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Influence of altitude of planting on quality of south Indian black teas

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ABSTRACT

Influence of altitude of planting on the quality of black teas produced under south Indian conditions was studied. The experiment was carried out at three different altitudes viz., 2125, 1150 and 950 meters above mean sea level. Green tea leaves were analysed for individual catechins. The CTC (crush, tear and curl) black teas manufactured were analysed for theaflavins (TF), thearubigins (TR), water extract, crude fibre, individual TFs and aroma composition. The results showed that the altitude of planting had significantly affected the catechin composition of green tea leaves. Black teas from higher altitude had higher levels of TFs and its fractions, aroma composition and water extract. Crude fibre remained unaffected by the changes in the altitude.

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

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INTRODUCTION

The quality of black tea is mainly assessed by the taste and aroma characters. The term 'Quality' in tea trade refers to a composite character, which depend as many factors from field to factory. Some of the factors are controllable viz., harvesting style, pest, disease and nutrient management, manufacturing conditions and storage. Some non-controllable factors viz., altitude of planting, climatic seasons and cultivars could also influence the black tea quality. Tea planting areas in south India extend along the Western Ghats which run in north to south direction, parallel and close to the west coast of the peninsula. There are six major tea districts vary in elevation from 300 to 2500 meters above mean sea level (MSL) and the rainfall varies from 900 to 7500 mm per annum. Most of the tea estates are located in slopes with gradient between 10 and 33 percent. It is not uncommon to find areas with more than 50 percent slopes.

Tea plants can grow at various altitudes ranging from 700-3000 meters above MSL. As tea grown at this wide range of altitude, naturally tea plants at different altitudes will not experience the same climatic conditions. Even though, the inherent property is similar, due to the variations in the environment at which the tea plants grown, their biochemical makeup may be affected.

The reports on the effect of altitude on the chemical composition of south Indian teas are scanty. The only investigation on this aspect reports that, the polyphenols in black teas produced in south India vary with the variety, its geographical origin, environmental conditions, agronomic situations and the processing methods [1]. There are few reports available on the impact of altitude on black tea quality out-side south India. Under north-east Indian conditions, the variations in the aroma composition of black teas with respect to the altitude of planting are discussed by Mahanta et al.[2]. Assam teas had more mono terpenoids and fewer non-terpenoids. In volatile flavour composition geranoic acid was detected in Darjeeling but not in Assam teas. However, the differences in the terpenoid components of teas from various altitudes appeared to be negligible under north-east Indian conditions.

Under Kenyan conditions [3], any significant effect of altitude could be observed on the quality constituents of black tea. The individual aroma compounds such as linalool and geraniol varied with the altitude, but the terpene index remained unaffected with the altitude of planting. Teas from lower elevation had higher fatty acids than those from higher altitudes. Also the teas made from higher altitudes contained higher amounts of group II volatiles, which contribute positively to the aroma of black tea [4].

The present investigation was carried out to study the influence of altitude of planting on the quality precursors in the green leaves and quality and aroma components of CTC black tea under south Indian conditions.

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 three different altitudes representing 2125, 1150 and 953 meters above mean sea level (MSL). The cultural practices and pest, disease and nutrient management practices are kept similar as suggested by UPASI [5].

Experimental CTC black tea manufacture

About 2 kg green leaves (2 leaves and a bud) of respective cultivars were collected from the fields and the black tea samples were manufactured by following standard methods. The pekoe fanning grade tea samples were taken and were analysed for theaflavins (TF) and thearubigins (TR) as per the methodology by Thanaraj and Seshadri (1990). Water extract and crude fibre were analysed as per Indian standards (Anonymous, 1999 & 1999 A). The individual theaflavins were analysed using the method by Bailey et al (1990). Volatile aroma composition of black tea was analysed using gas chromatography

RESULTS AND DISCUSSION

Influence of Altitude on theaflavin content of black teas

The results on the TFs in CTC black tea manufactured from the leaves of different cultivars planted at various altitudes are given in TABLE 1. Irrespective of the cultivars, the black teas produced from the higher altitude (2125 m above MSL) had higher TFs. Black teas from the altitudes 1150 and 953 m above MSL are found to be on par with each other. Beyond the changes in altitude, the black tea manufactured from the cultivar CR-6017 had higher levels of TF and rest of the cultivars had similar levels of TFs. This may be due to the genetic makeup of the cultivars tested. The recent AFLP studies showed that the cultivars UPASI-3 and UPASI-9 belong to the Assam type [11] and hence there existed a similarity in their biochemical composition also. For the same cultivar at different altitudes, it was found that, performance of the cultivars UPASI-3, UPASI-9 and Assam seedlings remained almost unaffected with the altitude of planting and resulted in black teas containing similar levels of TF. The cultivar CR-6017 resulted in black teas with higher TF at higher altitudes (2125 m above MSL) and its performance is on-par in the two mid elevation regions. While comparing the performance of the cultivars at the same altitude, only at higher elevation the cultivar CR-6017 had higher TF and found at par with UPASI-3. The TF content in black teas of UPASI-9 and Assam seedlings was found on par at high elevation (2125 m above MSL) at mid elevation TF content did not vary irrespective of the cultivars.

The production of higher TFs by the cultivars planted at higher altitude may be due to favourable climatic conditions prevailed at higher altitude for synthesis of TFs. For the production of higher TF, cold humid condition which prevails at higher altitude is essential [12]. Under Kenyan conditions similar results were reported [3].

Influence of altitude on thearubigins content of black teas

At higher altitude, black teas of all the four cultivars had similar levels of TR (TABLE 2). This trend is noticed in tea samples manufactured from all the four cultivars. Elevations had no influence on TR content irrespective of the cultivars. It seems that synthesis of TR is mainly substrate and enzyme dependent and not dependent on the temperature and humidity of the environment where the plants grown. But this observation is in contradiction to that reported from Kenya, where higher temperature and lower elevation resulted in black teas of higher TR content [13].

Impact of altitude on water extract of black teas

The black teas were analysed for their water extract content and the statistically analysed data are presented in TABLE 3. Irrespective of the cultivars, the black teas produced from various altitudes are found to be on par with each other. The black tea of cultivar UPASI-3 had higher water extract and found at par with CR-6017 and UPASI-9. The black tea from Assam seedlings registered lower water extract. The performance of the cultivars UPASI-3, UPASI-9 and CR-6017 are similar at various altitudes of planting. Assam seedling resulted in black teas with lower water extract at higher altitudes, while water extract was at par of UPASI-3, UPASI-9 and CR-6017. At elevation of 1150 m above MSL, CR-6017 had higher water extract and found at par of UPASI-3 and UPASI-9. At the elevation 953 m above MSL, all the cultivars are on par with each other in their water extract content.

Water extract content varied in the clonal black teas manufactured from the leaves of different altitudes (TABLE 3). The altitude of planting had almost no effect on the water extract content black teas of the cultivars. This could be due to the cumulative effect of all the cultivars under investigation. Black teas from the cultivar UPASI-3 resulted in higher water extract followed by CR-6017 and UPASI-9. This is mainly due to the genetic characters of the individual cultivars and formation of more water soluble components during the manufacturing process. At higher elevation, UPASI-3 resulted in higher water extract than other cultivars. Since water extract is directly correlated to the cuppage of the black teas, it is essential to have more water extractives in black teas [14]. Black teas from Assam seedlings possess higher water extractives at higher altitudes, but lower levels at lower altitudes. This may be due to the heterogeneity in the seedling population. Since the seedlings plants are not uniform in their biochemical composition, they could not result in teas of consistent quality.

Effect of altitude on crude fibre content of black teas

The crude fibre content of clonal tea samples (manufactured using the leaves of plants grown at different altitudes) are presented in the TABLE 4. Black teas of different cultivars are found to be on par with respect to their crude fibre content at various altitudes of planting. In the cultivars, black tea from UPASI-3 registered higher crude fibre content than teas from rest of the cultivars analysed and are on par with each other. When comparing the performance of individual cultivar at various altitudes, teas of all the four cultivars had similar levels of crude fibre contents in all the three altitudes in the present investigation. At higher elevation region, all the four cultivars resulted in black teas of similar crude fibre content. But at mid elevation regions at 1150 m above MSL, the cultivar UPASI-3 produced black teas with higher crude fibre and at par with UPASI-3 and Assam Seedlings. Similarly, at 953 m above MSL the cultivar UPASI-3 had high crude fibre content and at par with UPASI-9.

The altitude of planting had no effect on the crude fibre content of the black teas of various cultivars under investigation (TABLE 4). This is mainly due to the genetic diversity of the planting materials used for the study. Black teas of the cultivar UPASI-3 had higher crude fibre content irrespective of the altitudes of planting. This could be due to the genetic characters of the particular cultivar under south Indian conditions. Rest of the cultivars under investigation had similar levels of crude fibre in their black teas. Crude fibre content in black teas are mainly influenced by the environmental conditions and genetic characters of the material used. At higher temperature regions the crude fibre content of teas was found to be more. That is the reason of lower crude fibre content at higher elevation due to low temperature and higher crude fibre content at mid elevation due to higher temperature. At higher temperatures the simple sugars may get polymerized to form structurally strong cellulosic materials which can contribute to the crude fibre of black tea [15].

Theaflavin fractions and Digallate equivalent of theaflavins of black teas as affected by altitude

The individual TFs of black teas from different cultivars planted and manufactured at different altitudes are analysed using HPLC and the results statistically analysed in randomized block design and are presented in TABLE 5. The DGETF is the superior measure of quality than individual TFs.

The relative proportion of individual TF and DGETF of black teas from different cultivars, showed that the cultivar CR-6017 is superior (TABLE 5) followed by UPASI-3 and UPASI-9. Black teas of Assam seedlings had lowest DGETF. The primary reason for this could be the presence of adequate substrates, enzymes and the duration of fermentation phase of black tea manufacturing. The DGETF in the black teas of various cultivars at low altitude is comparatively lower than that from the higher altitude. Thus the altitude of planting influences the DGETF of black teas through the climatic conditions necessary for the production of more substrates, optimum enzyme activities and micro climate in tea factories for efficient formation of individual TFs [6].

Changes in flavour index of black teas due to altitude of planting

The clonal black tea samples were analysed for their aroma composition using GC, flavour index values were arrived at and the statistically analysed data are presented in TABLE 6. Irrespective of the cultivars, the black teas from higher altitude had higher flavour index and are in the order 2125 > 1150 > 953 m above MSL. The cultivar UPASI-3, resulted in black teas with good aromatic character followed by CR-6017, UPASI-9 and Assam seedlings. At 1150 m above MSL, the performance of UPASI-3 was found superior followed by CR-6017, UPASI-9 and Assam seedlings. At 2125 m and 953 m above MSL, the flavour Index of UPASI-3 was found at par with CR-6017 followed by UPASI-9 and Assam seedlings.

TABLE 1. Influence of altitude on Theaflavin content (%) of clonal black teas

Altitude*	UPASI-3	UPASI-9	CR-6017	Assam Seedlings	Mean altitude
2125	1.23	1.18	1.38	1.00	1.20
1150	1.09	1.12	1.15	1.06	1.11
953	1.06	1.07	1.11	0.98	1.06
Mean cultivars	1.13	1.12	1.21	1.01	
	SE±	CD (0.05)	CD (0.01)		
Altitude	0.021	0.057	0.095		
Cultivars	0.061	0.129	0.176		
Cultivars x Altitude	0.106	0.223	0.305		
Altitude x Cultivars	0.094	0.201	0.279		

** - Meters above mean sea level;SE – Standard error; CD – Critical difference*

TABLE 2. Impact of altitude on thearubigins content (%) of clonal black teas

Altitude*	UPASI-3	UPASI-9	CR-6017	Assam Seedlings	Mean altitude
2125	7.03	6.77	7.66	7.79	7.31
1150	7.19	7.79	8.67	7.34	7.75
953	5.99	6.84	7.57	7.00	6.85
Mean cultivars	6.74	7.13	7.97	7.38	
	SE±	CD (0.05)	CD (0.01)		
Altitude	0.617	1.714	2.841		
Cultivars	0.502	1.055	1.446		
Cultivars x Altitude	0.870	1.827	2.504		
Altitude x Cultivars	0.974	2.310	3.478		

** - Meters above mean sea level; SE – Standard error; CD – Critical difference*

TABLE 3. Impact of altitude on water extract (%) of clonal black teas

Altitude*	UPASI-3	UPASI-9	CR-6017	Assam Seedlings	Mean altitude
2125	39.71	38.94	38.70	35.50	38.22
1150	39.31	38.70	40.34	37.29	38.91
953	39.65	37.51	38.41	37.87	38.36
Mean cultivars	39.56	38.38	39.15	36.89	
	SE±	CD (0.05)	CD (0.01)		
Altitude	0.933	2.591	4.297		
Cultivars	0.599	1.258	1.724		
Cultivars x Altitude	1.037	2.179	2.985		
Altitude x Cultivars	1.295	3.175	4.889		

** - Meters above mean sea level; SE – Standard error; CD – Critical difference*

Higher flavour index in black teas of higher altitudes reveals the fact that the cultivars planted at higher altitudes are capable to form more group II compounds than group I compounds. For the formation of more group II compounds,

clear, cool and cloudless days followed by cold and clear nights are essential. Under these conditions, the growth of tea plant is slow and accumulations of essential bio-constituents were also noticed [16, 17]. While comparing the individual cultivars, UPASI-3 resulted in black teas with good aromatic characters followed by CR-6017, UPASI-9 and Assam seedlings. This could be due to the genetic makeup of the individual cultivars under south Indian conditions.

TABLE 4. Effect of altitude on crude fibre content (%) of clonal black teas

Altitude*	UPASI-3	UPASI-9	CR-6017	Assam Seedlings	Mean altitude
2125	14.71	12.52	13.55	14.16	13.74
1150	15.13	13.78	12.66	13.20	13.69
953	16.00	14.32	13.47	12.97	14.19
Mean cultivars	15.28	13.54	13.23	13.44	
	SE±	CD (0.05)	CD (0.01)		
Altitude	0.455	1.264	2.096		
Cultivars	0.635	1.334	1.828		
Cultivars x Altitude	1.100	2.310	3.165		
Altitude x Cultivars	1.055	2.350	3.377		

** - Meters above mean sea level; SE – Standard error; CD – Critical difference*

TABLE 5. Theaflavin fractions[#] and Digallate equivalent of theaflavins of clonal black teas as affected by altitude

Altitude*	Cultivar	TF	TF-3-G	TF-3'-G	TF-3,3'-G	DGETF
2125	UPASI-3	9.78	28.19	25.22	36.81	0.77
	UPASI-9	7.83	27.485	23.965	40.72	0.77
	CR-6017	9.03	26.48	23.73	40.76	0.89
	Assam seedlings	8.58	29.67	26.03	35.72	0.62
1150	UPASI-3	8.04	29.77	27.29	34.9	0.67
	UPASI-9	10.68	30.79	27.15	31.38	0.66
	CR-6017	7.74	27.935	25.155	39.17	0.74
	Assam seedlings	10.92	29.32	25.41	34.35	0.64
953	UPASI-3	8.04	26.845	23.425	41.69	0.70
	UPASI-9	9.15	31.07	27.51	32.27	0.64
	CR-6017	9.36	26.57	23.68	40.39	0.72
	Assam seedlings	9.84	25.985	22.335	41.84	0.64
	CD at P=0.05	0.23	0.37	0.36	0.80	0.02

** - Meters above mean sea level; # - 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 due to altitude

Altitude*	UPASI-3	UPASI-9	CR-6017	Assam Seedlings	Mean altitude
2125	1.83	1.50	1.78	1.37	1.62
1150	1.46	1.11	1.33	0.83	1.18
953	1.23	1.01	1.17	0.74	1.04
Mean cultivars	1.51	1.21	1.43	0.98	
	SE±	CD (0.05)	CD(0.01)		
Altitude	0.025	0.069	0.114		
Cultivars	0.011	0.024	0.033		
Altitude x Cultivars	0.030	0.077	0.122		
Cultivars x Altitude	0.020	0.041	0.056		

**- Meters above mean sea level; SE – Standard error; CD – Critical difference*

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

CONCLUSION

The altitude of planting had significant influence on the quality of black tea. The cultivars which are genetically related to each other tended to behave similarly at different altitudes with respect to theaflavins of black tea. Black

teas from higher elevation (2125 m above MSL) had good aroma characters (flavour index) and more quality components (TF).

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