

FACTORS AFFECTING QUALITY OF TEA DURING PROCESSING

Beena Agarwal

(National Agricultural and Scientific Research Foundation, 113/2, Amherst Street, Calcutta - 700 009, India.)

The factors affecting quality and flavour during manufacture of black tea as well as the overall influence of some other factors on tea manufacture have been discussed.

INTRODUCTION

Tea is the most widely used stimulant throughout the world. This beverage is obtained from dried and carefully processed leaves of the tea plant (*Camellia sinensis*). Variations in flavour and quality of this beverage is largely determined by the interplay of complex metabolic events that occur in the leaves during processing. Although it is assumed that the differences in black tea aroma and quality vary with the type, it has been observed that the manufacturing technique is also responsible to a great extent.

Once the leaf is plucked the anabolic reactions practically cease while the catabolic reactions continue resulting in a continuous loss of organic matter from the time of leaf plucking. Some of the catabolic reactions are desirable from the point of view of tea making and it is the proper control of such catabolic processes that lead to good quality tea. Thus it is evident that whatever traits the genetic make up of a tea cultivar contributes towards quality, the exploitation of such potentials are ultimately dependent on the controls in leaf processing for a given cultivar. Careful handling and proper manufacture will tend to realize the maximum potential of the fresh leaf, while poor handling and manufacturing techniques will result in inferior quality.

In order to improve our understanding of the potential of fresh tea leaf, it is necessary to define potential in terms of biochemical composition of the tea leaves. To this end an investigation into the chemical composition of fresh tea leaf as relating to the quality of tea made from such leaf may be considered (Sanderson, 1964).

The manufacture of tea may vary, but usually it is made into black or green tea with numerous factors affecting the final product. After plucking, the lipids of tea leaf tissues undergo significant changes producing volatile flavour compounds

(VFC) during post harvest changes. A chain of reactions take place from the time, the leaves and buds are plucked from the plant through the process of tea manufacture.

It was reported by Bokuchava and Popov (1954) that amino acids added to a solution of flavanols undergoing oxidation, produce volatile compounds (VFC). Furthermore, Wickremasinghe and Swain (1964) have shown that there is an increase in certain volatile aldehydes concomitant with a decrease in the level of related amino acids. These results suggest that amino acids are involved in the formation of chemical compounds during fermentation which determine quality in the black tea. It has been shown that amino acids present in fresh flush and to an even greater extent in withered flush are reduced in amount during the fermentation process (Roberts and Sanderson, 1966).

Polyphenols present in the cell sap of tea leaves undergo a series of chemical changes during the fermentation process which are initiated after the withered leaf has been macerated during rolling. The oxidation of the polyphenols upon exposure to air is very slow, unless brought about by the activity of the appropriate enzyme i.e. polyphenol oxidase or catechol oxidase. In the intact tissues of the living plant this enzyme is in the epidermal cells and probably also in the vascular bundles of the leaf. The purpose of fermentation is to bring, in the presence of oxygen, the enzyme and substrate together by rupturing the membrane. The most important fact is that during withering the cell membrane has already grown more or less permeable and this facilitates mixing of enzyme and substrate during rolling. The action of enzyme oxidase is the oxidation of the polyphenolic bodies to orthoquinones (Bhatia, 1963, Bhatia and Ullah, 1965).

It is generally assumed that subsequently the orthoquinones by a process known as dimerisation condense to bis-flavonols and these, in turn, condense rapidly to theaflavins, which are golden yellow bodies. An additional oxidation not controlled by enzyme action, transform these theaflavins to thearubigins. An ideal fermentation process results in a proper balance of theaflavins and thearubigins (Sanderson, 1964).

The characteristic volatile flavour constituents are mostly formed by the hydrolytic action of enzymes on cell constituents during leaf maceration (Takeo, 1981a; Renold *et al.*, 1974). Thus it is seen that the processing technique largely determines the quality of black tea.

The amount of volatile flavour compound (VFC) which constitute aroma in tea of withered leaves is small. Their formation starts with lipid degradation during the withering stages which gains momentum during rolling and fermentation (Hazarika, Mahanta and Takeo, 1984).

Any injury during the rolling process brings about an increase in the rate of polyphenolic oxidation. This hinders the formation of VFC or destroys the product formed initially. Keeping this in view the fermentation is usually maintained at a

low temperature. This reduces the rate of polyphenolic oxidation reaction thus allowing formation from other flavour producing substrates to take place (Mahanta, Hazarika and Takeo, 1985; Hazarika and Mahanta, 1984).

Contents of Volatile Compounds in black tea

The following components are generally associated with VFC of tea (Takeo, 1984).

- t-2 — Hexenal
- cis-3 — Hexenal
- t-2 — Hexenyl formate
- Linalool oxide
- Linalool

- Phenyl - acetaldehyde
- cis-3 — Hexenyl caproate
- Methyl salicylate
- Geraniol
- Benzyl alcohol
- 2 phenylethanol
- Cis - Jasmone + β - Ionone
- Nerolidol
- n - Hexanal

Among these linalool and its oxides, geraniols, 2-phenylethanol, benzyl-alcohol and methyl salicylate are the important aromatic compounds in making flavoured black tea. The aroma pattern of linalool and its oxides and geraniol show typical differences among black teas made from cultivars of different geographical locations. Sri Lankan tea has a sweet fruity and flower like flavour. Darjeeling tea is famous for its characteristic heavy rosy flavour. Keemun tea has also a rosy and thick flavour (Takeo, 1983).

Takeo (1981b) reported that monoterpene alcohols, as linalool and geraniol, were liberated from non volatile compounds by the hydrolytic breakdown in injured shoots. The liberation of monoterpene alcohols was favoured by anaerobic conditions and was depressed by the good aeration required to promote the oxidation of tea catechins.

Effect of withering on tea aroma and quality

The withering process is important in the formation of black tea aroma. The ratio of E-2-hexenal, geraniol, benzyl alcohol and 2 phenyl ethanol are higher in non withered tea, whilst that of linalool and its oxides, methyl salicylate are higher in withered tea. From the aroma pattern it is considered that the higher proportion of linalool and its oxides in the total aroma of withered teas, especially hard withered teas may be one of the reasons why such teas are more fragrant than non-withered

teas. It is well established that linalool and its oxides along with methyl salicylate play an important role in flowery flavour of black tea while E-2-hexenal constitutes the grassy flavour found in non-withered tea (Takeo, 1984).

A high ratio of theaflavins and thearubigins in the unwithered manufacture denotes brighter and brisker liquor. This ratio is largely controlled during withering. Quantity of theaflavin formed is highest in unwithered CTC manufacture and decreases with increasing hardness of withering. The thearubigins content is low in unwithered manufacture, but increase sharply on withering. Formation of both theaflavins and thearubigins are however restricted in highly withered tea. This is accompanied by reduction in the moisture content of the shoots.

Depression in polyphenol oxidase activity in withered tea shoots is likely to affect the oxidation of tea flavanols and thus influence the formation of theaflavins and thearubigins which are closely associated with the liquor character of black teas (Biswas, Biswas and Sarkar, 1971; Biswas, Sarkar and Biswas, 1973). With hardness of wither accompanied by reduction in moisture content of tea shoots, the production of theaflavin gradually declines and thearubigins increase up to a certain degree (80%), beyond which the increase is marginal. Therefore it appears that a high reduction in the moisture content of tea shoots during withering is deleterious to the quality of CTC teas. Storage of tea shoots under light wither seems to be beneficial for CTC manufacture to produce brisk liquor similar to unwithered CTC (Ullah, Gogoi and Baruah, 1984).

Effect of fermentation on tea aroma and quality

The volatile flavour components are lower in non fermented tea than semi-fermented tea. Linalool oxides are found in the volatile oil extracted from fermented leaves but not identified in the homogenates of fresh leaves. Volatile contents of semi-fermented and black tea compared from the same tea cultivar, showed, that black tea had a higher level of trans - 2 - hexenal, cis - 3 - hexenal, trans - 2 - hexenyl formate, monoterpane alcohols and methyl salicylates, while semi-fermented tea had a high content of cis-furanoid - β - ionone, uroledal, Jasmine lactone and methyl jasmcnate. Generally, after rolling in orthodox manufacture, there is a large amount of VFC, but this falls as fermentation progresses. When the polyphenolic oxidation reaction slows down after optimum fermentation, the reaction of the residual flavour substrates may produce small increases in the amount of VFC in the over fermented tea. Rapid oxidation of polyphenols hamper VFC formation in tea leaves (Takeo, 1981a; Hazarika and Mahanta, 1983). Lowering of fermentation temperature may result in greater production of VFC polyphenolic oxidation (Hazarika et al, 1984). Thus, duration and temperature of fermentation should be optimized so that a perfect flavoured tea is processed.

It is proposed that the compounds which comprise quality and which are formed in fermentation are formed as a result of flavanol oxidation, but the flavanols themselves are not a major part of quality *per se*. The cyclic action of the flavanols, however

can be broken by the joining of two oxidised flavanol molecules (dimerisation) to form the golden brown coloured theaflavin. It is believed that the theaflavin can be further inactivated by oxidation and condensation with amino acids to form the dark brown and insoluble thearubigins (Sanderson, 1965).

Effect of temperature

The enzymic oxidations in fermentation proceed most rapidly at about 28° C; above or below this temperature the rate of activity drops, the enzymes are destroyed at 54° C. The relative proportion of the end products depend on the temperature at which fermentation takes place. The complex changes will continue best at temperatures ranging from 24° - 28° C.

The initial temperature during drying should be high enough to inhibit fermentation, otherwise, this process will continue for a considerable time and at a very rapid rate. This will carry softness in the liquor and losses of soluble matter and essential oils, some 10% of the catechins present at the end of fermentation may be soluble and the tea may lack aroma. Clones which give blacker teas have higher levels of gallic acid. When the drying temperature is increased from 80° to 125°C through 100°C the gallic acid content of teas increases with the improvement in blackness. TF content of CTC black teas have been co-related with briskness and brightness of the liquor. Clones which produce blacker teas have less TF. Samples dried at 100°C have higher amount of TF than drying at 80°C but an excessively high temperature (viz. 125°C) has been found to affect TF content of tea (UPASI ANN REV, 1984).

Seasonal variation in tea aroma and quality

The increase or decrease of flavour during different seasons is the consequence of enzymic reaction sequences controlling the dynamic metabolic systems in pre-and post-harvest tea leaves. Most of the VFCs are present in large amounts in April which is often perceived as flavory tea in the market. High monoterpene alcohol generally present in leaves during this month produces superior tea. The reason may be that the atmospheric temperature in April is low, leading to intermediate rate of fermentation so that the reaction sequences leading to VFC formation may also take place (Hazarika et al, 1984).

The linalool oxide (2-furanoid) content is higher in the second flush along with geraniol and benzyl alcohol contents. In September as autumn approaches a marked fall in the amount of E - 2 - hexenyl formate, linalool, methyl salicylate and geraniol is observed. It is interesting to note that most of the compounds show an increase during autumn when atmospheric temperature and humidity fall considerably. This upward trend in the concentration of VFC might impart a flavory nature to autumn teas.

It is noteworthy that the level of nitrogenous compounds viz. total nitrogen, caffeine and protein are not affected by the dry season. The increase in pectin content of the flush in the dry season suggests its importance in governing fermentation rate in tea manufacture (Lamb and Ramaswamy, 1958).

The level of total soluble solids increase in the dry season while that of crude fibre decrease. Polyphenol oxidase activity declines during dry seasons (Sanderson and Kanapathipillai, 1964).

CTC and Orthodox teas

The aroma concentrate of orthodox and CTC teas are essentially different and the flavour of CTC tea is generally inferior to that of orthodox tea. The liberation of monoterpene alcohol is favoured by anaerobic conditions. The total amount of volatiles as well as their components like cis - 3 - hexanal, linalool and its oxides and methyl salicylate extracted from CTC teas are lower than those from orthodox teas. The less fragrant nature of CTC teas may be assigned to the lower amounts of essential volatile compounds, especially linalool and its oxides together with methyl salicylate (Takeo, 1984).

Higher theaflavin value in CTC tea as compared to orthodox teas is associated with higher activity of the oxido reductase enzymes on the catechin substrate which inhibits the action of the hydrolytic enzyme reported to be responsible for producing linalool and its oxides and methyl salicylate in triturated tea leaf tissues under anaerobic conditions (Takeo, 1981, 1982; Takeo and Mahanta, 1983; Ullah and Roy, 1982).

Effect of fertilizer

In East Africa K is known to help tea recover from pruning, However N is the major nutrient on which tea yields depend. TF content, however, decreases with the increasing rate of fertilizer up to 150 kg, N ha⁻¹ and then increases with increasing fertilizer rate, while VFC and TR decrease (Owner *et al.*, 1987a).

Effect of plucking standard

A fine plucking standard produces black teas with high contents of caffeine, crude fibre, TF and total water soluble solids, the ash content being lowest in two leaves and a bud. The high amount of TF content in two leaves and a bud is probably due to the fact that the polyphenol oxidase activity increases from the bud to the mature leaf stage while the reverse is true of the catechin concentration (Owner *et al.*, 1987b).

Caffeine in tea

The caffeine content of the tea shoot is highest in the terminal bud and first leaf where it may range from 4 to 5%. In the second leaf it may be 3% and in the stalk it could be up to 1.5%. There is no caffeine in tea seeds. Caffeine does not play an active part in the changes taking place during manufacture. However, caffeine has an important function in forming the cream or precipitate seen when a tea infusion cools, which is a mixture of caffeine, TF and the TRs (Harler, 1970).

Enzymes and precursors

There are two main enzymes involved in tea manufacture : (1) Pectase, (2) Polyphenol oxidase. Pectase acts on the carbohydrates in the leaf cell walls, making them soluble and works best at about 120°C. It probably functions to form a kind of varnish on the outside of the leaf during the early stages of its living processes. Such a coating may aid the keeping qualities of tea.

The most important enzyme in the tea leaf is the polyphenol oxidase. It is of the copper protein type and most readily acts on the catechin group of polyphenols in the tea leaf to change them to orthoquinones. These orthoquinones by a process of dimerization condense to bis - flavanols and these in turn condense rapidly to theaflavins which are yellow bodies. An additional oxidation not controlled by enzyme action transform these theaflavins into thearubigins. These are red brown bodies with tanning properties.

Poly-unsaturated fatty acids released from lipids have already been identified as precursors of C-6 aldehydes and alcohols. Recent work on the production of volatile carbonyl compounds in disrupted plant tissues have revealed that they are produced by the enzymic oxidation of poly-unsaturated fatty acids from lipids. This investigation has also confirmed that hexenal found in tea shoots was produced by macerating the shoots in the presence of air and the metal containing enzyme lipoxygenase (Takeo, 1981 a).

An endogenous β - glucosidase appears to be responsible for the release of linalool and geraniol in disrupted shoots. Glucosides of monoterpene alcohols are known to occur in many plants and are hydrolysable by glucosidase. It is assumed that linalyl and geranyl glycosidase occur in the tea shoots (Takeo, 1981).

The activity of lipoxygenase increases after plucking of the shoots. The changes of lipoxygenase activity are accelerated by the dehydration of tea leaves. The enzyme acts in good fermenting clones of black tea. The content of peroxide in tea shoots increase with rising lipoxygenase activity.

Vigorous catechin oxidation during processing results in depression of cis - 3 - hexenols and its esters with the consequent increase in the amount of trans - 2 - hexenol.

Higher TF value in CTC teas as compared to orthodox teas is associated with higher activity of the oxidoreductase enzymes on the catechin substrate which inhibits the action of the hydrolytic enzyme, reported to be responsible for producing monoterpene alcohols in anaerobic conditions (Takeo, 1981; Ullah and Roy, 1982).

REFERENCES

- BHATIA, I.S. (1963), Chemical aspects of green leaf processing. *Two and a bud* 10 (2), 28-36.
- BHATIA, I.S. and ULLAH, M.R. (1965). Quantitative changes in the polyphenols during the processing of tea leaf and their relation to liquor characters of made tea. *J. Sci. Fd. Agric.* 16, 408-416.
- BISWAS, AJIT K., BISWAS, ASIM, K. and SARKAR, A.R. (1971). Biological and chemical factors affecting the valuation of North East Indian teas. II. Statistical evaluation of the biochemical constituents and their effects on briskness, quality and cash valuations of black teas. *J. Sci. Fd. Agric.* 22, 196-204.
- BISWAS, AJIT K., SARKAR, A.R. and BISWAS, ASIM K. (1973). Biological and chemical factors affecting the valuation of North East Indian teas. III. Statistical evaluation of the biochemical constituents and their effects on colour, brightness and strength of black teas. *J. Sci. Fd. Agric.* 24, 1457-1477.
- BOKUCHAVA, M.A. and POPOV, V.R. (1954). The significance of amino acids in the formation of tea aroma by interactions with tannin substances under conditions of elevated temperature. *Dokl. Akad. Navk. USSR*, 99, 145-148.
- HARLAR, C.R. (1970). *Tea Manufacture*. Oxford University Press.
- HAZARIKA, M. and MAHANTA, P.K. (1983). Some studies on carotenoids and their degradation in black tea manufacture. *J. Sci. Fd. Agric.* 34, 1390-1396.
- HAZARIKA, M. and MAHANTA, P.K. (1984). Compositional changes of chlorophylls and carotenoids during four flushes of tea in North East India. *J. Sci. Fd. Agric.* 35, 298-303.
- HAZARIKA, M. and MAHANTA, P.K. and TAKEO, T. (1984). Studies on some volatile flavour constituents in orthodox Black Teas of various clones and flushes in North-east India. *J. Sci. Fd. Agric.* 35, 1201-1207.
- LAMB, J. and RAMASWAMY, M.S. (1958). Studies on the fermentation of Ceylon tea XI. Relations between polyphenol oxidase activity and pectin methyl esterase activity. *J. Sci. Fd. Agric.* 9, 51-56.
- MAHANTA, P.K., HAZARIKA, M. and TAKEO, T. (1985). Flavour volatiles and lipids in various components of tea shoots *Camellia sinensis*, L.O. Kuntze. *J. Sci. Fd. Agric.* 36, 1130-1132.
- OWNER, P.O., OTHIENO, C.O., HORITA, M., TSUSHIDA, T. and MURAI, T. (1987 a). Effects of nitrogenous fertilizers on the chemical composition of C.T.C. Black Tea. *Agric. Biol. chem.*, 51, 2665-2670.
- OWNER, P.O., OBANDA, M.A., OTHIENO, C.O., HORITA, H., TSUSHIDA, T. and MURAI, T. (1987 b). Changes in chemical composition and quality of Black tea due to plucking standards. *Agric. Biol. Chem.* 51, 3383-3384.
- RAMASWAMY, S. (1985). Report of the Tea Technologist for 1984. *Ann. Rep. Sci. Dept. UPASI*, 110-124.
- RENOLD, W. NAF-MULLER, R. KELLER, U. WILLHALM, B. and OHLAFF, G. (1974). An investigation of tea aroma. Part I, New volatile black tea constituents, *Helv. Chim. Acta.* 57, 1301-1308.
- ROBERTS, G.R. and SANDERSON, G.W. (1966). Changes undergone by free amino acids during the manufacture of black tea. *J. Sci. Fd. Agric.* 17, 182-188.

- SANDERSON, G.W. (1964). The chemical composition of fresh tea flush as affected by clone and climate. *Tea Q.* 35, 101-110.
- SANDERSON, G.W. (1965). On the chemical basis of quality in black tea. *Tea Q.* 36, 172-182.
- SANDERSON, G.W. and KANAPATHIPILLAI, P. (1964). Further studies on the effect of climate on the chemical composition of fresh tea flush, *Tea Q.* 35, 222-229.
- TAKEO, T. (1981 a). Production of linalool and geraniol by hydrolytic breakdown of bound forms in disrupted tea shoots. *Phytochemistry*, 20, 2145-2147.
- TAKEO, T. (1981 b) Variation in amounts of linalool and geraniol produced in tea shoots by mechanical injury. *Phytochemistry*, 20, 2149-2151.
- TAKEO, T. (1982). Variations in aromatic compound content in non-fermented, fermented and semi-fermented tea. *Nippon Nog. Kaishi*, 56, 79-80.
- TAKEO, T. (1983). Effect of clonal specificity of the monoterpene alcohol composition of tea shoots on black tea aroma profile, *JARQ.* 17, 1210-1247.
- TAKEO, T. and MAHANTA, P.K. (1983). Comparison of black tea aromas of orthodox and CTC tea and of black teas made from different varieties. *J. Sci. Fd. Agric.* 34, 307-310.
- TAKEO, T. (1984). Effect of withering process on volatile compound formation during black tea manufacture. *J. Sci. Fd. Agric.* 35, 84-87.
- TAKEO, T. and MAHANTA, P.K. (1983). Why CTC tea is less fragrant? *Two and a bud*, 30, 76-77.
- ULLAH, M.R. and ROY P.C. (1982). Effect of withering on polyphenol oxidase level in the tea leaf *J. Sci. Fd. Agric.* 33, 492-492.
- ULLAH, M.R. GOGOI, N. and BARUAH D. (1984). The effect of withering on fermentation of tea leaf and development of liquor characters of Black Teas *J. Sci. Fd. Agric.* 35, 1142-1147.
- WICKREMASINGHE, R.C. and SWAIN, T. (1964). The flavour of black tea. *Chem. & Ind.* 1574-1575.