During the season between January and April, the cultivar UPASI-3 had higher levels of (+) catechin followed by CR-6017. The cultivars UPASI-9 and Assam seedlings are found to be on-par with each other with respect to their (+) catechin content. Similar observations are noticed in case of EC contents. The cultivars UPASI-3 and Assam seedlings had higher and same value of ECG content followed by the cultivar CR-6017 while UPASI-9 possessed lowest ECG content. The levels of EGC are higher in the cultivar UPASI-3 and the cultivars UPASI-9 and CR-6017 are at par with respect to their EGC content and lowest was obtained with Assam seedlings. Similar trend was noticed in case of EGCG content also.

During the season May to August, the cultivars UPASI-3 and UPASI-9 had intermediate (+) catechin content and are at par with each other. The cultivar CR-6017 had higher and Assam seedlings had lower (+) catechin contents. The level of ECG in the tea leaves was highest in CR-6017 and at par with UPASI-3 followed by UPASI-9 and the lowest was with Assam seedlings. In case of EGC, the cultivar CR-6017 had higher levels followed by UPASI-9 and UPASI-3. Assam seedlings had lower EGC contents. EGCG was found present in the cultivar UPASI-3 in higher quantities. The cultivars UPASI-9 and CR-6017 are at par with each other in their EGCG contents. Assam seedlings had lower EGCG content in their leaves. The cultivar UPASI-9 had higher levels of EC in their leaves. While the cultivars UPASI-3 and CR-6017 had intermittent values of EC, they were at par with each other. Assam seedlings had lower EC contents.

During the season from September to December, the cultivar CR-6017 had higher (+) catechin content in their leaves followed by UPASI-3, UPASI-9 and Assam seedlings. When comparing the ECG levels, the cultivar CR-6017 had higher quantities followed by UPASI-9, UPASI-3 and Assam seedlings. With respect to EGC, higher value was obtained with CR-6017 and was found at par with UPASI-3 followed by UPASI-9 and Assam seedlings. In case of EGCG, UPASI-3 had higher contents followed by CR-6017, UPASI-9 and Assam seedlings. Based on the EC contents, the cultivars CR-6017 and Assam seedlings were at par with each other and had lowest value. Higher EC content was observed with the cultivar UPASI-3 followed by UPASI-9.

The changes in composition of individual catechins present in clonal tea leaves with climatic seasons are presented in Table 7. During the summer season of the year, there is an increased levels of catechins noted. The increase is more in case of EGCG and ECG. This is mainly due to the active synthesis of catechins during the summer seasons. This may be due to the irradiation effects of sun [22]. Also the active synthesis of catechins by phenylalanine ammonia lyase during summer season was reported by Zagoskina et al [12] under Russian conditions.

During the rainy seasons, the catechins are found to present comparatively lower levels. These results are in contradiction to those reported by Bhatia and Ullah [23] under north-east Indian conditions. But the results of the present study are in line with those reported from south India [1]. During rainy season, the synthesis of catechins hindered due to the low enzyme activity registered. The results are also in line with those from Australia [24]. There also higher levels of individual catechins noted during the warmer moths and lower levels during the cooler months of the year.

Table 1: Influence of climatic seasons on theaflavin content (%) of clonal black teas

Season	UPASI-3	UPASI-9	CR-6017	Assam Seedlings	Mean Season
Jan. – April	1.22	1.02	1.09	1.04	1.09
May – August	0.93	0.82	0.78	0.67	0.80
Sept.-Dec.	1.01	0.98	1.03	0.89	0.98
Mean cultivars	1.05	0.94	0.97	0.87	
	SE±	CD (0.05)	CD (0.01)		
Season	0.014	0.038	0.063		
Cultivars	0.060	0.120	0.170		
Season x cultiva	0.160	0.224	0.317		
Cultivar x Seaso	0.100	0.190	0.288		

SE – Standard error; CD – Critical difference

Table 2: Impact of climatic seasons on thearubigin content (%) of clonal black teas

Season	UPASI-3	UPASI-9	CR-6017	Assam Seedlings	Mean Season
Jan. – April	7.58	8.26	8.62	8.07	8.13
May – August	5.09	4.77	4.74	5.51	5.03
Sept.-Dec.	6.93	6.81	7.35	7.65	7.19
Mean cultivars	6.54	6.61	6.90	7.08	
	SE±	CD (0.05)	CD (0.01)		
Season	0.05	0.14	0.23		
Cultivars	0.28	0.58	0.80		
Season x cultivar	0.42	0.88	1.22		
Cultivar x Season	0.48	1.09	1.38		

SE – Standard error; CD – Critical difference

Table 3: Water extract (%) of clonal black teas as influenced by climatic seasons

Season	UPASI-3	UPASI-9	CR-6017	Assam Seedlings	Mean Season
Jan. – April	39.05	38.73	38.21	38.83	38.71
May – August	38.63	35.84	35.13	34.84	36.11
Sept.-Dec.	36.08	37.93	36.08	38.03	37.03
Mean cultivars	37.92	37.50	36.47	37.23	
	SE±	CD (0.05)	CD (0.01)		
Season	0.87	2.43	4.03		
Cultivars	0.69	1.45	1.98		
Season x cultivar	1.35	3.23	4.87		
Cultivar x Seasor	1.19	2.51	3.44		

SE – Standard error; CD – Critical difference

Table 4: Changes in crude fibre content (%) of clonal black teas with climatic seasons

Season	UPASI-3	UPASI-9	CR-6017	assam Seedlings	Mean Season
Jan. – April	14.36	13.16	12.09	12.44	13.01
May – August	15.41	14.96	13.72	14.39	14.62
Sept.-Dec.	15.88	13.63	14.54	13.85	14.48
Mean cultivars	15.22	13.92	13.45	13.56	
	SE±	CD (0.05)	CD (0.01)		
Season	0.73	1.02	2.36		
Cultivars	0.46	0.97	1.33		
Season x cultivar	1.07	2.47	3.81		
Cultivar x Season	0.80	1.68	2.31		

SE – Standard error; CD – Critical difference

Table 5: Theaflavin fractions# and Digallate equivalent of theaflavins of clonal black teas as influenced by climatic seasons

Season	Cultivar	TF	TF-3-G	TF-3'-G	TF-3,3'-G	DGETF
Jan. - April	UPASI-3	6.45	30.29	27.83	35.43	0.76
	UPASI-9	10.92	27.345	24.775	36.96	0.63
	CR-6017	6.15	28.155	24.895	40.8	0.72
	Assam seedlings	7.92	30.995	27.515	33.57	0.64
May - August	UPASI-3	10.41	26.18	23.6	39.81	0.59
	UPASI-9	10.92	27.985	24.015	37.08	0.51
	CR-6017	9.87	25.89	23.25	40.99	0.50
	Assam seedlings	7.68	26.835	22.985	42.5	0.44
Sept. – Dec.	UPASI-3	9.72	25.84	23.35	41.09	0.65
	UPASI-9	8.07	29.705	27.235	34.99	0.61
	CR-6017	10.71	30.82	27.2	31.27	0.61
	Assam seedlings	8.25	24.88	21.69	45.18	0.60
	CD at P=0.05	0.29	0.36	0.35	0.69	0.02

 # - Percent relative distribution; CD – Critical difference; DGETF – Digallate equivalent of theaflavins
TF-3-G – Theaflavin-3-gallate; TF-3'-G – Theaflavin-3'-gallate; TF-3,3'-G – Theaflavin-3,3'-digallate

Table 6: Changes in flavour Index of clonal black teas with respect to the climatic seasons

Season	UPASI-3	UPASI-9	CR-6017	Assam Seedlings	Mean Season
Jan. – April	2.16	1.69	1.91	1.16	1.73
May – August	1.36	1.02	1.19	0.83	1.10
Sept.-Dec.	1.49	1.22	1.33	0.95	1.25
Mean cultivars	1.67	1.31	1.48	0.98	
	SE±	CD (0.05)	CD (0.01)		
Season	0.027	0.074	0.122		
Cultivars	0.014	0.030	0.041		
Season x cultivar	0.034	0.086	0.135		
Cultivar x Season	0.025	0.052	0.072		

SE – Standard error; CD – Critical difference

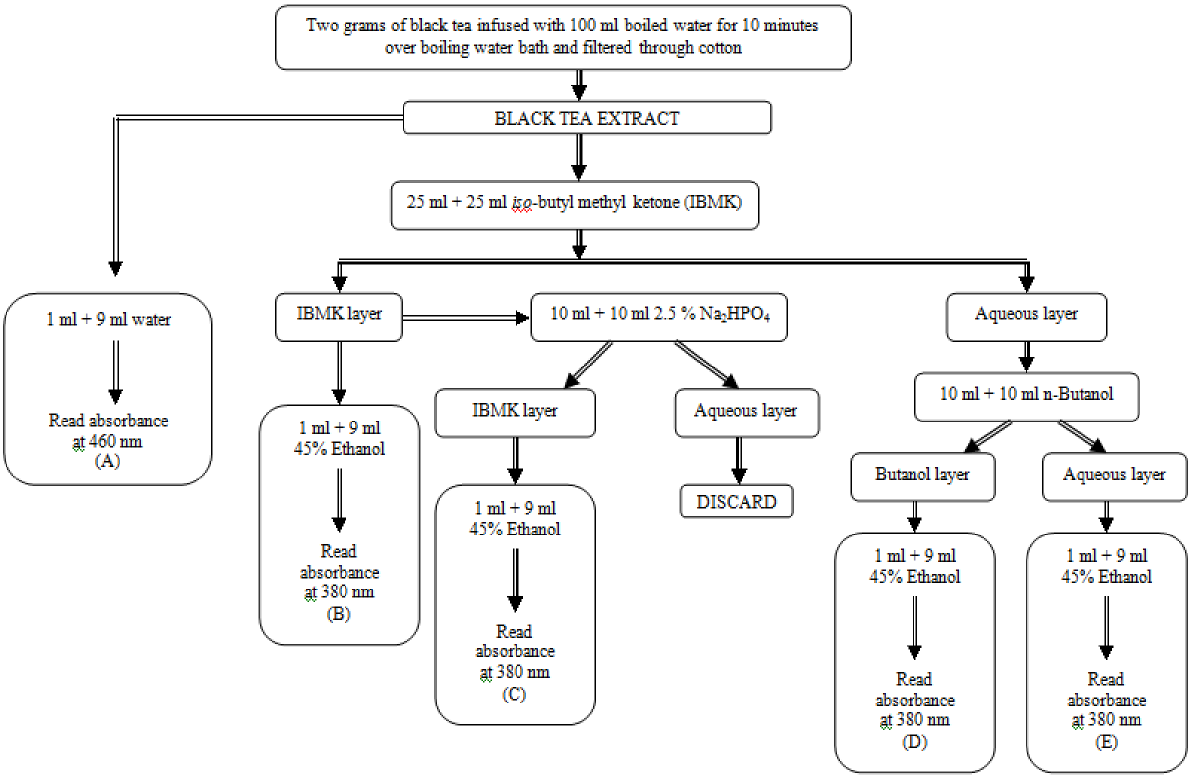
$$\text{Flavour index} = \frac{\text{Sum of percent relative distribution of group II compounds}}{\text{Sum of percent relative distribution of group I compounds}}$$

Table 7: Influence of seasons on catechin composition of clonal tea leaves

season	Cultivar	(+) C (%)	ECG (%)	EGC (%)	EGCG (%)	EC (%)
Jan. - April	UPASI-3	0.59	3.81	4.32	13.68	1.22
	UPASI-9	0.39	3.18	3.68	13.02	0.80
	CR-6017	0.53	3.49	3.62	13.25	0.97
	Assam seedlings	0.37	3.81	3.26	12.38	0.78
May - August	UPASI-3	0.21	2.74	2.95	10.53	0.87
	UPASI-9	0.20	2.54	3.12	10.21	1.07
	CR-6017	0.48	2.81	3.34	10.11	0.88
	Assam seedlings	0.16	2.24	2.68	9.82	0.62
Sept. – Dec.	UPASI-3	0.35	3.15	3.51	11.88	1.05
	UPASI-9	0.31	3.28	3.33	10.91	0.97
	CR-6017	0.45	3.39	3.58	11.28	0.86
	Assam seedlings	0.28	2.82	2.46	9.73	0.89
	CD atP=0.05	0.02	0.10	0.07	0.24	0.03

CD - Critical difference; (+) C- (+) Catechin; ECG- Epicatechin gallate; EGC- Epigallo catechin; EGCG- Epigallocatechin gallate; EC- Epicatechin

Figure 1: Determination of TF, TR, HPS and TLC in black tea



CONCLUSION

Climatic conditions prevailed in Anamallais of south India significantly influenced the quality composition of black teas produced in that region. Black teas manufactured during January to April possessed higher TF content, water extract and aroma composition. Rain flush teas are found to be poor in quality in terms of TF and catechins.

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