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The impact of pruning and time from pruning on quality and aroma constituents of black tea

Ramaswamy Ravichandran

Regional Institute of Education (NCERT), Bhopal, 462 013, India

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Abstract

The precursors responsible for tea quality, such as polyphenols, were found to increase in the first year and thereafter declined in content with time from pruning. While the green pigment content and ash content increased, the lipoxygenase activity showed substantial and progressive decline with time from pruning. The content of carotenoids were found to increase in the first 3 years after pruning and then showed a decline. A quantitative assessment of the various biochemical and quality parameters, such as theaflavin content (TF), total liquor colour (TLC), and water extract, showed progressive increase with time from pruning. The polyunsaturated fatty acids showed a marked decrease in their contents with decrease in the total fatty acids and various lipid fractions with time from pruning. However, C (18: 0) showed an increasing trend. While the sum of VFC Group II showed an enhancement, that of Group I showed a decline with time from pruning. As a result, the flavour index value was found to increase with time from pruning. The sensory evaluation supported the trends observed in the analytical data.

Keywords: Black tea; Pruning; Quality; Aroma

1. Introduction

Black tea is the cheapest non-alcoholic stimulant taken throughout the world and is manufactured from the young tender shoots of *Camellia sinensis* (L) O Kuntze, grown in some tropical and temperate countries (Hampton, 1999). India is the major producer, consumer and exporter of tea (UPASI, 2001). The profitability of the operation is governed by the quantity and quality of the plucked shoots (Obanda & Owuor, 1995; Owuor & Odhiambo, 1993; Ravichandran & Parthiban, 1998a). Pruning is an essential agronomic practice in the production of leaves for the manufacture of black tea (UPASI, 2002). It leads to enhanced branching and hence a greater number of tender leaves (Satyanarayana, Sreedhar, Cox, & Sharma, 1994). The plant height normally increases by 15–20 cm annually and leads to low productivity, as the plucking becomes more difficult (Sharma, 1997). Hence in order to maintain the tea bushes in a manageable condition for plucking and in order to enhance production by increasing branching, pruning becomes essential (Ravichandran & Parthiban, 1998a). In South India a pruning cycle of four years is practised (Sharma, 1997).

Unpruned tea plants produce more dormant buds than growing buds (Satyanarayana et al., 1994). Therefore pruning prior to harvest has been considered to have great effects on plant productivity. In the first 3 months after pruning, there will not be any shoots to pluck and this yield loss is made up by the subsequent fast growth (Ravichandran & Parthiban, 1998a). However, as the time for the next prune approaches, the growth rate decreases (UPASI, 2001). This variation in growth rate is expected to cause some changes in the green leaf constituents and hence the quality of made tea (Ravichandran & Parthiban, 2002). Also, due to the sharp rise in the labour costs and shortage of manpower, along with the ever-increasing cost of production/power, the tea industries in South India have become non-profitable (Ravichandran & Parthiban, 1998b). Due to the high competition existing in the tea trade, quality of made tea has become an important parameter in fixing the price of tea (Ravichandran & Parthiban, 1998c). Due to this changing economic scenario, scientists have been asked to enhance profitability through quality improvement (UPASI, 2001). This has made it necessary to understand how agronomic and manufacturing practices affect the quality of made tea

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(Ravichandran & Parthiban, 1998d, 2000). This study was undertaken to clarify the effect of pruning and time from pruning on biochemical and quality parameters of black tea.

2. Materials and methods

Four different plots of UPASI-3 clonal material, each one of which was pruned at different periods namely, April 2002, 2001, 2000 and 1999, were taken for this study. Thus, at the time of study, plots A, B, C and D, pruned in April 2002, 2001, 2000 and 1999, respectively, were 0, 1, 2 and 3 years old, since pruning in the said order. Tea shoots for manufacture were collected in September 2002, in triplicate, from these plots located on an experimental farm (altitude 1050 masl). They consisted of two leaves and a bud with minor amounts of three leaves and a bud. The harvested leaves were withered at a thickness of 20 cm with an air flow of 25 ft^3/min/kg of leaves for 16 h, in order to obtain a moisture content of 65% (normal weather). The ambient air with a hygrometric difference of over 3 °C normally undergoes forced circulation. Whenever the hygrometric difference is below 3 °C, hot air is mixed in an appropriate proportion. However, the dry bulb temperature of air after mixing was restricted to 25 °C. The relative humidity was 88%, with maximum and minimum mean room temperatures of 27 and 17 °C, respectively. The withered leaves were subjected to crush, tear, curl (CTC) rolling in a continuous four-cut system. The machine-rolled leaves were fermented in a continuously rotating aluminium drum for 45 min (moisture content 55%) with air flow and fired in a fluid-bed drier (FBD) at 130C for 30 minutes with hot air to obtain black tea containing 3% moisture. The material passing between sieves BSS 18 and 24 mesh number was taken for analysis.

The biochemical constituents and quality parameters were analysed by following the methods described by Ravichandran and Parthiban (1998a; AOAC, 1996). Lipid content, lipid factions and fatty acids were analysed by following the procedure described by Ravichandran and Parthiban (2000). Volatile flavour compounds were extracted and analysed by following the procedure described by Ravichandran and Parthiban (1998c). Organoleptic evaluation was carried out by a panel of professional tea tasters based at different locations in India. They assessed the tea blindly and independently on a scale of 0–10.

3. Results and discussion

The effect of time from pruning on the biochemical constituents is presented in Table 1. The total polyphenols and catechin contents of green leaf showed an increase in the first year and started decreasing thereafter. The green pigment (chlorophyll) content showed enhancement with time from pruning. However, the total carotenoids increased up to 2 years and started decreasing thereafter. The lipoxygenase activity was found to decline with time from pruning. The gradual attainment of maturity in shoot components can be attributed to a higher accumulation of lipid, and decline in enzyme activity, resulting in desirable flavour in manufactured tea, with time from pruning. The crude fibre increased with time from pruning along with the yield. But, the percentage increase in yield for each year was found to decrease with time from pruning. With regard to ash content, there was an increase in total ash content with a decrease in both water-soluble as well as acid-insoluble ash content with time from pruning. A progressive increase in the percentage out-turn with time from pruning could also be noticed here. However, this seems to be partly compensated by the lower percentage of waste in the first 2 years.

It is well established that plain black teas of high quality are characterized by high theaflavins (TF), caffeine, total liquor colour (TLC), water extract, VFC Group II compounds and flavour index, along with medium amounts of TR, HPS, lipids and VFC Group I compounds (Owuor, Reeves, & Wanyoko, 1986; Yamanishi, 2000). It is interesting to note that the present study very clearly demonstrates that the desirable parameters such as TF, caffeine, TLC, water extract, VFC Group II compounds and flavour index increase with time from pruning and other parameters, which are needed only in moderate quantity, such as TR, HPS, lipids and VFC Group I, show a slight decrease, leading to the overall improvement of quality with time from pruning. It is also known that the larger the value of TLC and water extract, the higher will be the cuppage and colour of the liquor (Obanda & Owuor, 1995). Thus, increase in time from pruning improves the colour and cuppage of the liquor by enhancing TLC and water extract values. The flavour index value is directly correlated to the flavour of black tea (Owuor, Othieno, Howard, Robinson, & Cooke, 1988). The value of flavour index depends on the ratio between the sum of VFC Group II and I compounds. VFC Group I compounds are mostly derived from lipid degradation during manufacture (Ravichandran & Parthiban, 1998d, 2000) and give rise to inferior greenish flavour, while VFC Group II compounds impart sweet flowery aroma to black tea (Ravichandran & Parthiban, 1998c, 2002). Thus the flavour of black tea improves with time from pruning, with an increase in flavour index value due to increase in VFC Group II compounds and a decrease in VFC Group I compounds. In order to understand it better, both fatty acid composition and VFC composition were also studied.

Table 1
Effect of time from pruning on biochemical and quality constituents of tea[a]

Time of pruning	April 2002	April 2001	April 2000	April 1999
Total polyphenols (%)	12.6	15.5	14.0	14.4
Total catechin (%)	9.11	10.2	9.37	9.10
Total chlorophyll (μg/g)	687	791	920	1032
Total carotenoids (μg/g)	151	166	169	134
Lipoxygenase activity[b]	15.1	13.8	12.7	12.0
Total ash (%)	4.40	4.90	5.60	7.10
Water-soluble ash (%)	47.0	41.0	38.0	36.0
Acid-insoluble ash (%)	1.10	0.80	0.70	0.60
Crude fibre (%)	13.7	14.5	14.6	15.5
Caffeine (%)	2.72	2.80	2.85	2.92
Lipid (%)	3.24	3.90	4.17	4.23
Theaflavins (%)	1.17	1.19	1.26	1.27
Thearubigins (%)	9.09	8.63	8.09	7.46
HPS (%)	8.32	8.41	7.27	8.14
Total liquor colour	2.67	2.84	3.06	3.08
Water extract (%)	40.1	43.4	45.6	46.1
Sum of VFC Group I[c]	3.17	2.68	2.46	2.39
Sum of VFC Group II[c]	5.93	6.47	6.81	7.04
Flavour index	1.87	2.41	2.77	2.95
Tasters score[d]	29.0	32.0	34.0	35.0
Out-turn (%)	18.0	19.0	20.0	21.0
Waste (%)	4.00	4.00	5.00	5.00
Yield (kg/ha/year)	1282	3085	4296	5038

[a] Average of three determinations with CV less than 1.1%.
[b] Units/mg of protein at pH 7.5.
[c] As ratio of peak area to that of internal standard.
[d] Based on liquor, flavour, briskness, infusion and quality.

The changes in fatty acid composition with time from pruning are given in Table 2. It is seen that the total fatty acid content shows a decline with time from pruning and that this applies also to the polyunsaturated fatty acids. In general, the saturated fatty acid (18:0) showed an increase with time from pruning and the unsaturated fatty acids (18:1,2,3) showed the opposite trend. The changes were different for each individual fatty acid. The data presented here very clearly explain the higher flavour index of the samples approaching pruning. This is because of the decrease in total fatty acid content and unsaturated fatty acids, which contribute to VFC Group I compounds, with the time from pruning. The role of saturated fatty acids is unknown (Skobeleva, Petrova, & Bokuchava, 1987). The contents of lipid factions, such as neutral lipid, glycolipids and phospholipids, were also found to decline with time from pruning (Table 3). The fatty acid composition of these fractions also declined with time from pruning. The high content of linolenic acid may be related to chloroplast development, as it is one of the major constituents of chloroplast membrane lipids.

Table 4 presents the VFC composition with time from pruning. A decrease is noticed in the VFC Group I compounds with time from pruning. The major component influencing the sum of VFC Group I compounds was Trans-2-hexenal. A significant increase is noticed with VFC Group II compounds, especially linalool,

Table 2
Variation in the fatty acid composition (mg/g dry weight) with time from pruning[a]

Time of pruning	April 2002	April 2001	April 2000	April 1999
C (16:0)	18.0	15.9	14.7	14.2
C (18:0)	7.07	7.99	8.76	9.09
C (18:1)	12.1	10.6	9.47	8.98
C (18:2)	25.4	23.3	22.2	21.6
C (18:3)	70.0	68.1	67.0	66.3
Total fatty acids	133	126	122	120
Total unsaturated fatty acids	108	102	98.6	96.9
Total polyunsaturated fatty acids (18:2,18:3)	95.47	91.40	89.1	87.9

[a] Average of three determinations with CV $<1.9\%$. Difference between fatty acids are highly significant at $P<0.01$. mg/g dry weight as fatty acid methyl esters.

Table 3
Variation in fatty acid composition of neutral lipids, glycolipids and phospholipids with time from pruning[a]

Lipid	Fatty acid composition (μg/g)	Time of pruning			
		April 2002	April 2001	April 2000	April 1999
Neutral lipid	(%)	2.01	1.61	1.41	1.33
	16:0	651	650	647	646
	18:1	474	391	344	299
	18:2	1002	981	949	923
	18:3	801	761	689	661
Glycolipid	(%)	4.29	4.13	4.06	4.02
	16:0	1062	976	881	841
	18:1	419	416	397	364
	18:2	521	491	429	419
	18:3	4037	3902	3738	3636
Phospholipid	(%)	1.25	1.15	1.09	1.06
	16:0	2328	2281	2109	2077
	18:1	1061	979	816	786
	18:2	2097	2069	2036	2011
	18:3	1661	1659	1622	1595

[a] Average of three determinations with CV $<1.9\%$. Difference between fatty acids are highly significant at $P<0.01$.

Table 4
Variation in the volatile flavour compounds with time from pruning[a]

Time of pruning	April 2002	April 2001	April 2000	April 1999
VFC Group I				
1-Penten-3-ol	0.13	0.12	0.09	0.11
n-Hexanal	0.30	0.21	0.20	0.17
n-Hexanol	0.03	0.04	0.04	0.03
cis-3-Hexenal	0.38	0.27	0.24	0.22
trans-2-Hexenal	1.94	1.70	1.62	1.59
cis-3-Hexenol	0.11	0.10	0.07	0.09
trans-2-Hexenol	0.12	0.10	0.09	0.11
n-Pentanol	0.16	0.14	0.11	0.07
VFC Group II				
Linalool	1.01	1.15	1.22	1.29
Linalool oxides	0.49	0.56	0.58	0.57
Methyl salicylate	0.74	0.71	0.71	0.69
Phenylacetaldehyde	0.99	1.11	1.19	1.27
Geraniol	1.03	1.06	1.17	1.26
Benzyl alcohol	0.14	0.11	0.15	0.14
2-Phenylethanol	0.60	0.61	0.64	0.68
Benzaldehyde	0.15	0.13	0.12	0.11
α-Ionone	0.41	0.50	0.53	0.57
β-Ionone	0.37	0.53	0.50	0.46
Sum of VFC II	5.93	6.47	6.81	7.04
Sum of VFC I	3.17	2.68	2.46	2.39
Flavour Index	1.87	2.41	2.77	2.95

[a] As ratio of peak area to that of internal standard. Average of three determinations with CV $<1.2\%$

phenyl-acetaldehyde and geraniol, with time from pruning. The changes were maximum in the recently pruned fields and decreased with time. The trend observed in VFC Group I volatiles can be explained by the trend of total polyunsaturated fatty acids (Tables 2 and 3), as they are the precursors of these volatiles. All the above observations lead to enhancement of the flavour index and hence the tea flavour quality, with time from pruning. The analytical data obtained were also compared with organoleptic evaluation. The tasters scores presented in Table 1 also reveal the earlier finding that the tea quality, in all respects, improves with time from pruning.

It is established that the quality of tea is affected by the growth rate of the pluckable shoots and improves as growth rate decreases (Owuor, Obaga, & Othieno, 1990). It is also known that, the shoot growth rate is slower when the time from pruning is greater (Grice, 1985). Based on this, it is not surprising to note that the quality improves with time from pruning. The quality changes observed in this study would be attributed to these changes. Thus the present study very clearly demonstrates that the quality of black tea improves with time from pruning, and pruning as such leads to adverse effects on tea quality. However, as mentioned in the introduction, pruning is essential and cannot be avoided. Hence, further studies are to be undertaken to assess the changes in quality parameters and aroma constituents with height and type of pruning.

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