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Biochemical constituents (precursors) in tea shoots responsible for quality and their effect on made teas in different regions of North Bengal

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ABSTRACT: North Bengal comprising of two tea producing regions Dooars and Terai besides Darjeeling, contributes significantly to total Indian annual production of made tea with its share of approx. 240 Mkg. To evaluate the quality aspect of made tea of these regions a systematic study on biochemical parameters was carried out. This investigation signifies that biochemical compositions present in tea shoots under North Bengal condition are suitable for producing tea with high quality. Total chlorophyll (CHt), chlorophyll a (CHa) and chlorophyll b (CHb) were found to vary significantly (at $p<0.05$) among the clones selected for this study. EC, ECG, EGC, EGCG and total catechin(TC) were found significantly different among the clones while catechin (C) has almost uniform distribution though their content are lower in comparison to Assam tea. All quality parameters of made teas such as TF, TR1, TR2, TR, BR, TC, TSS, CA content were higher in miniature factory (MF) manufacturing condition than manufacturing at garden factory (GF) except TPP. So with some modifications in the key steps of manufacturing processes quality of made tea can be enhanced at GF level with desired appearance.

KEYWORD: *Appearance; Googies; Plant pigments; Quality*

Introduction

Tea is a most popular beverage in the world. It is processed from the leaves of *Camellia sinensis* (L) O. Kuntze. Agro-climatic conditions play an important role on the synthesis of chemical constituents present in tea shoots and influence the quality of made tea. In 1994, Wachira[1] reported that genotypes superior in one environment may not be superior elsewhere. Again quality of made tea varies with cultivars and is also dependent on the agro-climatic conditions of the area of production.[2,3] Cultivar variation in catechin profile and chlorophylls content of tea shoots were recorded by Tamuly *et al.*,[4] and Gogoi *et al.*[5] The creaming properties of Assam tea which is responsible for fullness of Assam cup made the produced unique.[6] Recent works of Bhuyan et al.[7] has confirmed variation in quality parameters of CTC teas by recording higher TF, TR, and soluble solids levels in made teas of Brahmaputra valley region in comparison to Barak velley and Dooars regions.

Besides Darjeeling, North Bengal comprises two tea growing regions, Dooars and Terai (Fig. 1) having longitude 26°54′E and 26°38′E and latitude 88°55′ and 88°48′, respectively, are known for producing ~240 Mkg tea mainly of CTC type. The regions receive average precipitation of 2500–3500 mm within a span of eight months, *i.e.* from April to November and have loamy to sandy loam type of soils in the western part of Dooars and Terai and silt clay type of soils in eastern part of Dooars. These soil properties, agro-climatic conditions, processing techniques especially use of googies have induced wide variation in the bio-chemical parameters of made tea of these area in comparison to Assam. The quality conception of tea in North Bengal depends more on appearance (blackness) because of its market demand, so evaluation of quality as an integrated perception of appearance, colour, brightness, briskness, strength and aroma was not explored for this region in depth.

A study was therefore needed for a systematic evaluation of the chemical constituents present in tea shoots and their effect on made tea quality parameters of different cultivars from this area.

Brightness, briskness, strength, total colour of the liquor, appearance (blackness) of made teas are considered as the most important factors for quality in CTC (*curl*, *tear*, *crush*) teas. Chemical constituents act as the precursors for these quality parameters are chlorophylls, polyphenols, sugars, lipids, amino acids, *etc.*

Chlorophyll is the major plant pigment made up of components, chlorophyll a (bluish black) and chlorophyll b (dark green) are the attributes of appearance (blackness) in made tea. At the time of processing mainly during fermentation (oxidation) and drying chlorophylls are degraded into phaeophytin (black) and phaeophorbide (brown). The concentration of phaeophytin and phaeo-

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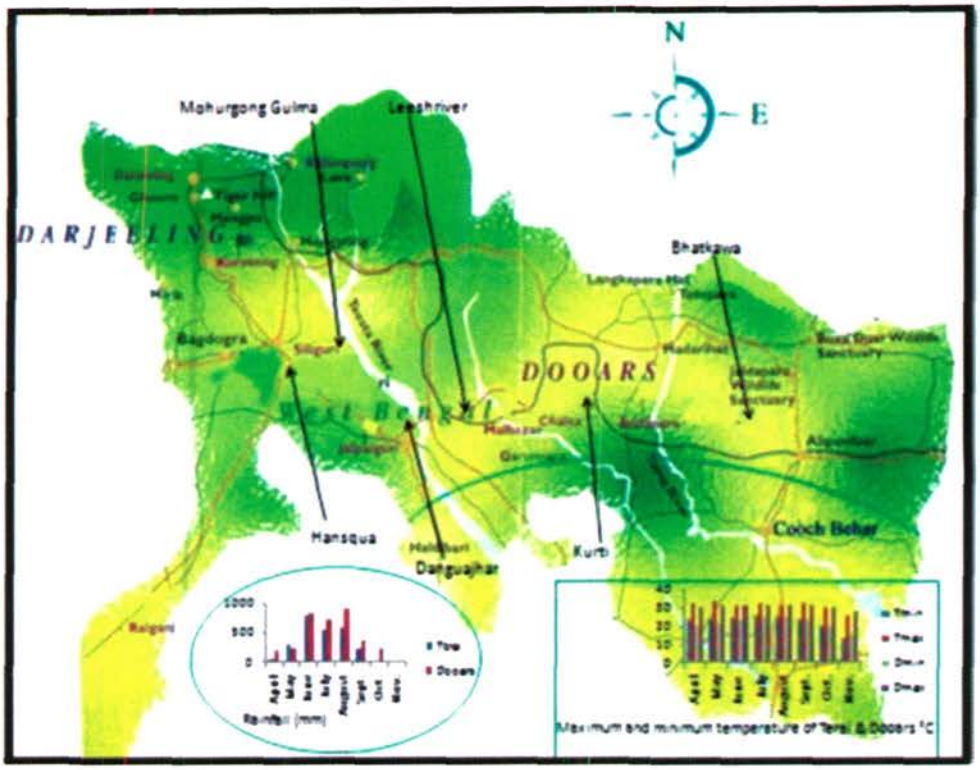


Figure 1. Map of Dooars and Terai region along with average rainfall(cm), maximum and minimum temperature from April to November.

phorbide are deciding factors for appearance (blackness).[8] It was reported that high chlorophyll content is negatively correlated with the liquor character though it enhances appearance of made tea.[9] Ratio of phaeophytin to thearubigin (TR) was reported as a good index of appearance by Mahanta and Hazarika.[10] Black tea quality can be predicted from the carotenoid and chlorophyll composition of fresh green tea leaves as reported by Taylor *et al.*[11]

Polyphenolic compounds are also most important chemical constituents of tea shoots. Catechins *viz.* (+) catechin (C), (–)epicatechin (EC), (–)epigalocatechin (EGC), (–)epicatechingallate (ECG) and (–)epigallocatechingallate (EGCG) belong to the flavanol subgroup of polyphenolic compounds form ~90% of the total weight of the polyphenols in tea leaves. During the black tea manufacturing process, in presence of atmospheric oxygen and enzymes like polyphenoloxidase (PPO) and peroxidase (PO), colourless catechins convert into some colored compounds namely theaflavins (TF) and thearubigins (TR).

These TF and TR are responsible for brightness, briskness, strength, total colour and body of the liquor. Formation of TF and TR depend on fermentation time, temperature and humidity.[12] According to Obanda *et al.*[13] the fractions of TR, *i.e.* thearubigins I (TR1) contributes

Table 1: Catechin, Sugar and Lipid Composition of Tea Shoots from Different Clones (n = 6)

Clone	EC	ECG	EGC	EGCG	C	TC	TPP	TS	L	NL	PL	GL
TV1	1.19^{ab}	3.47^{c}	2.51^{b}	7.99^{c}	0.23^{a}	16.83^{b}	21.66^{bc}	2.01^{c}	5.30^{d}	0.39^{ab}	1.28^{ab}	3.58^{a}
TV18	0.98^{bc}	4.18^{abc}	2.74^{ab}	9.11^{b}	0.36^{a}	17.89^{ab}	23.26^{a}	2.10^{bc}	6.45^{ab}	0.46^{a}	1.26^{ab}	4.02^{a}
Tin17	0.90^{cd}	3.74^{bc}	3.00^{ab}	8.80^{bc}	0.25^{a}	17.32^{ab}	21.31^{c}	2.85^{a}	5.75^{bcd}	0.40^{ab}	1.46^{a}	3.67^{a}
TV20	1.24^{a}	4.46^{ab}	2.99^{ab}	9.31^{ab}	0.30^{a}	18.22^{ab}	22.55^{ab}	2.34^{b}	5.48^{cd}	0.35^{b}	1.06^{b}	3.93^{a}
TV23	0.70^{d}	4.90^{a}	2.74^{ab}	10.21^{a}	0.25^{a}	18.97^{a}	23.40^{a}	2.14^{bc}	6.26^{abc}	0.33^{b}	1.48^{a}	3.95^{a}
TV25	1.03^{abc}	4.33^{abc}	3.54^{a}	8.66^{bc}	0.33^{a}	17.11^{b}	22.90^{a}	2.04^{c}	6.66^{a}	0.41^{ab}	1.32^{ab}	3.93^{a}
±SE	0.04	0.14	0.11	0.17	0.02	0.24	0.18	0.06	0.13	0.01	0.05	0.08
CD	0.232	0.911	0.776	1.012	0.138	1.624	0.92	0.256	0.771	0.094	0.368	0.571

EC = (-) Epicatechin, ECG = (-) Epi catechin gallate, EGC = (-) Epigallocatechin, EGCG = (-) Epigallocatechin gallate, C = (+) Catechin, TC = Total catechin, TPP = Total polyphenol, TS = Total sugar, L = Lipid, NL = Neutral lipid, PL = Phospholipid, GL = Glycolipid.
DMRT ranking – Mean within a column followed by the same letter are not significantly different at P = 0.05 according to Duncan's multiple range test – DMRT.

Table 2a: Made Tea Quality Parameters of Clones and Their Mix (n = 12)

Clones	TF	TR1	TR2	TR	BR	TC	TSS	CA	CF	TPP	PTIN	PBIDE
TV1	1.31[a]	6.69[a]	10.62[a]	16.17[a]	19.91[b]	5.39[a]	38.51[b]	4.14[b]	10.70[a]	11.28[a]	1.78[c]	2.99[a]
TV18	1.12[d]	5.83[b]	10.50[a]	15.87[a]	18.97[b]	4.94[b]	40.34[a]	4.70[a]	9.69[b]	11.70[a]	2.58[a]	2.19[b]
Tin17	1.23[b]	5.78[b]	9.19[b]	15.30[a]	21.26[a]	5.06[ab]	38.58[b]	4.84[a]	9.90[ab]	10.72[a]	2.76[a]	2.59[ab]
Mixed	1.16[c]	5.71[b]	9.90[ab]	15.40[a]	19.84[b]	4.90[b]	38.45[b]	4.65[a]	9.70[b]	11.14[a]	2.21[b]	2.47[b]
±SE	0.012	0.32	0.41	0.50	0.35	0.153	0.30	0.10	0.292	0.46	0.019	0.013
CD 0.05	0.038	0.864	1.175	1.285	1.353	0.446	0.86	0.282	0.831	1.20	0.229	0.503

TF = Theaflavin, TR1 = Thearubigin1, TR2 = Thearubigin2, TR = Thearubigin, BR = Brightness, TC = Total colour, TSS = Total soluble solids, CA = Caffeine, CF = Crude fibre, TPP = Total polyphenol, PTIN = Phaeophytin, PBIDE = Phaeophorbide

Mean within a column followed by the same letter are not significantly different at P = 0.05 according to Duncan's multiple range test – DMRT

positively towards brightness and thearubigins II (TR2) contributes towards colour and strength of the tea liquor.

Tea shoot contains soluble sugars. During drying sugars caramelizes into black appearance of made teas.[14] Some secondary metabolites, namely polyphenols, lipids, terpenoids, amino acids are also synthesized from sugars.

Lipid is an important biochemical component in plant tissues because of its structural and storage composition.[15] The reserve lipids supply the energetic requirements and the structural lipid helps in build up of biological membranes, protective layers in plants. They are heterogeneous group of compounds and are precursors of some flavour compounds which are biosynthesized during processing of black teas.[16]

Hence identification and evaluation of these biochemical parameters responsible for quality in made teas of Dooars and Terai are the basic objectives of this study.

Materials and Methods

Selection of Location and Cultivars

An initial survey was carried out in different estates of Dooars and Terai for selection of locations having popularly used varieties like TV1, TV18, TV20, TV23, TV25 and Teenali17 under similar conditions of age, shade and prune *etc*. Six locations that were selected for the purpose of present investigation are as follows:

Name of Estates	Location	Coded as
Kurti T.E.	Central Dooars	A
Bhatkawa T.E.	Eastern Dooars	B
Leeshriver T.E.	Western Dooars	C
Danguajhar T.E.	South Dooars	D
Mohorgung Gulma T.E.	South Terai	E
Hansqua T.E.	South Terai	F

Collection and Preparation of Samples

Freshly plucked green tea shoots (two leaf and a bud) of six clones viz. TV1, TV18, TV 20, TV 23, TV 25 and Teen Ali 17 from all six locations were collected in ice box to analyze the moisture and chlorophylls content. Some of the samples of these clones were steamed separately for three minutes and dried in oven at 600 c for twelve hours. Dried leaf samples were stored properly for analysis of total polyphenols, sugars, catechin profile and lipids, *etc*.

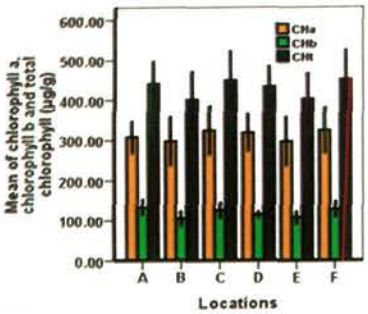
Four CTC made teas were processed per occasion for each estate collecting leaves separately from TV1, TV18, Teenali17 and a equally mix (33.33%) of these three clones at NBRRDC miniature factory (MF) by tak-

Table 2b: Made Tea Quality Parameters of Different Locations (n = 8)

LOC.	TF	TR1	TR2	TR	BR	TC	TSS	CA	CF	TPP	PTIN	PBIDE
A	1.24[a]	5.90[ab]	10.02[ab]	16.11[a]	20.67[a]	5.13[a]	38.29[a]	4.52[a]	10.29[a]	11.53[ab]	2.47[a]	2.29[b]
B	1.22[a]	6.36[a]	9.75[ab]	14.96[a]	19.46[a]	5.08[a]	39.38[a]	4.41[a]	9.62[a]	10.28[b]	2.06[a]	3.09[a]
C	1.18[a]	6.47[a]	9.48[b]	15.74[a]	20.18[a]	5.27[a]	39.30[a]	4.78[a]	9.71[a]	10.42[ab]	2.19[a]	1.62[c]
D	1.20[a]	6.10[a]	9.87[ab]	16.41[a]	20.43[a]	5.26[a]	38.62[a]	4.74[a]	9.89[a]	11.81[a]	2.34[a]	3.27[a]
E	1.16[a]	6.19[a]	10.06[ab]	15.22[a]	19.87[a]	4.93[a]	39.55[a]	4.42[a]	10.04[a]	11.35[ab]	2.37[a]	2.51[b]
F	1.22[a]	4.99[b]	11.12[a]	15.67[a]	19.37[a]	4.75[a]	38.68[a]	4.64[a]	10.42[a]	11.88[a]	2.55[a]	2.58[b]
±SE	0.014	0.39	0.51	0.62	0.43	0.19	0.37	0.13	0.36	0.56	0.023	0.015
CD 0.05	0.087	1.04	1.479	1.564	1.852	0.563	1.298	0.433	1.095	1.383	0.471	0.374

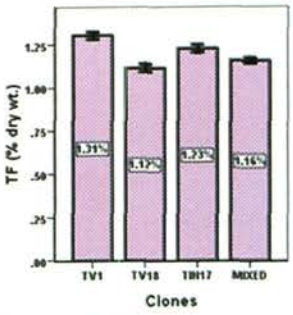
TF = Theaflavin, TR1 = Thearubigin1, TR2 = Thearubigin2, TR = Thearubigin, BR = Brightness, TC = Total colour, TSS = Total soluble solids, CA = Caffeine, CF = Crude fibre, TPP = Total polyphenol, PTIN = Phaeophytin, PBIDE = Phaeophorbide

Mean within a column followed by the same letter are not significantly different at P = 0.05 according to Duncan's multiple range test – DMRT.



Clone	CHa	CHb	CHt
TV1	212.88^{a}	98.72^{c}	311.11^{a}
TV18	348.39^{b}	130.16^{ab}	478.50^{b}
Tin17	271.00^{a}	107.83^{bc}	378.44^{a}
TV20	324.11^{b}	126.66^{ab}	447.94^{bc}
TV23	316.50^{b}	113.94^{abc}	430.50^{c}
TV25	391.61^{b}	132.89^{a}	525.00^{b}
±SE	9.54	7.60	13.04

Figure 2. Mean of chlorophyll a, chlorophyll b and total chlorophyll in various locations along with a table representing clonal variation of chlorophylls (mean within a column followed by the same latter are not significantly different at $p = 0.05$).



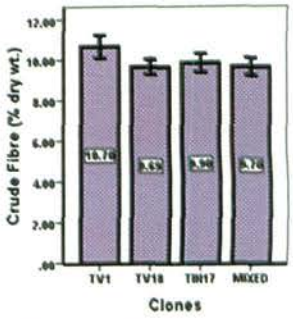


Figure 3. Comparison of TF and CF content under seven days plucking.

ing 1 kg of leaf from each variant. The leaves were subjected to withering for 12 hrs followed by the steps like 25 min of rolling, 4 CTC cuts, floor fermentation and dried at 100°C for 25 min. The processes were continued for three occasions and the samples were analyzed for biochemical parameters.

Bulk teas were also processed at estate level for three occasions by mixing leaves of TV1, TV18 and Teenali17 in equal quantities adopting gardens' manufacturing (GF) practices with following steps.

Wtthering. Harvested shoots comprise of the mixed leaves from TV1, TV18 and Teenali17 of ~1,500 kg in total were spread in an open trough of capacity 23 kg m^{-2} and artificial wither was given by using ambient air supply for a period of 12–14 hr.

Rotorvane/CTC. The withered leaves were passed through Rotorvane followed by four successive CTC (*Crush, Tear, & Curl*) to get adequate maceration then passed through Googie and the resultant cutdhool was given for fermentation.

Fermentation. The cutdhool was spread over the fermenting floor at a thickness of 1.3 – 1.5 cms for about an hour and thirty minutes at around 280 c and the relative humidity was maintained between 90% and 95%.

Drying. The fermented dhool was passed on to a vibratory fluid bed drier (VFBD), and hot air was blown through the tea with an inlet temperature of ~120–125°C. The fermented leaves were dried for about 20 min so that the moisture content of the made tea is maintained at 2.5–3%.

Methods of Determination

Moisture. Moisture content of the sample was determined by heating the sample (5 g) in oven at 103°C following the method Indian Standard IS 13853: 1994.[17]

Theaflavins and Thearubigins. Theaflavins and Thearubigins were determined by extracting the liquor from the made teas following the method of Ullah.[18]

Thearubigins(TR) and fractions TR1, TR2, total colour and brightness were estimated by extracting tea

Table 3: Comparison of Biochemical Parameters under MF and GF Manufacturing Condition

LOC.	TF		TR1		TR2		TR		BR		TC		TSS		CA		CF		TPP	
	MF	GF	MF	GF	MF	GF	MF	GF	MF	GF	MF	GF	MF	GF	MF	GF	MF	GF	MF	GF
A	1.18	0.97	5.76	3.57	10.18	10.23	15.86	14.02	21.63	14.60	5.12	4.41	37.76	36.83	4.54	4.06	10.50	11.26	11.58	13.91
B	1.16	0.73	6.20	4.25	10.04	10.00	14.94	14.07	19.86	12.48	4.79	4.16	38.46	36.32	4.52	3.87	9.32	11.83	10.36	13.10
C	1.15	0.72	6.16	2.97	9.12	9.58	15.56	13.08	21.12	11.70	5.00	5.12	38.60	37.23	4.93	3.94	9.25	11.35	10.64	13.37
D	1.15	0.78	5.57	3.62	9.08	10.16	15.59	14.30	18.99	11.24	5.03	5.59	38.28	37.85	4.88	3.81	9.20	11.45	11.23	14.69
E	1.14	0.52	6.20	3.31	9.94	9.36	15.03	13.56	19.64	11.18	4.85	4.31	39.46	36.90	4.40	3.75	9.99	12.34	11.23	13.64
F	1.18	0.81	4.34	2.90	11.06	8.78	15.43	12.32	17.83	12.98	4.63	4.59	38.12	35.89	4.61	3.87	9.91	12.11	11.84	13.97
Mean	1.16	0.75	5.71	3.44	9.90	9.68	15.40	13.56	19.84	12.36	4.90	4.70	38.45	36.84	4.65	3.88	9.70	11.72	11.14	13.78

TF = Theaflavin, TR1 = Thearubigin1, TR2 = Thearubigin2, TR = Thearubigin, BR = Brightness, TC = Total colour, TSS = Total soluble solids, CA = Caffeine, CF = Crude fibre, TPP = Total polyphenol, MF = Miniature factory, GF = Garden factory.

Table 4: Correlation Coefficient Matrix Analyses between Catechin Profiles, Total Polyphenol, Total Sugar and Lipid

	EC	ECG	EGC	EGCG	C	TC	TPP	TS	L
EC	1	-.446*	.140	-.531*	-.042	-.346	-.234	-.431*	-.223
ECG		1	-.427*	.588**	.632**	.727**	.574**	.118	.106
EGC			1	.131	-.046	.054	-.029	.085	.040
EGCG				1	.540*	.632**	.461*	.199	.071
C					1	.505*	.366	-.115	-.067
TC						1	.612**	.021	.078
TPP							1	-.278	.491*
TS								1	.031
L									1

EC = (-) Epicatechin, ECG = (-) Epi catechin gallate, EGC = (-) Epigallocatechin, EGCG = (-) Epigallocatechin gallate, C = (+) Catechin, TC = Total catechin, TPP = Total polyphenol, TS = Total sugar, L = Lipid.
* Correlation is significant at 0.05.
** Correlation is significant at 0.01.

infusion with isobutyl methyl ketone following the method by Tea Board, Kenya.[19]

Total Soluble Solids. Total soluble solids in black teas was determined through refluxing following the method of ISO 9768: 1994.[20]

Crude Fibre. Crude fibre content in made teas were determined removing acid soluble, alkali soluble and alcohol soluble parts following the method IS 10226 (Pt 1): 1982.[21]

Total Polyphenols. Total polyphenols content in tea shoot was extracted from the sample with methanol following the method ISO/CD 14502-1-2: 2001.[22]

Catechin Profile by HPLC. Catechin profile of tea shoots was analysed by HPLC using ISO the method ISO TC 34/SC8: 1999.[23]

Chlorophylls in Green Tea Shoot. Chlorophylls content in tea shoot was estimated by extracting the sample with 80% acetone following the method of Harborne.[24]

Caffeine. Caffeine in made teas was determined in the sample with chloroform following the method of Ullah *et al.*[25]

Phaeophytin and Phaeophorbide. Phaeophytin and phaeophorbide were determined following the method of Mahanta and Hazarika[10] with minor modification.

Lipids. Total lipids in tea shoots were determined according to the method of Bligh and Dyer,[26] and the total lipids were further fractionated by the method of Hirsch and Ahrens *et al.*[27]

Statisistical Analysis

Data were subjected to analysis of variance using SPSS Inc., Ver. 16.0 Software. The Duncan's Multiple Range Test (DMRT) was used to separate the mean. A probability (p) value < 0.05 was considered significant.

Results and Discussion

Green Tea Shoot Compostion

Different components of chlorophylls which are known to vary with the cultivars and locations besides variation in the seasons, pruning, plucking and shade etc. were estimated for TV1, TV18, TV 20, TV 23, TV 25 and Teen Ali 17. The observations recorded on total chlorophyll (CHt), chlorophyll a (CHa) and chlorophyll b (CHb) of the clones and their differences of mean are presented in Fig. 2.

CHt, CHa and CHb were found to vary significantly (at $p < 0.05$) among the clones. All chlorophyll components were highest in TV25 and lowest in TV1. It can also be seen that variation exists in chlorophyll content among the locations though not very significantly. This variation of chlorophyll content is found to create differences in appearance in made teas of all locations by way of forming various degree of phaeophytin and phaeophorbide levels (Table 2b).

Some of the most important green tea shoot compositions which contribute towards quality of made tea are mainly their catechin profile, total catechins, total polyphenols, total sugar, total lipid content and lipid fractions etc. Their presence in tea shoots of different clones under North Bengal condition are presented in Table 1.

Among the catechines, EGCG content was recorded highest followed by ECG, EGC, EC and C in green tea shoots, though EGCG, and total catechins content in the shoots of different clones under North Bengal condition were comparatively lower than in Assam.[7]

EC, ECG, EGC, EGCG and total catechin (TC) were found significantly different among the clones while C has almost uniform distribution. EC is highest in clone TV 20 followed by TV1. It can be seen from tTable. 1 that ECG, EGCG, TC, TPP and PL content in green

Table 5: Correlation Coefficient Matrix between Black Tea Biochemical Parameters

	TF	TR1	TR2	TR	BR	TC	TSS	CA	CF	TPP
TF	1	.616**	.117	.442**	.856**	.167	.342*	.611**	-.606**	-.605**
TR1		1	.088	.676**	.761**	-.043	.442**	.536**	-.561**	-.678**
TR2			1	.587**	.089	-.095	.231	.190	-.210	-.060
TR				1	.525**	.093	.265	.357*	-.453**	-.367*
BR					1	.195	.381*	.689**	-.714**	-.717**
TC						1	.027	-.137	-.136	.102
TSS							1	.534**	-.415*	-.232
CA								1	-.776**	-.572**
CF									1	.624**
TPP										1

TF = Theaflavin, TR1 = Thearubigin1, TR2 = Thearubigin2, TR = Thearubigin, BR = Brightness, TC = Total colour, TSS = Total soluble solids, CA = Caffeine, CF = Crude fibre, TPP = Total polyphenol.
* Correlation is significant at 0.05.
** Correlation is significant at 0.01.

shoots are highest in clone TV23, the result is in agreement with the previous study.[28] Significant clonal variation was observed in TPP content. Total soluble sugar (TS) content was found to be varied among the clones and recorded highest in clone Teenali17 and lowest in TV1.

Table 1 shows that clone TV25 contains highest amount of total crude lipid (L) while TV1 has the lowest. All clones used in the study were found to have significant variation in L, NL and PL content, however, no such variation was noted in GL content.

Made Tea Compositions

TF and TR are the major components responsible for brightness, briskness, strength and colour of the liquor and create chemical basis for the various quality characteristics of made tea.[29] Different quality parameters in made teas processed at miniature factory are presented in table 2a and 2b to ascertain their cultivar and location variation.

TF content in made teas processed from three clones namely TV1, TV18, Teenali17 and mix of these three clones shows significant variation among themselves but not much variation of TF was observed within the locations (Table 2b). Again a heterogeneous group of compounds thearubigins (TR) are responsible for colour, strength and body of the liquor showed no appreciable variation neither among the clones nor within locations. TR1 a fraction of TR is responsible for brightness found more in clone TV1 followed by TV18 and Teenali17. TR1, TR2 varied significantly between clones and within location also.

From Table 2a it can be seen that except TPP there exist significant clonal variation for all other parameters such as BR, TC, TSS, CA, CF, PTIN and PBIDE, contrary to this it is observed that there are no remarkable variation of BR, TC, TSS,CA, CF and PTIN among locations. However, significant variation of TPP and PBIDE are noted between locations. A high content of PTIN and PBIDE are good indicator of black and brown appearance respectively. PTIN is found more in Tin17 and PBIDE is highest in TV1, signifying their characteristic of appearance.

In this study, 7 days plucking interval was adopted for manufacturing of black tea from the selected clones. TF content is considered as an index of made tea quality while CF inversely affects the quality. It is evident from Figure 3 that TF is highest in TV1 followed by Tin17, the trend is similar in case of CF content also. This finding points that 7 days of plucking for all clones may not help in achieving desired quality under North Bengal condition.

A comparison in quality parameters of made teas processed at both miniature factory (MF) and garden factory (GF) were presented in Table 3. It has been observed that all quality parameters of made teas such as TF, TR1, TR2, TR, BR, TC, TSS, CA content were higher in MF manufacturing condition than manufacturing at GF except TPP. A high content of TPP in made teas of GF may be due to remaining of un-oxidized catechins. Un-oxidized catechins take part in the formation of high polymerized substances (HPS) during processing thereby reducing TF and TR, which affects the briskness of liquor and ultimately making the liquor thin and less astringent.[30]

Statistical correlations among the biochemical parameters of green the shoot components and made tea under North Bengal condition are presented in Tables 4 and 5.

It can be seen from Table 4 that EC is negatively correlated with ECG, EGCG, TS while there exist strong positive correlation with ECG and EGCG, C, TC, TPP.

A negative relation is found to exist between EGC and ECG. It is observed that Lipid (L) is holding positive correlation with TPP.

A highly significant positive correlation was observed between TF and TR1, TR, BR, TSS and CA. It is also observed from Table 5 that TF is having a significant negative correlation with CF and TPP. Again TR1 is significantly correlated with TR, BR, TSS and CA. There is a negative correlation between CF and TPP with TR1. It revealed from Table 5 that TPP is having strong negative correlation with TF, TR1, TR, BR, CA except CF which is having positive correlation, similar correlations were observed by Bhuyan *et al.*[7] also.

Conclusion

It is observed that biochemical compositions present in tea shoots under North Bengal condition are suitable for producing tea with high quality. Hence, by undertaking some modifications in the key steps of manufacturing operations quality of made tea can be enhanced at GF level also with desired degree of appearance. It can be opined from this study that clone like TV1, Teenali17 known for producing good quality tea may be plucked at shorter intervals than from normal 7 days round to achieve the best quality from them.

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