2 Withering Process

2.1 Introduction

Tea is a popular beverage around the world [3, 25] due to its distinctive taste, aroma and variety. Tea varieties are achieved by processing green tea leaves in different ways where various biochemical reactions contribute to the formation of their unique characteristics. Biochemical changes in tea leaves begin just after plucking. Withering is the first stage of tea manufacturing process after plucking tea leaves for fermented and semi-fermented tea. Proper withering determines the quality of end product. In this chapter the withering process and its different aspects are discussed.
2.2 Withering Process

The withering process has two main aspects -

1. Chemical withering and
2. Physical withering.

In chemical withering, different biochemical reactions occur in tea leaves. These biochemical reactions contribute to the quality attributes of tea. The removal of moisture from the fresh tea leaves is referred as physical withering [1, 5].

2.2.1 Chemical Withering

Chemical withering in tea leaves start immediately after plucking. Since quality contributing biochemical reactions starts just after plucking, care should be taken so that biochemical pathway is not disturbed. Improper leaf handling leads to loss of important water soluble compounds that contributes to quality of tea. Because of improper leaf handling, 25% of the market value of tea may be lost before the arrival of the leaves to the factory [24]. Chemical withering is independent of moisture loss rate but dependent on temperature and time. Sufficient supply of air is necessary for breakdown of large organic molecules present in fresh tea leaves to simpler structures. Several biochemical changes occur during withering:

1. Due to fragmentation of larger molecules carbon dioxide and water are released.
2. Partial fragmentation of proteins to amino acids occurs, which act as precursors for aroma.
2.2 Withering Process

3. Enzyme activity changes.

4. Caffeine content, that contributes towards briskness, increases.

5. Volatile flavour components (VFC) are produced. Some of the VFCs contribute to the grassy odour and some others are responsible for the flowery aroma.

6. Chlorophyll content reduces.

The above mentioned biochemical changes are intrinsic to the biochemical structure of the leaf, although the range and the extent of the reactions are dependent on the breed, commonly known as jat, cultural practices and physical parameters such as temperature, humidity etc.

The biochemical changes also present to the very important quality features of tea like the ‘body’ and the ‘flavour’. Generally, in a period of around 12-16 hours chemical withering is completed. [5].

2.2.2 Physical Withering

In physical withering, the moisture content from the plucked tea leaf is reduced. Physical withering is generally carried out by passing air through the leaves. It also makes the leaves flaccid, which is necessary for convenient operation in the next stage of tea manufacturing.

Reduction of moisture or the flaccidity of leaf can be achieved in a shorter period of time, but chemical withering requires a longer period; therefore physical withering is done in a slower rate so as to get the desired level of moisture in tea leaves at the same duration of as required for chemical withering.
Level of withering is expressed in percentage. Percentage of wither is defined as the weight in Kg to which 100 Kg of leaf is reduced at the end of the withering irrespective of the initial moisture content of the leaf. In this method moisture content of the withered leaf varies depending on the initial moisture content of the leaf although the leaf has been subjected to the same percentage of wither. Therefore, in different periods of the season, tea leaves are withered to different percentage.

In withering, the moisture removal process is accomplished by vaporizing the water contained in the tea leaves by supplying latent heat of vaporization. There are two important process-controlling factors -

1. Transfer of heat to provide the necessary latent heat of vaporization,

2. Movement of water or water vapours through the tea leaves to separate the moisture.

The necessary latent heat of evaporation is achieved from the inlet temperature of the incoming air. The moving air carries evaporated water vapour towards the outlet of withering trough.

Moisture release from the leaves starts from the surface and later on is governed by diffusion or capillary movement [17]. Withering is a complex process, in which the release of moisture from the leaf is governed by many factors involving complicated mechanisms. Effects of RH, temperature and air speed are remarkable compared to other factors.
2.3 Withering Equipment

Withering is a natural process and the goal can be achieved without using any special equipment. But natural withering takes a longer period of time and it is not suitable for production in commercial purpose. Also, due to daily as well as seasonal weather variation it becomes necessary to use some special equipments for withering. Withering systems that have been used are Tat withering, Tunnel withering, Drum withering and Trough withering. Trough withering is the most commonly used system all over the world. The advantages of a trough withering system are:

1. Economy,

2. Higher flexibility with respect to degree of wither and capacity,

3. Constructional flexibility,

4. Easy scalability,

5. Ease of operation and maintenance and


Withering trough is a rectangular duct with one opening for air inlet and another opening for air outlet or the leaf bed itself acts as an outlet or exhaust. Air is blown into the trough by an axial flow fan through the tea leaves. The moving air carries away the moisture released from the leaves. The most widely used troughs in the factories are:

1. Open trough and
2.3 Withering Equipment

2. Enclosed trough.

2.3.1 Open Trough

In the open type of trough, leaves are spread at a given thickness and air is allowed to flow upwards from the bottom of the perforated leaf bed. This results in the withering of the bottom layer of the leaf first. Therefore, fans need to be periodically reversed to ensure that the leaf in the upper layer also get withered since air is drawn into the leaf bed. In case of open troughs, fan motor is provided with facility for reversing the direction of rotation by means of a switch. However, during the reverse rotation or the suction mode of fan operation, the efficiency of fan is drastically reduced to about 60 %, thus, consuming more power with respect to the work done as compared to that of the forward or blowing mode of operation. Moreover, in the reverse mode, it is not possible to draw hot air through the leaf bed. The dual direction of movement of air is, however, expected to furnish more uniform wither, but very often sandwich effect results, whereby, leaf at the middle layer does not get the desired wither. It is, therefore, necessary at some time to turn the leaf or shuffle to achieve more uniform wither. To ensure hygiene, one has to ensure cleanliness of hand or use clean gloves for turning the leaf.

2.3.2 Enclosed Trough

In the enclosed type troughs the leaf bed is kept in an enclosed environment where the the sides of the withering troughs are raised and a cover on top of the bed is used. This is
designed to create a plenum chamber on top of the leaf bed as well. In an enclosed type trough, the fan is always directed to blow air only in the forward direction and air can be made to blow either from top to the bottom or from bottom to the top with damper and shutter control at the air entry and exit points respectively without reversing the direction of the fan. Since handling of leaf is less, the chance of leaf damage in enclosed trough is much lower. The leaf also gets some isolation from the sudden variations in ambient atmospheric conditions. It is, however, more convenient to load and unload leaf in the open troughs and it is easier to check the progress of wither. Therefore, open troughs are still popular in the industry. In some models of the enclosed trough, air is continuously drawn in instead of being blown with same effects on the leaf. In this configuration, heating of air is to be done at the front end of trough and not at the fan end.

A two-stage wither is related to a chemical wither where the leaves are stored followed by a physical wither. The depth of the leaf may be greater than that of the trough wither. The term tank-withering is used in this case [24].

### 2.4 Withering Fans

Fan is one of the most important components of withering trough. For the purpose of withering axial flow fans are used. The direction of airflow in axial fans is essentially parallel to the axis of the impeller. These fans operate at a static pressure of 12 mm (½ in) water gauge and can handle large volumes of air. One advantage of axial flow fans is that their direction of rotation can be reversed to make the air flow in the reverse direction. But with
reversal, capacity of the fans reduces nearly to half. Even if the blades are specially designed
to give same air flow in both directions the power required will be 40-60 % higher than the
power required for normal blades [1].

2.5 Leaf Loading and Thickness of Spread

The spread of leaves actually act as a valve and create the necessary system resistance for the
airflow helping to even out the static pressure in the plenum chamber.

Leaf is generally spread uniformly on the trough at the rate of 23 Kg m$^{-2}$ for CTC or
13-16 Kg m$^{-2}$ for orthodox tea manufacture in the plains and 8-10 Kg m$^{-2}$ for orthodox tea
manufactured in the hills [1].

2.6 Period of Wither

The period of wither is ascertained by taking both physical and chemical wither; physical
wither can be achieved in 3-4 hours but chemical wither requires 12-16 hours. In case the
leaf is under withered, the following problems are envisaged:

1. Rolling of unwithered leaf leads to break up into small flakes, which would not respond
to the subsequent processing steps.

2. Greater flexibility with respect to capacity and degree of wither,
3. If the leaf were under-withered valuable water-soluble solids would be lost during the leaf conditioning process.

4. Under-withered leaf when rolled turns into a wet watersogged mass; the sogginess restricts supply of oxygen and hinders uniformity in the subsequent oxidation reaction (fermentation).

5. Maceration of under withered leaf also leads to formation of lumps during fermentation.

6. At temperature more than 25 ºC with under-withered leaf, chances of bacterial contamination increase.

7. Proper physical wither reduces load on the dryers.

Duration of withering plays a very important role in withering. A longer duration of withering produces better quality than that of a shorter wither [26].

2.7 Heating of Air for Withering

The following methods are employed for heating of air for withering:

1. Individual gas burners for each trough, where gas is available.

2. Hot air ducting to each trough from a separate heater.

3. Direct use of hot air from the drier when it is empty.

4. Using exhaust air from drier.
The last two methods are used extensively in Darjeeling, for which bulking chambers are used. But the fourth method may give humid hot air. The first method is used only where natural gas is available. The second method is used almost everywhere. As a thumb rule, hot air is mixed at the rate of 1/10th of the volume of ambient air.

For heating of natural air either a diesel fuel oil heater or a conventional coal heater can be used. But since the temperature of air obtained from the above sources is much higher, it is to be bulked with a certain quantity of cold air to attain the requisite temperature.

2.8  Withering: Considerations in Relation to Manufacture

For orthodox manufacture in the plains of N.E. India, wither should be aimed to achieve 60-65% moisture in the withered leaf. For Darjeeling manufacture the wither is rather hard, moisture content of the withered leaf being around 30%.

For CTC manufacture, moisture content of 70% in the withered leaf should be adequate. The thickness of spread should not come below 10 cm in the plains. However, in the hills a minimum thickness of 7.5 cm is used. Subject to this minimum thickness, thinner the spread, the better.

While loading the trough, a small volume of ambient air (by use of damper) should be passed through the leaf in order to cool it. This will prevent further damage of leaf particularly during the summer, when the temperature of the leaf brought for wither may touch 45 °C (113 °F).
Spreading of leaf should be uniform across the length and breadth of the trough. Bunching of wet leaf should be avoided.

Air velocity should be such that the leaves are not lifted up.

Leaf should be handled carefully. At the time of spreading the leaves, drainage should be avoided. Also, it is better not to allow the labourers to walk on the leaf.

The withering period and temperature influence the character of produced tea. Low temperature favours development of quality, although high temperature may develop a better colour at the expense of quality. Unwithered tea is flaky which may be brisk but with poor quality. A period of 12-16 hours of wither is essential for completion of chemical wither.

Proper monitoring of withering through is necessary. Use of hygrometers, dry and wet bulb thermometers, moisture meter, weighment before and after wither will help in producing better quality tea.

Effort should be made to wither evenly over the entire period of withering, so that the rate of loss of moisture proceeds at a uniform rate. This will allow the chemical reaction to proceed in the desired manner.

At the end of withering ambient air should be blown to cool down the leaf.

Troughs should be emptied one at a time. Withered leaf must be loosely packed in the basket.

Tea manufacturing involves several processing stages including withering. Proper level of withering ensures the presence of quality attributes of tea in its final product. Modified technology in later stages for improving productivity cannot improve the quality of product without proper level of withering [27].
2.9 Summary

In tea processing, the quality of the final product is highly influenced by the withering process. Withering involves physical and chemical processes. Both are important for better quality of produced tea. Leaf handling is also a very important aspect. The duration of withering plays a vital role in achieving some important biochemical properties and sensory quality attributes of the finished product. During withering of black tea production, various biochemical processes take place. The characteristics of phenol oxidase, which is the main enzyme of tea production, and its hydroxylase and catechol oxidase activities are changed. These changes are responsible for the main transformation of phenol compounds determining the quality of the product. Modified technologies only in the other stages of tea manufacturing excluding the withering process cannot provide high quality product.