Chapter III

Tea Manufacturing Process
3.1 Tea Production System

The study of manufacturing process of tea is of great significance as it deals with the basic building blocks of tea. In general, TQM point of view demands a generalized understanding of the product which includes the basic manufacturing process. Thus this part of the thesis discusses the processes involved in tea production.

The production system for made tea is similar to that of any other industry. That is, ‘Tea Manufacturing System’ comprises of an input, an output and a process. Fig 3.1 shows the tea production system.

![Fig 3.1: Production System of a Tea Industry](image)

The inputs are in the form of green tea leaves plucked from the garden. These leaves are carried to the factory for further processing. Process is the tea manufacturing process which takes place inside the factory. The plucked tea leaves, which is the raw material in the factory, undergo various processes. The output is the final made tea.

3.2 Classification of Tea

Based on different types of processing techniques, tea can be classified into four broad types (Banerjee B; 1993):

- Green Tea or Unfermented Tea
- Oolong Tea or Semi fermented Tea
- Instant Tea
- Black Tea or Fermented Tea
3.2.1 Green Tea

A brew made from green tea is similar to the one prepared from dried tea leaves in taste and composition. In the manufacture of Green tea, three principal operations are involved – pan firing or steaming, rolling and drying. The objective is to destroy the enzymes in the tea leaf as soon as it is plucked, thus preventing fermentation all together.

3.2.2 Oolong Tea

It is an intermediate type of made tea between green and black tea. While the latching process is the same as that of green, Oolongs are allowed to ferment while green are not. On the other hand, the fermentation is only partial and not optimum as in black tea. The oolong tea has the colours and appearances of black tea but it has flavour and taste of green tea.

The green leaf in case of Oolong manufacture, is slightly withered before panning, thereby allowing a light fermentation to develop.

3.2.3 Instant Tea

It is a ready-to-drink beverage just like instant coffee. The basic objective in the manufacture of instant tea is to extract the water soluble solids from a pure tea brew, and convert them into a powdery form. The brew can be prepared from black tea, or from partly processed green leaves. This method has been patented by Tocklai Tea Experimental Station, Jorhat (Assam).

3.2.4 Black Tea

The basic objective of black tea making is to condition green leaf for fermentation, and when that has been achieved, arrest the fermenting process through application of heat. Thus heat is to be applied at a much later stage than that of green tea manufacture. The basic operations involved in black tea manufacturing are: Withering, Rolling (plus crushing, tearing and curling in case of C.T.C.), Fermenting, Firing, Sorting and Grading, Storage and Packing.

Due to heavy demand of black tea, most of the tea estates are concentrating their production on black tea only. Black tea can be further subdivided into:

1. Orthodox Tea
2. CTC Tea
All the big tea estates of Assam have facilities for production of both the Orthodox and CTC tea. But now a days, as the demand for Orthodox tea is poor whereas its production cost comparatively higher, hence tea estates focus on CTC tea manufacturing.

3.3 Processes Prior to Manufacturing

Tea leaves are first plucked from the gardens which are normally spread over hundreds of acres of land and then transported to the factory. In the factory, it goes through various stages of processing to get made tea.

3.3.1 Plucking

Plucking is the process of collecting tea leaves from the bushes. The plucked leaves are transported to the factory for processing. Two standards of plucking are normally followed in tea gardens: fine and coarse plucking. Plucking fresh leaves with two leaves and a bud is termed as fine plucking. This type of plucking results in best quality of tea after processing. So, in most of the tea gardens, fine plucking is adopted when quality tea is to be produced. But when demand for tea in market increases, gardens can not meet the demand by adopting fine plucking only. In such a case, plucking is carried out irrespective of freshness and age of leaf. This type of plucking is termed as coarse plucking.

In the tea gardens of Assam Pluckers pluck the tea leaves and put it on a basket made of bamboo. The pluckers carry the baskets on their shoulders. The plucked leaves, when the basket is full, are kept on leaf carriers. The leaves are then carried to the factory for processing.

3.3.2 Pruning

Quantity and quality of crop in a tea estate depend largely on pruning practices. Pruning is the process of removal of the top congestion of the bushes by the removal of dead, diseased and unproductive branches at certain interval. This interval is known as
pruning interval. Pruning also arrests unproductive growth and stimulates vegetative growth. In tea gardens of Assam, three to four year interval is followed.

Thus, the main objectives of pruning are (Chakravatee et al., 1994):

1. To check reproductive growth and provide stimulus for vegetative growth, especially for the production of young shoots that constitute the crop.
2. To remove the dead or unproductive wood and renew the actively growing branches which can support sufficient volume of maintenance foliage on it.

Pruning is usually done after every three to four years at 3 - 4 cm above the previous pruning mark: it is generally described as Light Prune (L. P.). But when the bush frame grows more and plucking becomes difficult, it is brought down to optimum height by Medium Prune (M. P.) at 50 - 70 cm above the ground.

3.4 Manufacturing Process

Once the tea leaves are plucked from the garden and transported to the factory, it goes through various stages in factory. All the processes involved in the tea processing play an important role in building the quality of tea. Careful and proper processing normally bring out the full potential of the green leaf. The processes involved in the manufacturing of tea are (The Planter's Handbook, TRA):-

1. Withering
2. C.T.C./Orthodox Process
3. Fermentation
4. Drying
5. Sorting & Packaging

Fig 3.2 shows the steps of tea manufacturing process.
3.4.1. Withering

Withering is the first process carried out within the factory on the plucked tea leaves. The fresh plucked leaves after sorting are placed on the withering troughs and air is allowed to pass over the leaves. The air fans which are used in this process are called ‘withering fans’. The process of wither aims at partial removal of moisture from the fresh leaf. It is carried out in order to condition the leaf physically for subsequent processing. Besides, some chemical changes also take place during withering and these are independent of the physical process. The process of withering involves:-

1. Physical Wither    2. Chemical Wither
3.4.1.1 Physical Wither

During physical wither the leaf loses its moisture and hence turgidity which makes the leaves flaccid or rubbery, a most desirable condition to help in its rolling and for obtaining the desired style and appearance. The extent to which the wither is to be carried out will depend upon the method of manufacture. Under the North East Indian conditions the norms usually adopted are given in Table 3.1 (The Planter’s Handbook, TRA):

![Photograph 3 Withering Troughs](image)

<table>
<thead>
<tr>
<th>Method of Manufacture</th>
<th>Wither (% - Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTC</td>
<td>70-72</td>
</tr>
<tr>
<td>Orthodox</td>
<td>65-68</td>
</tr>
<tr>
<td>Dual</td>
<td>67-69</td>
</tr>
</tbody>
</table>

[\% wither = The weight of 100 Kg of fresh leaf at the end of the withering process]

3.4.1.2 Chemical Wither

Chemical wither starts immediately after leaf is detached from the plant. It is independent of the rate of loss of moisture and is the function of time and temperature. Following chemical changes occur within the leaf cells (Khanna, A.I.N. 1999 & Gogoi, M.N., 1999):

1. Breakdown of larger molecules to smaller ones that results in the increase of contents of amino acids and flavor compound
2. Increase in caffeine which is responsible for the stimulant effect of tea.
3. Increase in permeability of cell membranes which has a great effect on the mixing of polyphenols, enzymes and oxygen for even fermentation.
3.4.2 Green Leaf Processing

Green leaf processing is that step in the process of tea manufacture where the withered leaf is subjected to some kind of mechanical operation whereby the leaf cells are ruptured to give the desired style and appearance to the made tea. During this operation the leaf undergoes the process of size reduction with a degree of cell disruption to allow the exposure of new surfaces to air during the fermentation process. Fig 3.3 shows the processes involved in black tea manufacturing (both Orthodox and CTC).

3.4.2.1 Orthodox Manufacture

In the conventional orthodox process, the leaf distortion is achieved by rolling, during which the withered leaf is subjected to the motions of conventional rolling machine. The purpose of rolling is to primarily break up the leaf cells and to mix up the chemical components of the leaves with the enzymes. In orthodox method of manufacture, these chemical constituents are ‘wrung’ out by subjecting the leaves to twisting or ‘rolling’ that imparts the leaf a twisted appearance and a special character to the liquor of made tea.

The simultaneous twisting and rupturing of the leaf cells allow the chemical contents of the leaf to be mixed up in presence of air (i.e. oxygen). This starts off the chemical changes necessary for production of black tea characteristics through the fermentation process. During rolling, tender leaf parts are torn off, leaves are detached, stalks are broken up into smaller parts, and the leaf juice is forced to come over the surface of the broken leaf particles. The expression of juice is dependent on the physical condition of the leaf after wither during which the cell membranes become more permeable. The thorough mixing of the catechins present in leaf and the enzyme under exposure to oxygen facilitate initiation of the fermentation process.
Figure 3.3
Processes Involved in Black Tea Manufacturing
The twisted appearance in the leaf during the rolling process can be imparted with a lighter roll in a rolling table with very little breaking up of the leaf into pieces. Hard rolling on the other hand breaks the leaf into small pieces with little rolled appearance in the product. For the sake of efficiency of brewing, the orthodox tea traded all over the world comprises of small leaf particles with leaf juice dried on its surface. The requirement of the rolling machine as well as the process is, therefore, a compromise between the twisted appearance and liquor.

The number of rolls and the period of rolling are dependent on the following factors (Tankariwala N.F, 1999):

1. Type of leaf.
2. Degree of wither.
3. Roller charge and speed
4. Pressure.
5. Temperature.
6. Type of tea required.

Generally a roll of 20-30 minutes is given in the orthodox roller without or with light pressure, and the leaf is then passed through a shifter to extract fines. The length of rolling varies from factory to factory, but it should not be shorter than 15 minutes to avoid formation of flaky leaf appearance. The question whether two or three passes (Refer Fig: 3.3) are necessary is usually decided by the plucking standard and the withering facilities prevailing in a particular factory. With fine plucking two passes through Rollers are known to have yielded desired results, but with coarse plucking third cut may be necessary.
3.4.2.2 C.T.C. Manufacture

The CTC (crushing, tearing and curling) manufacture is the contribution from Sir William Mckercher, an ex-Superintendent of Amgoorie T.E., Assam (Griffits P., 1977). He invented the CTC machine in 1930. The CTC machine consists of two stainless steel engraved rollers with circumferential helical grooves. They are meshed closely and made to rotate in opposite directions at a speed differential of 1:10. The rolled leaves are allowed to pass through the zone between the two rollers. The teeth of the rollers perform the crushing tearing and cutting operations simultaneously. The following three parts of a tooth are responsible for the CTC process.

The ‘Tooth Body’ or shoulder length is responsible for crushing. The ‘Milling Groove’ which creates the flanks of the teeth helps in curling of the leaf. The ‘Sharp Edges’ of the teeth are responsible for cutting and tearing of the leaf.

Processing of leaf in a CTC machine requires that the leaf be rolled or conditioned prior to feeding in the CTC machine. Therefore, the rolling table has to be used which is to be synchronized to be able to feed the CTC machine continuously. Meanwhile, Rotorvane, invented at Tocklai initially as continuous roller, proved to be an ideal machine for rolling/conditioning the leaf for CTC manufacture. The throughput through a 15inch rotovane varies between 550-1600 kg of processed leaf per hour. Its speed varies from 15 to 45 rpm. The throughput is 37 kg of processed leaf per hour. Thus with good plucking standard the capacity of a 15 inch rotovane matches with that of a 36 inch CTC machine.
3.4.2.3 Dual Manufacture

Though CTC machine was developed in 1930, it did not catch on for next two decades because the early users failed to produce quality CTC tea as they did not shorten the time for fermentation. (Dutta. A.K., 1992). Thus the CTC manufacturing method commercially started in the fifties. After just ten years of time, more than two-thirds of the Teas manufactured were CTC tea. It was however; observed that from time to time there has been a greater demand for Orthodox tea. This led to the development of a new concept of tea manufacture popularly known as dual manufacture. The attractive benefit derived from this process in that: the fines, containing much of the valued tips are extracted from the normally rolled leaf and subsequently fermented and fired conventionally, while the coarse leaf is put through a CTC machine. This method of manufacture has been carried out by the industry with mixed leaf i.e. clones and jats as well as from only seed jats. However, some estates adopt the method of dual manufacture at a particular season depending upon the market demand.

3.4.3 Fermentation

Fermentation of tea is the most significant step in tea manufacturing since in this step the most important properties of tea i.e. liquor characteristic develops. The term 'fermentation' is rather historical and does not accurately describe the process that occurs during the manufacture of black tea. This process involves enzymic oxidation/degradation of polyphenols, lipids, carotenoids and tarpene-glycosides, and their subsequent condensation/degradation leading to formation of coloured polymers and aroma and flavor compounds. (Goswami et al., 1999)

Fermentation of leaf begins with its rolling to bring about the necessary changes to make tea liquor palatable. The complex changes occurring during fermentation, in which the polyphenols are oxidized and other associated chemicals also undergo some changes, make the liquor develop mellow character. Under optimum condition of fermentation, the liquor becomes bright and brisk with adequate colour and strength. These attributes of quality develop only up to a certain stage of fermentation beyond which the quality begins to decline.
3.4.3.1 Development of Color and Quality During Fermentation

Various liquoring qualities of tea are mainly derived from the same group of chemical compounds. Therefore, the excessive production of one property will naturally take place at the expense of another. Briskness, quality, strength and colour change with time and temperature during fermentation and each character is at its best at different times (Goswami et al., 1999). In under-fermented tea the leaf yields poor liquor and hence less quality, but well fermented leaf will give good colour. Over-fermented leaf may produce coloury liquor, no briskness and very poor quality. Only optimum fermentation ensures strength, brightness, briskness and quality of the liquor.

3.4.3.2 Fermentation System

The common fermentation systems practised in tea manufacture are described below:

3.4.3.2a Floor fermentation

Fermentation on cement floor is the oldest and most popular method. Leaf is spread over cement floor of racks at 2.5-3.75 cm thickness for orthodox and 1.25 cm in case of CTC tea. The floor should not be wet when the leaf is being spread and there should never be any stale juice deposits. This will help to keep the bacteria away. Washing of the floor daily with a suitable detergent is absolutely necessary. Floors with glazed marble tiles are also used but care should be taken that the joints between tiles do not become the source of bacterial contamination. Aluminum and plastics trays are sometimes used for fermentation. Leaf spread over the trays should be sprayed thin so that proper aeration can take place. Only plain aluminum or plastic sheets should be used to avoid bacterial contamination.

3.4.3.2b Trough fermentation

In trough fermentation, troughs made of aluminum are placed on saddle to facilitate uniform distribution of air. Rubber or fads lining are used as pads on the
fermenting units to prevent air leakage. Two types of *gumlas* (shallow large container without lid) are used, one with valves and the other with four holes at the bottom. The air pressure should be maintained at 2 inch water gauge. Fermenting containers do not work well with the under withered leaf.

Through fermentation is more controllable because the quantity of air flow and the pressure can be adjusted. It also cuts down the total surface area required. A 15 cm deep container can hold up to 16 kg of pressed leaves when filled to the top. However, the containers are not filled to the top level so as to facilitate turning of leaves as and when required.

In through fermentation the temperature encountered is high but experimental results have shown that even at temperature up to 43° C is not harmful to quality if adequate amount of humidified air is used to pass through the leaf bed and the fermentation time is cut down.

### 3.4.4 Drying

Drying is the final stage of manufacturing of tea. During drying the moisture is removed from the fermented leaf particles in a suitable chamber by vaporization of water in a stream of hot air as the carrier fluid. Drying is a simultaneous heat and mass transfer process—gain in temperature or heat, loss in moisture or mass. Air in warmed up condition and in adequate quantity is the most convenient medium for heat and mass transfer during tea drying.

The objective of drying of tea is two fold.

1. To arrest the fermentation and to fix the desirable properties.
2. To remove the moisture from the leaf particles and to obtain a finished product that is stable which can be handled and transported.

### 3.4.4.1 Technology of Tea Drying

When a particle is surrounded by moisture molecules in its surface, the removal of these moisture is relatively easy and such evaporation rate is independent of the properties of the particles. This rate of evaporation is governed by the mass flow rate and drying potential of air only. In the drying process this stage is known as 'Constant Rate
Period of drying. (Chaliha, R², 1984)

With the removal of freely available water from the surface of the solid particle, a stage is reached where some portions of the particles surface would be devoid of any moisture molecules and the balance would still have some. The rate of drying of such particles will continuously decrease and drying will become increasingly more difficult. Once the surface drying is complete, diffusion processes control the drying rates. Those moisture molecules entrapped inside the particles have to come out to the surface either in liquid or in vapour form before leaving the tea granule. As the moisture level of the particles decreases, the concentration gradient decreases too reducing the rate of drying. This stage of drying is known as the 'Falling Rate Period' of drying. The critical moisture content at which the rate of drying slows down depends on the size and shape of the solid particles and their texture.

Early types of dryers were simple batch types, in which the leaf was spread on a perforated mesh or tray and heated air blown through until the tea was dried. A semi-continuous system employing a series of trays mounted horizontally on a vertical stack was constructed. Sequential mechanical tripping was employed to drop the contents of each tray at selected intervals onto the tray immediately below. Hot air was fed from below and the dried tea eventually emerged at the lowest point. These dryers known as Venetian dryers are not in use now-a-days.

The modern machine consists of two or three endless chains where perforated trays are mounted. In the present design the drier is situated on the pressure side of the fan, but in the earlier versions the fans sucked air through the drier. Fermented leaf is dropped on the top tray of the drier by a conveyer. The leaf particles falling on the perforated tray are taken through the drier by the moving trap. At the end of each tray level the leaf is dropped to the tray immediately below. Hot air is sent from the bottom of the drier and is made to flow up through the perforations. The arrangement ensures progressively higher
temperature during the course of drying and the air is made to come in contact with the increasingly moist leaf particles.

A tea drier consists of the dryer unit, the air heater and the fan. The hot air is provided by a furnace to which are connected the heat exchangers. An induced drought is maintained by the fan. The fermented tea particles, when ready for drying, are regularly fed into a hopper with automatic spreader. Thickness of spread, speed of trays and the volume of air flow through the trays are regulated as desired. As is clear from the design at each stage of drying, the leaf is subjected to a different temperature. The exhaust temperature should be such that the fermentation process is brought to a stop immediately after the leaf has entered to the top tray of the dryer. However, in actual practice the fermentation, which is enzymic in nature, continues for some time in the dryer.

3.4.5 Sorting & Packaging
After the tea has been dried, its separation into grades is necessary in order to produce tea which will be acceptable to buyers and blenders. Separation of tea particles according to various shapes and sizes conforming to trade requirement involves many operations. Machine sorting alone is not enough. Hand sieves have to be used. The whole procedure is long and laborious when a large number of grades are made. This, on account of variations of leaves and methods of manufacture, varies considerably in different factories.

It is one process in manufacture for which no hard and fast rules are laid down. Careful judgment is required to decide whether or not a grade is true to the type and whether it is sufficiently uniform and free from fiber, stalk, etc. Such consideration necessitates a considerable amount of skill, care, and attention. A sorting procedure, that may suit one factory, may therefore prove unsuccessful in another. Tea is sorted for quality and size. There are four main sizes viz. Whole Leaf Grades, Brokens, Fannings
and Dusts. Each of these has their sub-grades.

For various reasons, often it is not desirable to divide the tea into the greatest possible number of grades. The percentage of leaf suitable for the production of some of the grades is small and it may take too long to collect sufficient quantity of these to make a large invoice to attract attention in the market. Tea grading percentage must of course vary according to plucking standards and the market demand. The different marketable grades of tea are given in Table 3.2.

3.4.5.1 Sorting of Orthodox Tea

The dried tea is initially passed through a Myddelton Stalk Extractor. The Myddeltons are fitted with trays. The top and bottom trays of Myddelton are so adjusted that only broken grades are removed. These feed directly into the sorter conveniently sited near the Myddelton. The bottom tray of the Myddelton contains mainly whole leaf grades and these feed into wire mesh having no. 12, 10, 8 and 6 meshes. The spill goes to the breaker cum stalk separator machine. From the breaker the mass go to a Myddelton. From the top tray of Myddelton the mass will go to a pucca sorter and the broken grades are obtained. From the bottom tray of Myddelton the smaller grades will be obtained through another pucca sorter.

3.4.5.2 Sorting of C.T.C. Tea

The CTC bulk mass is passed through a fiber extractor and a presorter. From the presorter the larger leaf goes to a sorting machine from where the broken grades are obtained. Medium sized particles go to another sorting machine to give fannings. Likewise the smaller particles go to a third sorting machine from where dust grades will be obtained. Fig 3.4 shows the process.
<table>
<thead>
<tr>
<th>Kind of Tea</th>
<th>Grade Name</th>
<th>Nomenclature</th>
<th>Kind of Tea</th>
<th>Grade Name</th>
<th>Nomenclature</th>
<th>Kind of Tea</th>
<th>Grade Name</th>
<th>Nomenclature</th>
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<tbody>
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<td>Orthodox Tea</td>
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<td>C.T.C. Tea</td>
<td></td>
<td></td>
<td>Green Tea</td>
<td></td>
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<tr>
<td>Whole leaf</td>
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<td>BOP</td>
<td>Broken orange pekoe</td>
<td></td>
<td>Whole leaf</td>
<td>YH</td>
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<td>Fannings</td>
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</tbody>
</table>

Table 3.2
Different Grades of Tea

Chapter III: Tea Manufacturing Process
Table 3.3 shows the sizes of the sorting trays.

<table>
<thead>
<tr>
<th>THOROUGH TOP TRAY</th>
<th>THROUGH BOTTOM TRAY</th>
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<tr>
<td>Through No.10 mesh over 12-BOP</td>
<td>Through No. 22 mesh over 24-FOF/GOF</td>
</tr>
<tr>
<td>Through No. 12 mesh over 14-BP</td>
<td>Through No. 24 mesh over 26-PF</td>
</tr>
<tr>
<td>Through No. 14 mesh over 16-FBOP</td>
<td>Through No. 28 mesh over 30-OPD</td>
</tr>
<tr>
<td>Through No. 16 mesh over 18-GBOP</td>
<td>Through No. 30 mesh over 40-OD</td>
</tr>
<tr>
<td>Through No. 18 mesh over 20-GFBOP</td>
<td>Through No. 40 mesh over 60-OCD</td>
</tr>
</tbody>
</table>

3.4.5.3 Packaging

After the tea has been sorted into respective grades, it is necessary to pack these in suitable packages/sacks so that the quality of made tea does not deteriorate in transit. Tea is packed by packing machines having magnetic attachment to prevent possible pieces of iron metal fillings from mixing with tea. Efforts are made to prevent tea from absorbing moisture. Tea chests used for packing tea are moisture-proof.

In most of the tea gardens in Assam, the present mode of packing is not absolutely air-tight and as a result tea absorbs more than 3% moisture by the time it reaches market. It has been found that plywood tea chests with lining of alumina and tissue paper, metalized polyester or cellophane are suitable for packing tea. (Das, A.K., 1999)