Chapter IV

Volatile Flavour Components (VFC)
4.1 Introduction

Volatile components are responsible for flavour of black tea. Flavour, as we all know is an integrated sensation of many attributes like taste and aroma. Though concept of flavour is complex, in case of tea it is largely dominated by volatile flavoury constituents (VFC). Fresh tea leaves contain trace amount of VFC but the amount increases upto 0.02-0.03 % in made tea. VFC, although low in quantity plays an important role in determining overall perception of the brew. About 700 VFC have been identified in tea (Owuor and Robinson, 1992; Teranishi and Hornstein, 1995) but the characteristics aroma of black tea is influenced by 18 distinct classes depending on their functional groups. They are mainly alcohols, aldehydes, ketones and esters (Flament et. al., 1988). Studies of two exquisite green tea varieties, Kiyosawa tea from Japan and Long Jing tea from China reported some new compounds responsible for the characteristic flavour of a green tea brew. Compound 3-methyl-2,4-nonanedione (1) increases the sweet, creamy aroma and the characteristic mouthfeel of a green tea flavour. Compound 3-hydroxy-3methyl-2,4-nonanedione (2) and 1-methyl-2-oxopropyl hexanoate (3) contribute to its floral, juicy notes (Regula Naef et. al., 2006).

The chemical constituents of tea leaf contributing to quality of made tea, undergo series of biochemical changes in black tea manufacturing. These changes are dependent on process variables such as moisture, temperature, humidity etc and they have significant influence on quantity of VFC in the end product. Important precursors for production of volatile components are amino acids, lipids, carotenoids, carbohydrates and terpenoids (Saijo, 1973; Sanderson and Graham, 1973; Wright and Fishwick; 1979; Takeo and Tsushida,1980; Hazarika and Mahanta, 1983; Baruah, D. et. al. 2008).
Degradation of fatty acids, present in leaf to VFC is influenced by the variation in the pattern of moisture loss, temperature during withering (Saijo and Takeo, 1972, 1975; Mahanta & Singh, 1990). Major part of the VFC are derived from linoleic and linolenic acids. Linoleic, linolenic acids along with palmitic acid, which account for about 90% of total fatty acids released during black tea processing, produce VFC like C6 aldehydes and alcohols. The green fruity aroma is associated with higher content of Z-3-hexenol, its ester, Z-3- hexenal, E-2-hexenal, hexanal etc.

In general unsaturated fatty acids, linoleic and linolenic acids are degraded in presence of lipoxygenase enzyme (whose activity increases on dehydration of tea leaf during withering) to hydroperoxides which undergo subsequent cleavage by hydroperoxidelyase to C6 compounds (Selvendvan, 1978, Wright & Fishwick 1979). All the biochemical reactions are dependent on various physical parameters, optimization of which is necessary to regulate the composition of quality parameters of the end product (Tamuly et. al., 2005).

As soon as shoots are detached from the plant, some deep seated chemical changes occur, such as respiration with evolution of CO₂ and loss of moisture with reduction in dry matter (Sugars). Degradation of protein by protease results in increase in amino acids and some nitrogenous compounds. Moreover increase in caffeine and inorganic phosphate is also observed during storage of shoots. All these changes are collectively known as chemical withering. These changes involve biochemical reactions in presence of certain enzymes and their rate depends on temperature and on other process variables viz. duration of leaf storage and rate of moisture loss during storage. The extent of chemical wither or chemical changes associated with senescence of tea shoots is found to be time dependent (Ullah, M.R, 1984).
Restriction of moisture loss in initial period of withering could increase flavour index considerably. This is due to restriction in degradation of lipid to C6 aldehydes and alcohols (Tamuly et al., 2005).

Increase in floral aroma content is very essential for the improvement of flavour quality. Linalool, linalool oxides, geraniol, methylsalicylate etc. are obtained from hydrolysis of terpene glycosides by glycosidase and these VFCs are mainly responsible for floral aroma in made tea (Sakata et al., 2004). A high correlation between the essential VFC and dehydration condition during withering might exist.

Extent of fermentation with proper time, temperature and humidity has significant influence on formation of volatile components for aroma. It has been found that VFC are lower in non-fermented tea than that of the fermented tea. Linalool oxides are found in essential oil extracted from fermented tea but not in the homogenates of fresh leaf. Hexenols, linalool and its oxides, methylsalicylate and geraniol increase remarkably during fermentation (Yamanishi, T., 2004).

Some of amino acids glycine, alanine, valine, leucine, isoleucine and methione form the respective strecker aldehydes - formaldehyde, acetaldehyde, isobutylaldehyde, isovaleraldehyde, 2-methyl butanal and methional during fermentation (Yamanishi, T., 2004). Sugars react with amino acids to form certain flavour components (Devchoudhary & Bajaj, 1979). Carotenoids, the yellow pigment present in green leaf undergo oxidative and thermal degradation during withering, fermentation and drying and produce high flavoured quality tea (Trimanna & Wickremasinghe, 1965; Sanderson et al, 1971; Renold et al, 1974; Devchoudhary & Bajaj, 1980; Hazarika & Mahanta, 1983). Mahanta and Baruah (1989) indicated the development of terpenoid compounds during withering. Hydrolysis of terpene glycosides which enhances the formation
of linalool, linalool oxides, geraniol and methyl salicylate with sweet aroma of black tea, take place during withering (Mizutani et al. 2002; Sakata et al., 2004). Glycosides are known to be precursors of alcoholic aroma compounds of black tea. Primeverosides are 3-fold more abundant than glucosides in fresh leaves, but they decrease greatly during tea processing, especially during rolling. After the final stage of fermentation, primeverosides almost disappear whereas, glucosides remain almost unchanged. So primeverosides are the main aroma precursors and not the glucosides. This is also supported by the changes in glycosidase activities in tea leaves. Glycosidase activities remain at high level during withering and decrease drastically after rolling (Wang et al., 2001).

Fast fermenting clones have shown better results at low temperature, around 26°-28°C while slow fermenting clones have given optimum quality parameters at around 32°C (Tamuly 2005). So fermentability varies from cultivar to cultivar and dependent on temperature and moisture content of withered leaf.

Drying is the last stage of processing where a series of thermolabile reactions are triggered by hot air to shrink the size of leaf particles and to reduce the moisture content to around 3%. During drying some of VFC are lost but many nitrogen containing volatiles such as pyrazines, quinolines, thiazoles and aromatic amines are formed (Hazarika et al, 1984). These components are formed as a result of oxidative degradation of certain aroma precursors in presence of enzymes. α-ionone and β-ionone, two essential flavoury components, are formed as a result of pyrolytic and photo and/or autoxidative reactions of carotenes during drying (Kawashima and Yamanishi, 1973; Hazarika and Mahanta, 1983). Inlet temperature during drying has significant influence on formation of VFC. It was reported earlier that most of the volatile components with higher volatility and diffusivity are lost in early stage of drying which affect in total amount of aroma of aroma complex (Yamanishi et al., 1990).
4.2 Effect of wet bulb depression during withering on formation of volatile flavour components of black tea.

Effect of chemical wither on formation of volatile components in black tea was studied maintaining three hygrometric conditions viz. T₁, T₂ and T₃ with two Tocklai released clones, TV1 and TV26. The details about T₁, T₂, and T₃ are as follows:

T₁: Leaves were allowed to undergo wither for 5 hrs in 2° wet bulb depression (WBD).

Leaf moisture after initial 5 hr stress was 74.8% ±1

T₂: Leaves were allowed to undergo wither for 5 hrs in 1° wet bulb depression (WBD).

Leaf moisture after initial 5 hr stress was 76.3% ±1

T₃: Leaves were allowed to undergo wither for 5 hrs in 0° wet bulb depression (WBD).

Leaf moisture after initial 5 hr stress was 77.8% ±1
**Fig. 4.1**


NS: NOT SIGNIFICANT, * SIGNIFICANT AT 5%, ** SIGNIFICANT AT 1%, ***SIGNIFICANT AT 0.1%

**Fig. 4.2**

*F values for* 1. 1-Nonanol, 46.75***; 2. Phenylacetaldehyde, 1.04 NS 3. Terpineol, 0.10 NS; 4. Nerol, 2.69 NS; 5. Geraniol, 11.29***; 6. α - ionone, 0.80 NS; 7. Benzylalcohol, 6.12*, 8. 2-Phenylethanol, 3.91 NS; 9. β- ionone, 11.47**
Fig. 4.3 1. Hexanal, 2. 1-pentanol, 3. t-2-pentenal, 4. t-2-hexenal,
5. cis-3-hexene-1-ol, 6. Nonanal, 7. Linalool oxide-I,
8. Linalool oxide-II, 9. Linalool, 10. benzaldehyde

*F* values for 1. Hexanal, 42.22***; 2. 1- Pentanol, 7.36*; 3. trans 2-pentenal, 18.87***;
4. trans- 2- hexenal, 28.43***; 5.cis-3-hexenol, 12.17**; 6. Nonanal, 103.47***.
7 Linalool oxide-I, 2.05NS 8. Linalool oxide-II 53.06*** 9. Linalool, 11.44**;
10. Benzaldehyde, 21.10**

Fig.4.4 1. 1-Nonanol, 2. Phenylacetaldehyde, 3.Terpineol,
8. 2-Phenylethanol 9. β- ionone.

*F* values for 1.1-Nonanol=11.80**; 2. Phenylacetaldehyde=27.57***;3. Terpineol=23.14**;
8.2-Phenylethanol=22.39**;9. β- ionone=1.80 N.S

Figs.(4.1-4.4) Effect of different withering conditions on VFC profile of made tea
Results and discussions

VFC profile of the two clones are presented in Figs.(4.1-4.4). It is observed from the figures that amount of 1-pentanol, trans-2-pentenal, cis-3-hexene-1-ol, nonanal, linalooloxide–II, linalool, benzaldehyde are found to be less in T1 while the formation of hexanal, 1-pentanol, linalool, 1-nonenol, phenylacetaldehyde, terpeniol, geraniol, α-ionone, benzylalcohol, 2-phenylethanol and β-ionone are found to be higher in T3 for clone TV1(Fig.4.1-4.2). 1-Pentanol, trans-2-pentenal, cis-3-hexene-1-ol, nonanal and linalool were in lower amount in T1(Fig.4.3), whereas hexanal, trans-2-hexenal, linalool-oxide-I, benzaldehyde, 1-nonenol, terpineol, nerol, geraniol, α-ionone, benzylalcohol and β-ionone are found higher in T1 (Fig. 4.3-4.4) for clone TV26.

It is apparent from the Fig.4.5 that FI was maximum in T3 and T1 for clone TV1 and TV26 respectively. Trans-2-hexenal, with grassy note in tea flavour was found to be maximum in T1 (2° WBD) where as, linalool is found to be maximum in T3 treatment for both the clones (Fig.4.1 & 4.3). Linalool oxide- II is formed in the lowest quantity in T1 for clone TV1 and
in T₃ for clone TV26. Similarly formation of α-ionone, β-ionone, benzylalcohol etc. are varied in two clones. Formation of VFC depends on enzyme substrate interaction. Hydrolysis of glucosides to form linalool as well as other gr. II components are likely to be favoured in T₃ particularly in TV1 where loss of moisture from leaf is minimum during 5 hours of wither. In view of higher proportion of gr. II components FI in TV1 is higher in contrary to TV26 where group I components are higher (Fig. 4.5).

Some essential VFC like geraniol, linalool oxide-II, β-ionone etc. were found to be low in T₃ in TV26 causing lower value of FI. So it was apparent that initial moisture loss during withering appears critical for flavour of black tea.

Fig. 4a. Typical chromatogram of VFC of GC of black tea
4.3 Effect of duration of chemical and physical wither on volatile flavour components of black tea

This study was undertaken to investigate the effect of chemical and physical withering period on the level of volatile components of black tea. Leaves were stored for two different periods as against normal withering. Two clones TV19 and TV22 were taken for this experiment. The schematic diagram of the experiment is given in Figure 2.2 in Materials and Methods, chapter 2. The study has been undertaken to ascertain the period necessary to attain adequate chemical wither accompanied by senescence of tea shoots so that withering can be done more effectively and efficiently to enhance the quality of black tea. It was observed from the results that there was profound variation in VFC profile of black tea samples processed from varying degree of chemical and physical withering.
Fig. 4.6 1. Hexanal, 2. 1-Pentanol, 3. t-2-pentenal, 4. t-2-hexenal, 5. cis-3-hexen-1-ol


*NS*: NOT SIGNIFICANT, *SIGNIFICANT AT 5%, **SIGNIFICANT AT 1%, ***SIGNIFICANT AT 0.1%


Fig. 4.8 IHexanal, 2.1-Pentanol, 3.t-2-pentenal, 4.t-2-hexenal, 5.cis-3-hexen-1-ol, 6. Nonanal, 7.Linalool oxide-I, 8.Linalool oxide-II, 9.Linalool, 10.2-Phenylethanol


(Fig. 4.6-4.9) Effect of chemical and physical wither on VFC of black tea
In the first two treatments, two-stage withering was adopted, where for the first treatment leaves were initially stored for 4 hrs. and then allowed 8 ±1h. for physical wither (W1). For the second treatment, leaves were stored for 8hrs. initially and then allowed 4 ±1h. for physical wither (W2). These were compared against normal withering (W3).

![Fig. 4.10 Effect of chemical and physical wither on flavour index of Clone TV 19 & TV 22](image)

**Results and discussions**

Results presented in Fig. 4.6-4.9 showed that initial restriction of moisture loss improved group II VFC contributing to quality.

Although total amount of VFC was maximum in W3, overall quality of flavour was not up to the desired level due to higher amount of group I volatiles. On the other hand, leaves when stored for 8hrs. (W2) produce better flavour quality as reflected in the high flavour index (Fig. 4.10).
Flavour index is considered as an indicator of quality in tea. Due to optimum quantity in group II and group I VFC in W₂ flavour index was found to be maximum. Another important observation was made from this experiment was that, restriction of moisture loss of tea shoots for a longer period (W₂) prior to physical wither increases the amount of group II VFC, thus increasing over all quality of the aroma. On the contrary, group I volatile components are in the highest quantity when tea shoots were subjected to more stress. The flavour index need to be optimum to have positive impact on quality. It is to be noted that some of the components of VFC in small quantity may be critical for acceptability of flavour (Howard, 1978; Owuor et. al., 1986; Owuor et. al., 1989).

Formation of volatile components in relation to different withering methods is although cultivar specific, the trend of overall flavour quality with wither methods is more or less identical as shown in Fig. 4.10 for the clones TV19 and TV22. So restriction of moisture loss in the initial period of withering is an essential step to reduce group I VFC and helps in improvement of quality.

4.4 Effect of withering temperature on formation of volatile flavoury components.

Temperature during withering is a triggering factor to regulate the production of volatile components in tea. A study was undertaken to investigate the variation of volatile flavour components at three withering temperatures viz. 22°C, 30°C and 35°C with clones TV18 and TV23. These temperatures were chosen to ensure that there is pronounced variation to enable us to understand the effect of temperature. VFC profile of TV18 and TV23 are presented in Fig.4.11-4.14 and Fig.4.15-4.18 respectively.

TV18(CPW)

CPW: 6h chemical wither + 6h physical wither


PW: 12h physical wither

F values for the components of Fig. 4.11 & 4.12
Fig. 4.13 1. cis-3-hexen-1-ol, 2. Linalool oxide-I, 3. Linalool oxide-II, 4. Linalool, 5. 1-Nonanol, 6. Terpineol, 7. Nerol, 8. α-ionone, 9. 2-phenylethanol

F values for components of Fig. 4.13 & 4.14


F values for components of Fig. 4.15 & 4.16
Fig. 4.17 1. cis-3-hexen-1-ol, 2. Linalool oxide-I, 3. Linalool oxide-II, 4. Linalool, 5. 1-Nonanol, 6. Terpineol, 7. Nerol, 8. α-ionone, 9. 2-phenylethanol

F values for components of Fig. 4.17 & 4.18
1. cis-3-hexen-1-ol, 2.05NS; 2. Linalool oxide-I, 1.79NS; 3. Linalool oxide-II, 0.15NS; 4. Linalool, 3.21NS; 5.1-Nonanol, 6.88*; 6. Terpineol, 36.27***; 7. Nerol, 94.96***; 8. α-ionone, 14.80**; 9.2-phenylethanol, 5.14*

(Fig. 4.11-4.18) Effect of temperature during wither on formation of volatile flavour components
Fig. 4.19 Effect of temperature during withering on flavour index of Clone TV18

Fig. 4.20 Effect of temperature during withering on flavour index of Clone TV23
Results and discussions

It is observed that low temperature withering (22°C) favours formation of VFC as indicated by high flavour index (Fig. 4.19 & 4.20) irrespective of clones and withering methods. However, in case of clone TV18 exceptions are seen for linalool oxide II, terpineol, nerol, α-ionone and 2-phenylethanol components in CPW conditions whereas in case of TV23 exceptions were observed for cis-3-hexen-1-ol, linalool oxide-I, linalool oxide-II, linalool and phenylacetaldehyde. Similarly in case of PW condition for TV18, linalool oxide-I, α ionone and 2-phenylethanol are exceptions in contrast to TV23 where trans-2-pentenal, cis-3-hexen-1-ol, linalool oxide-II and 2-phenylethanol are found to be exceptions.

In this study two process variables namely initial restriction of moisture loss and low temperature during withering are found to be essential to produce black tea of better quality.

4.5 Effect of moisture content (%) in withered leaf on formation of volatile flavour components in black tea

One of the important areas during withering is to study the correlation between the formation of volatile components with the changes in moisture content of withered leaf. Accordingly, this experiment was designed to study the quantitative variation on composition of certain VFC in relation to different withering conditions.

Black tea samples processed from different withered samples were identified and quantified in gas liquid chromatography (GLC) by comparing their peaks with standards of Sigma Chemicals.
### Table 4a: Variation on the composition of volatile flavour components in relation to moisture content of withered leaf

<table>
<thead>
<tr>
<th>Name of volatile components</th>
<th>Moisture content in withered leaf</th>
<th>F Values &amp; level of significance</th>
<th>CD at 5%</th>
<th>CD at 1.0%</th>
<th>CD at 0.1%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>73%</td>
<td>70%</td>
<td>67%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hexanal</td>
<td>0.697</td>
<td>1.118</td>
<td>0.613</td>
<td></td>
<td></td>
</tr>
<tr>
<td>t-2-hexenal</td>
<td>4.212</td>
<td>4.661</td>
<td>3.682</td>
<td>13.82**</td>
<td>0.518</td>
</tr>
<tr>
<td>Cis-3-hexen-1-ol</td>
<td>0.857</td>
<td>2.182</td>
<td>2.263</td>
<td>5.27 NS</td>
<td>1.351</td>
</tr>
<tr>
<td>Linalool</td>
<td>5.224</td>
<td>7.356</td>
<td>6.942</td>
<td>12.54*</td>
<td>1.251</td>
</tr>
<tr>
<td>Terpineol</td>
<td>0.376</td>
<td>0.249</td>
<td>0.238</td>
<td>2.10 NS</td>
<td>0.212</td>
</tr>
<tr>
<td>Nerol</td>
<td>1.517</td>
<td>1.700</td>
<td>1.893</td>
<td>8.69*</td>
<td>0.249</td>
</tr>
<tr>
<td>α-ionone</td>
<td>0.840</td>
<td>0.665</td>
<td>0.369</td>
<td>23.08**</td>
<td>0.194</td>
</tr>
<tr>
<td>Geraniol</td>
<td>0.354</td>
<td>3.317</td>
<td>2.420</td>
<td>8.63*</td>
<td>2.051</td>
</tr>
<tr>
<td>2-phenylethanol</td>
<td>2.685</td>
<td>4.736</td>
<td>4.292</td>
<td>276.83***</td>
<td>0.254</td>
</tr>
<tr>
<td>β-ionone</td>
<td>4.637</td>
<td>4.309</td>
<td>4.589</td>
<td>40.52**</td>
<td>0.109</td>
</tr>
<tr>
<td>Flavour index</td>
<td>2.711</td>
<td>2.805</td>
<td>3.163</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Results and discussions

VFC in relation to moisture content of withered leaf is presented in Table 4a. It was observed from the data that total quantity of VFC as well as lipid degraded volatile such as hexanal, trans-2-hexenal etc. were found to be maximum in leaf with 70% moisture. On contrary flavour index was relatively lower in view of high lipid degraded products. Leaf containing high moisture content of 73% did not favour the formation of C6 aldehydes and alcohols which were found to be lowest among these three treatments.
Flavour index was found to be maximum in leaf with 67% moisture content. Low moisture content favours the formation of higher quantity of Gr.II VFC. Low content of hexanal, trans-2-hexenal and high content of β-ionone, nerol and 2-phenylethanol have favourable influence on the flavour index.

Lipid degradation although is high in leaf with low moisture, need not necessarily favour the accumulation of lipid degraded products. Low molecular weight lipid degraded products such as hexanal, trans-2-hexenal with high volatility are likely to be lost faster during drying compared to other Gr.II high molecular weight components. This contributes to favourable ratio of these two groups to contribute to high flavour index.

4.6 Effect of fermentation temperature on formation of volatile flavoury components.

Fermentation with proper temperature and humidity is essential prerequisite for optimization of quality components in black tea. It has been found that VFC are lower in non-fermented tea than that of fermented tea. Linalool oxides which are important components of aroma of black tea are found in the essential oil extracted from fermented tea but not in the homogenates of fresh leaves. Oxidation during fermentation stage needs to proceed at an optimum rate for formation of essential and characteristic components contributing to flavour of tea. Hazarika and Mahanta (1983) reported that rapid oxidation of polyphenols hamper in the formation of VFC in tea leaves.
So control of both time and temperature of fermentation is essential to ensure optimum production of flavour components. Higher TF content has been associated with the inhibition of hydrolytic enzymes responsible for the formation of linalool and its oxides along with methylsalicylate (Takeo and Mahanta, 1983a). It will be very helpful information if a correlation between the formation of volatile flavour components and temperature of fermentation in black tea processing can be achieved. Variation in temperature during fermentation might lead to change in composition of VFC in black tea.

This experiment was designed to study the variation in the formation of volatile components influenced by different temperature during fermentation. Accordingly volatile components in black tea processed from different fermentation temperature were identified and quantified in gas liquid chromatography by comparing with standards from Sigma Chemicals and presented in Fig. 4.21-4.22 for clone TV 1 and in Fig. 4.23-4.24 for clone TV-23.

Fig. 4.22 1. Phenylacetaldehyde, 2. α-ionone, 3. Benzylalcohol, 4. Terpineol, 5. 2-Phenylethanol, 6. Nerolidol, 7. Benzyl alcohol, 8. β-ionone, 9. Methylsalicylate

F values for the components of Fig. 4.21 & 4.22
TV 23


F values for the components of Fig. 4.23 & 4.24

(Fig. 4.21-4.24) Effect of fermentation temperature on formation of volatile flavour components
Results and discussions

It is observed that variation in temperature was accompanied by changes in composition of VFC which is well reflected in TV1 at 30°C with higher amount of major components except hexanal, methylsalicylate, linalool oxide-II, phenylacetaldehyde, a-ionone and 2-phenyl ethanol. In the contrary methylsalicylate at all four fermentation temperatures and linalool except at 30°C are found in higher amount in clone TV23. In case of TV23 majority of volatile components except cis-3-hexene-1-ol, methylsalicylate, 2-phenyl ethanol and nerolidol are formed in higher quantity at 34°C.
Lipid degraded volatile components viz. hexanal and cis-3-hexen-1-ol are formed in higher amount at all temperatures in TV1 than in TV23.

Overall quality is assessed from flavour index. The ratio of Group II to Group I volatile flavoury components can be used to classify tea qualitatively in respect of aroma (Owuor et al., 1986, 1987, 1989; Wickremasinghe et al., 1973). From Fig.4.25 it was observed that flavour index is found higher in TV1 at 22°C whereas in TV23 flavour index was high at 34°C. So production of various volatile aroma components at different fermentation temperature are found cultivar specific.

4.7 Effect of number of CTC cut on formation of volatile flavoury components during fermentation.

This set of experiments was undertaken to study the variation in formation of VFC due to number of CTC cut. It was already established that finer the size of particles higher is the production of non-volatile pigments due to maximum aeration.
Fig. 4.26 1. Hexanal, 2. t-2-hexenal, 3. cis-3-hexen-1-ol, 4. Linalool oxide-I, 5. Linalool oxide-II, 6. Linalool, 7. Phenylacetaldehyde

Fig. 4.27 1. 1-nonanol, 2. Terpinol, 3. Methylsalicylate, 4. Geraniol, 5. Benzylalcohol, 6. 2-phenylethanol, 7. β-ionone

(Fig. 4.26-4.27) Effect of number of CTC cut on VFC formation

Fig. 4.28 Effect of number of CTC cut on flavour index
It has been reported (Sakata et. al. 2004) that during withering tea leaves are alive and when subjected to desiccation (water stress), VFC are formed as a response of tea leaf against water stress. They also reported that for the formation of floral aroma finer particle size of leaf is not essential whereas, a slight injury to leaves before fermentation enhances floral aroma. In view of this, a study was initiated to investigate the variation in composition of VFC in black teas for different CTC cut.

Results and discussions

It was observed from the results presented in Fig. 4.26 and Fig. 4.27 that all the volatile flavour components except methylsalicylate were produced in higher quantity in three cut (C3) CTC tea compared to one cut (C1) and two cut (C2) CTC tea. The lipid degraded volatile flavour components were higher in three cut (C3) CTC resulting undesirable flavour index. On the other hand in two cut (C2) CTC Gr.II, components are higher to provide better influence on overall flavour quality (Fig. 4.28).

4.8 Influence of different inlet temperatures during drying on composition of volatile components

The influence of volatile flavoury constituents (VFC) although are present in low concentration, can be critical for adding value to the made tea. Effect of inlet temperature during drying on variation of volatile components was studied in this investigation. Results of inlet temperature on VFC formation are presented in Fig. 4.29 and Fig. 4.30 for clone TV1.
Fig. 4.29 1. 1-Pentanol, 2. t-2-hexenal, 3. Linalool oxide-II, 4. 1-Nonanol, 5. Phenylacetaldehyde, 6. Benzaldehyde, 7. Terpineol, 8. α-ionone, 9. 2-phenyl ethanol

Fig. 4.30 1. Hexanal, 2. Linalool oxide-I, 3. Linalool, 4. Methylsalicylate, 5. Geraniol, 6. Benzylalcohol, 7. β-ionone


Fig. 4. 29 & 4.30 Effect of inlet drying temperature on formation of VFC in TV-1
Fig. 4.31 1. Hexanal, 2. t-2-hexenal, 3. Linalool, 4. Phenylacetaldehyde, 5. Terpineol, 6. Geraniol, 7. α-ionone, 8. Benzylalcohol

Fig. 4.32 1. cis-3-hexen-1-ol, 2. Nonanal, 3. Linalool-oxide-I, 4. Linalool-oxide-II, 5. Methylsalicylate, 6. 2-phenylethanol, 7. β-ionone, 8. Nerolidol

F Values and Level of Significance for components of (Fig. 4. 31- 4.32): Hexanal 7.45**, t-2-hexenal 43.64***, cis-3-hexenol 4.28*, Nonanal, 5.71*, Linalool oxide-I 34.32***, Linalool oxide-II, 11.92**, Linalool 25.32***, Phenylacetaldehyde 7.33**, Terpineol 3.36N.S, Methylsalicylate 5.27*, Geraniol 5.90*, α-ionone 6.07*, Benzylalcohol 5.45* 2-Phenylalcohol 12.11**, β-ionone 8.48**, Nerolidol 11.10**

Fig. 4.31 & 4.32 Effect of inlet drying temperature on formation of VFC in TV-23
Results and discussions

It is observed that VFCs except linalool oxide II are higher in tea dried at 120°C. Essential volatiles such as linalool oxide I, geraniol, β-ionone etc. which are primary oxidation products of carotenoids (Yamanishi, 1981) are present in high amount at 120°C.

Linalool and its oxides with sweet floral aroma significantly influence overall nature of tea. Flavour index (FI), the ratio of group II to group I VFC (Sanderson et al., 1971; Owuor et al., 1987; Owuor, 1992; Sanderson et al., 1973) is the determining factor for overall aroma of black tea. Group II VFC, dominated by linalool oxides, linalool, benzaldehyde, phenylacetaldehyde, geraniol, β-ionone etc. are found to be maximum in tea dried at 120°C inlet temperature in clone TV1. In spite of having high
quantity of important group II VFCs, FI is not found to be optimum for good quality tea as group I components such as hexanal, 1-pentanol and t-2-hexenal also equally dominate the VFC complex (Fig. 4.33).

Results presented in Fig 4.31-4.32 indicate that unlike TV1, in TV23 volatile components are found to be higher in tea, which was dried at 110°C inlet temperature. Significant variance among four inlet temperatures in all the VFCs except terpineol is observed. In this clone also high amount of hexanal, 1-pentanol and trans-2-hexenal at 110°C showed low value of flavour index (Fig. 4.33). FI was found to be the highest at 140°C.

Variation in response of cultivars to different drying temperature can be attributed to genetic and environmental factors, which influence the precursors of VFCs. It is noteworthy that most of the aroma components with higher volatility and diffusivity are lost in early stage of drying resulting in reduction of total amount of aroma complex.

4.9 Influence of different drying time on VFC profile in black tea on clone T3E3

Effect of drying time on formation of volatile flavour components was studied in this part of investigation. Details of the experiment are given in the Fig. 2.8 of materials and methods, chapter 2.
Table 4b Influence of different drying time on formation of VFC

<table>
<thead>
<tr>
<th>Name of VFC</th>
<th>$T_F$</th>
<th>$T_N$</th>
<th>$T_S$</th>
<th>F values &amp; level of significance</th>
<th>CD at</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5%</td>
</tr>
<tr>
<td>Hexanal</td>
<td>0.843</td>
<td>0.369</td>
<td>0.486</td>
<td>37.80***</td>
<td>0.14</td>
</tr>
<tr>
<td>t-2-hexenal</td>
<td>9.762</td>
<td>7.716</td>
<td>6.746</td>
<td>6.46*</td>
<td>2.09</td>
</tr>
<tr>
<td>Cis-3-hexenol</td>
<td>0.306</td>
<td>0.216</td>
<td>0.071</td>
<td>24.39**</td>
<td>0.08</td>
</tr>
<tr>
<td>Linalool oxide-I</td>
<td>0.661</td>
<td>0.551</td>
<td>0.341</td>
<td>34.92***</td>
<td>0.10</td>
</tr>
<tr>
<td>Linalool oxide-II</td>
<td>2.307</td>
<td>1.558</td>
<td>1.147</td>
<td>5.46*</td>
<td>0.87</td>
</tr>
<tr>
<td>Linalool</td>
<td>4.175</td>
<td>2.875</td>
<td>2.147</td>
<td>9.23*</td>
<td>1.17</td>
</tr>
<tr>
<td>Phenylacetaldehyde</td>
<td>12.936</td>
<td>10.854</td>
<td>10.243</td>
<td>21.24**</td>
<td>1.06</td>
</tr>
<tr>
<td>Methylsalicylate</td>
<td>0.191</td>
<td>0.205</td>
<td>0.223</td>
<td>0.17N.S</td>
<td>0.14</td>
</tr>
<tr>
<td>Nerol</td>
<td>0.224</td>
<td>0.190</td>
<td>0.026</td>
<td>13.53**</td>
<td>0.10</td>
</tr>
<tr>
<td>Geraniol</td>
<td>6.007</td>
<td>4.476</td>
<td>4.014</td>
<td>7.27*</td>
<td>1.36</td>
</tr>
<tr>
<td>Benzylalcohol</td>
<td>4.221</td>
<td>3.310</td>
<td>3.018</td>
<td>2.33N.S</td>
<td>1.42</td>
</tr>
<tr>
<td>2-phenylethanol</td>
<td>0.355</td>
<td>0.317</td>
<td>0.227</td>
<td>2.17N.S</td>
<td>0.09</td>
</tr>
<tr>
<td>$\beta$-ionone</td>
<td>11.465</td>
<td>8.941</td>
<td>10.671</td>
<td>1.84N.S</td>
<td>3.29</td>
</tr>
<tr>
<td>Nerolidol</td>
<td>0.636</td>
<td>0.332</td>
<td>0.361</td>
<td>48.37***</td>
<td>0.08</td>
</tr>
</tbody>
</table>

$T_F$: 15 min., $T_N$: 20 min. and $T_S$: 25 min.

Fig.4.34 Effect of different drying time on flavour index
Results and discussions

Formation of VFCs at different drying time is presented in Table 4b. Results indicate that most of the VFCs are found to be maximum in 15 min drying time ($T_f$). Although most of the VFCs which are perceived as essential volatile components are formed in the highest amount at $T_f$, hexenal, trans-2-hexenal and cis-3-hexen-1-ol being in maximum amount at this drying time, decreases the F.I. On the contrary, methylsalicylate is found to be higher in 25 min drying time ($T_s$). Flavour index is found to be the highest in 25 min drying followed by 20 min and 15 min drying (Fig. 4.34). In the recent past several attempts had been made by the scientist to establish the relationship between process variables and quality parameters of made tea (Bhuyan et al., 1991; Ravichandran and Parthiban, 1998; Venkateswaran et al., 2002). Earlier studies on drying are limited. Although, enzymic action is arrested, inlet temperature and time of drying continue to be a critical issue for the manufacture of tea. This study will throw some light in the biochemical status at the drying and its possible influence on quality of made tea.

Quality of made tea is influenced to a great extent by drying conditions during processing which was reflected in present study. Furthermore variable response of drying was observed due to change in planting materials as shown in quality of black tea. Hence in commercial processing, where mixed planting materials are available, drying time and temperature have to be optimized to get desired quality of the end product.