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The impact of mechanization of tea harvesting on the quality of south Indian CTC teas

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The chemical quality parameters and sensory evaluation of black teas changed with method of plucking. Hand-plucked teas were very rich in their green-leaf biochemical precursors and had higher contents of made-tea quality constituents than shear-plucked teas. The quality deterioration was mainly due to mechanical injury and non-selective plucking with shear-harvesting. However, tea obtained by shear-harvesting from a continuously sheared field over a prolonged period was found to be superior. The use of shears reduced the yield and increased the plucking average with a net decrease in cost of production compared to hand plucking. © 1998 Elsevier Science Ltd. All rights reserved

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, 1992). India is the major producer, consumer and exporter of tea. The profitability of the operation is governed by the quantity and quality of the plucked shoots (Mamedor and Dzhafarof, 1974; Baruah *et al.*, 1986; Obanda and Owuor, 1995; Owuor and Odhiambo, 1993). So far, tea leaves are harvested by hand-plucking without causing mechanical injury and manufactured under optimal conditions in order to maintain quality (Palmer-Jones, 1977; Tanton, 1979; Mahanta *et al.*, 1993; Owuor *et al.*, 1987). However, 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 (Sharma, 1987; Sharma *et al.*, 1981). Thus, with this changing economic scenario, scientists have been asked to enhance profitability. This has led to the partial mechanization of shoot-harvesting by using hand-operated shears (Fay, 1950; Harler, 1949; Gokhale, 1959; Myers, 1967; Shih *et al.*, 1974; Othieno and Anyuka, 1982). This process increases the rate of plucking and reduces the manpower involved. In this direction, UPASI TRI has offered new recommendations on harvesting using shears alternately with hand-plucking, depending on the season (UPASI, 1996*a*,*b*). However, in shear-harvesting, the selectivity in plucking is lost and enormous mechanical injury is caused to the leaf harvested (Dutta, 1956; Mwakha, 1986, 1990; Owuor *et al.*, 1991). This will certainly lead to deterioration of tea quality and hence price and profitability (Shkvatsabaya, 1972; Mwakha and Anyuka, 1984). This study was undertaken to compare the changes in biochemical and quality constituents of harvested shoots and black tea obtained from hand-plucked and shear-plucked shoots under south Indian conditions.

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MATERIALS AND METHODS

Tea leaves were collected from UPASI TRI experimental farm (altitude 1050 MSL), from UPASI-9 (chinary) clone in triplicate. Hand-plucking was done without breaking-back by removing all the available young shoots, irrespective of the number of leaves on them. Leaves were hand-plucked, as well as sheared (shear-plucked-A), from the fields which had been under continuous hand-plucking since being planted (30 years). Leaves were also shear-plucked from the field which had been under continuous shearing for the last 5 years (shear-plucked-B).

The leaves were manufactured in triplicate, by the crush, tear and curl (CTC) method, and subjected to chemical analysis and sensory evaluation. The professional tasters, based at different locations in India, assessed the teas blind and independently.

The biochemical constituents and quality parameters of both green-leaf and made-tea were analysed by following the methods reported by the AOAC (1996) and

others (Mahanta *et al.*, 1993; Owuor and Odhiambo, 1993; Obanda and Owuor, 1995). The lipids were extracted by homogenizing the sample with chloroform: methanol (2:1) for 5 min, filtering and concentrating to dryness. The residue was then hydrolysed with IM alcoholic KOH (refluxing for 2 h), washed with light petroleum (b.p. 40–60°C): diethyl ether (1:1) (to remove non-saponifiables), acidified and extracted with diethyl ether. Methylations of fatty acids were carried out by refluxing in anhydrous methanol with 2 drops of conc. H_2SO_4 for 2 h. Fatty acid methyl esters were determined by gas chromatography with FID, using a 10% DEGS column, programmed from 120 to 190°C at 4°C/min.

Volatiles were extracted in a simultaneous distillation and extraction apparatus, using dichloromethane. They were analysed by GLC using a DB-Wax fused-silica capillary column, programmed from 50 to 230°C at 2°C/min. Identification was done by comparision with authentic chemical standards obtained from Sigma.

RESULTS AND DISCUSSION

The changes in black tea quality parameters due to shear-plucking are summarized in Table 1. Most of the quality parameters show a decrease on using shears for harvesting. Theaflavins (TF), an important quality parameter, which are directly correlated with quality, show a decline with shearing. At the same time, the contents of thearubigins (TR) and highly polymerized substances (HPS), which are undesirable beyond a certain value, are seen to increase with shearing. Total liquor colour (TLC) showed a minor decline with shearing which was significantly observed by the tasters. The water extract value, which determines the cuppage value, also declined with shearing. The crude fibre content, an undesirable parameter whose limit has been fixed around 16%, decreased with shearing. A slight decrease in the caffeine content along with a slight increase in lipid content occurred with shearing compared to hand-plucking. The analytical data observed were complemented by organoleptic evaluation. The professional tasters rated the tea made from hand-plucked leaves much higher than that obtained from shear-plucked leaves. More specifically, they commented that both flavour and colour of tea infusion obtained from hand-plucked leaves were distinctly higher than those obtained by shear-harvesting. The quantity of green leaf harvested by use of shears was much higher than that by hand-plucking. Shear-harvesting leads to a reduction in plucker requirement. The cost of production, worked out taking all aspects into consideration, was found to be quite cheap by shear-harvesting. The use of shears increased the plucking interval and decreased the net yield/productivity. However, the decrease in productivity was not significant. The field observation showed poor leaf distribution in shear-operated fields. Also, hand-plucking produced more fine leaf than shearing. Indeed, shear-harvesting collected more coarse, mechanically injured leaves than intact standard leaf, while the hand-plucked harvest contained only 'three leaf and a bud'. Shear-plucking is non-selective and removes all available shoots, even immature ones, which could grow into the next generation of shoots within a short interval.

Table 1. Changes in black tea chemical quality parameters due to mechanization of harvesting[a]

Parameters	Hand-plucked	Shear-plucked-A	Shear-plucked-B
Theaflavins (%)	0.78	0.71	0.76
Thearubigins (%)	7.60	8.10	7.90
High polymerised substances (%)	7.10	7.70	7.30
Total liquor colour	2.60	2.50	2.60
Water extract (%)	41.90	40.70	41.60
Crude fibre (%)	15.40	14.90	15.20
Caffeine (%)	3.30	3.00	3.10
Lipid (%)	3.00	3.30	3.10
Protein (%)	16.0	16.6	16.2
Taster's score:			
A	33.00	30.00	32.00
B	36.00	32.00	33.00
Yield (kg/ha/year)	11 250	11 064	—
Leaf distribution	good	poor	good
Plucking average (kg/worker)	24.00	30.00	—
Cost of production (Rs/kg)	34.30	31.00	—

[a]Average of three trials with standard deviation less than 1%.

Table 2 shows the variation in green-leaf quality precursors upon mechanization of plucking. A significant decline in the content of total catechins and total polyphenols was registered due to shear-harvesting. This very much reflects the decline in made-tea quality parameters. In the case of pigments, while the carotenoids showed a reduction, the chlorophylls increased with mechanization. The lipoxygenase activity increased with shearing, but the opposite was observed with polyphenol oxidase. Both the total lipid and total protein increased with mechanical harvesting.

The data on changes in fatty acid composition with shearing are given in Table 3. While the content of

Table 2. Changes in green leaf biochemical constituents due to machine plucking[a]

Parameters	Hand-plucked	Shear-plucked-A	Shear-plucked-B
Total catechins (%)	18.4	17.8	18.2
Total polyphenols (%)	27.7	26.6	27.5
Carotenoids (mg/100 g)	71.0	66.0	69.1
Chlorophyll a (mg/100g)	1091	1201	1137
Chlorophyll b (mg/100 g)	448	493	482
Lox activity (U/mg protein)	11.5	14.0	12.9
PPO activity (U/mg protein)	24.4	23.1	23.0
Total lipid (%)	6.3	7.7	7.3
Total protein (%)	14.1	15.3	15.1

[a]Average of three trials with standard deviation less than 1%.

Table 3. Changes in fatty acid composition due to shearing (%)[a]

Fatty acid	Hand-plucked	Shear-plucked-A	Shear-plucked-B
Palmitic (16:0)	15.3	14.6	14.9
Stearic (18:0)	8.0	7.7	8.0
Oleic (18:1)	7.4	8.8	8.1
Linoleic (18:2)	20.7	22.5	21.3
Linolenic (183)	37.2	37.0	36.8
Others	11.4	9.4	10.9

[a]Average of three trials with standard deviation less than 1%.

saturated fatty acids showed a decline, that of unsaturated fatty acids showed a marked enhancement except for linolenic acid, which remained almost constant. The changes in volatile flavour compounds (VFC) are given in Table 4. In general, all VFC Group I showed an increase and VFC Group II a decline with machine plucking. Accordingly, the Flavour Index value declined with shear-harvesting.

Harvesting is the most expensive of all the agricultural operations in tea production. It presents a very delicate balance. It should aim at maximum production of shoots, without impairing the bush health and the end-product quality. The method of harvesting should represent the optimal compromise between yield, quality and cost. Hand-plucking is accompanied by short plucking intervals (32 rounds per year), but shears can only be used with long plucking intervals (24 rounds per year) (UPASI, 1996*b*). The highest yields were obtained only by short plucking intervals and so favour hand-plucking. However, the cost is much lower with shear-harvesting.

Table 4. Effect of mechanization of harvesting on black tea VFC composition[a]

VFC	Hand plucked	Shear plucked-A	Shear plucked-B
Group I			
1-Penten-3-ol	0.05	0.09	0.09
n-Hexanal	0.24	0.30	0.28
n-Hexanol	0.04	0.09	0.08
cis-3-Hexenal	0.33	0.42	0.39
trans-2-Hexenal	3.11	3.14	3.13
cis-3-Hexenol	0.07	0.12	0.11
trans-2-Hexenol	0.11	0.16	0.14
Pentanol	0.05	0.08	0.08
Group II			
Linalool	0.92	0.87	0.91
Linalool oxides	0.13	0.11	0.13
Methyl salicylate	0.49	0.40	0.47
Phenyl acetaldehyde	1.31	1.21	1.30
Geraniol	1.07	1.01	1.05
Benzyl alcohol	0.15	0.11	0.14
2-Phenyl ethanol	0.43	0.39	0.41
Benzaldehyde	0.07	0.06	0.06
α-Ionone	0.36	0.36	0.35
β-Ionone	0.27	0.28	0.28
Sum of VFC Group I	4.00	4.40	4.30
Sum of VFC Group II	5.20	4.80	5.10
Flavour Index (II/I)	1.30	1.10	1.20

[a]As ratio of peak area to that of internal standard. Average of three trials with standard deviation less than 1%.

It needs to be noted that each clone will respond differently to shearing and efforts are being made to identify the elite clones that can respond well to shearing.

The present study shows that quality decreases by the use of shears. However, south India produces mainly RC CTC teas, which lack quality/aroma and are marketed mainly for plain black-liquor-producing teas. Hence, quality reduction due to shearing is not likely to have a significant impact as far as the market is concerned. Taking all these factors into consideration, UPASI TRI has recommended an integrated harvesting system, consisting of mother-leaf addition by hand-plucking from January to March, followed by shear-harvesting in April to June, hand-level plucking from July to September and shearing from October to December (UPASI, 1996*a*). It is not advisable to use shears in freshly pruned fields, at least for 18 months.

This kind of mixed use of hand- and shear-plucking helps to achieve optimal yield, quality and profitability in south Indian tea industries. It could also be argued that mechanical tea harvesters, capable of harvesting only tender shoots, could produce good tea. Harvesting tender shoots only could be achieved by raising the plucking height at definite intervals. On the other hand, use of a mechanical harvester over several years might change the plucking table, allowing only the tender shoots to emerge out of the plucking table and keeping the mother leaf uniformly in a plain, horizontal level, thereby allowing the harvest of tender shoots alone. Preliminary data obtained on the changes in quality parameters of both green leaf and made tea, obtained by shear harvesting from fields under continual shearing over several years, are presented here in the various tables (shear-plucked-B). As anticipated, all the quality parameters were found to improve and to be very close to those of hand-plucking. The data obtained very clearly indicate that the quality deterioration on shearing decreases with time and normalises after several years of continuous shearing.

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