

A Review of Withering in the Processing of Black Tea

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Abstract

Purpose: Tea is the most frequently consumed drink worldwide, next to water. About 75% of the total world tea production includes black tea, and withering is one of the major processing steps critical for the quality of black tea. There are two types of tea withering methods: physical and chemical withering. Withering can be achieved by using tat, tunnel, drum, and trough withering systems. Of these, the trough withering system is the most commonly used. This study focuses on the different types of withering, their effect on the various quality attributes of tea, and other aspects of withering methods that affect superior quality tea. **Results:** During physical withering, tea shoots lose moisture content that drops from approximately 70-80% to 60-70% (wet basis). This leads to increased sap concentration in tea leaf cells, and turgid leaves become flaccid. It also prevents tea shoots from damage during maceration or rolling. During chemical withering, complex chemical compounds break down into simpler ones volatile flavor compounds, amino acids, and simple sugars are formed. Withering increases enzymatic activities as well as the concentration of caffeine. Research indicates that about 15% of chlorophyll degradation occurs during withering. It is also reported that during withering lipids break down into simpler compounds and catechin levels decrease. Improper withering can cause adverse effects on subsequent manufacturing operations, such as maceration, rolling, fermentation, drying, and tea storage. **Conclusion:** Freshly harvested leaves are conditioned physically and chemically for subsequent processing. There is no specified withering duration, but 14-18 h is generally considered the optimum period. Proper and even withering of tea shoots greatly depends on the standards of plucking, handling, transportation, environmental conditions, time, and temperature. Thus, to ensure consumption of high quality tea, the withering step must be monitored carefully.

Keywords: Biochemical changes, Black tea, Chemical withering, Withering, Physical withering

Introduction

Tea is manufactured from the young shoots of the tea plant *Camellia sinensis*, which consist of two or three leaves and an unopened terminal bud. Tea is a non-alcoholic aromatic beverage and it is generally accepted that, next to water, it is the most frequently consumed beverage in the world. It is also one of the lowest cost beverages and is consumed by a large number of people around the world (Katiyar and Mukhtar, 1996; Heneberry, 2006). The tea

plant *C. sinensis* is native to Southeast Asia but is currently cultivated in more than 30 countries around the world (Chaturvedula and Prakash, 2011). In India, tea was used as a medicinal plant before the British arrived and introduced it as a drink for pleasure in the 19th century (Bhagat et al., 2010). India is the second largest producer of tea next to China. It occupies an important place in the worldwide production of tea and plays a very vital role in India's national economy. Tea is perhaps the only industry for which India has retained its leadership over the last 150 years (Gupta and Dey, 2010; Jolvis Pou, 2016; Kumar and Jolvis Pou, 2016).

There are two major methods for manufacturing tea: the crush, tear, and curl (CTC) method and the orthodox

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method. CTC tea processing involves using a suitable maceration device like the vertical maceration machine, horizontal maceration machine, or the rotorvane, and the orthodox method involves using a roller or manual hand rolling (Jolvis Pou, 2016). Tea is processed in different ways in different countries as per the tasters' requirements and depending on the factory and region. The general stages in the processing of tea include plucking (picking), withering, macerating, rolling, fermenting (oxidizing), and drying (firing). All types of tea are produced from the same plant and the differences among them result from the different processing procedures used while producing the tea. The major steps in tea manufacturing and the corresponding types of tea produced are shown in Figure 1 (Jolvis Pou, 2016). In India, black tea of both the CTC and the orthodox type are produced, which need proper control of process parameters to produce quality tea. Appearance (grain size, shape, and liquor color), aroma, and taste are the three main quality attributes that determine the quality of manufactured tea (Yan, 2007; Chen et al., 2008; Sharangi, 2009). The quality of tea is further governed by crop quality, standard of plucking, and various post-harvest unit operations. Withering is the first processing step in the factory for black tea production. During this process, the fresh tea leaves are conditioned physically and chemically for the subsequent processing steps. It begins from the moment the leaves are picked to the time of rolling or maceration. This study focuses on the various aspects of withering in the manufacturing of black tea including the types of withering (physical and chemical), their effect on the various quality parameters of tea, the roles of withering in different types of tea manufactured, and the fundamentals of good withering practice.

Withering process

Withering or partial desiccation is the first important step for improving the quality of final tea. The picked leaves are usually spread in a series of enclosed/open trough fitted with perforated trays under forced air circulation (Baruah, 2003; Fard et al., 2015). Withering is one of the processed requiring the most space (Owuor and Orchard, 1992). The freshly harvested leaves are conditioned physically and chemically for the next operation (maceration or rolling) (Ghodake et al., 2006). During this period, the shoots partially lose moisture with moisture levels dropping from approximately 70-80% to 60-70% (wet basis), and the turgid shoots become flaccid. The rigid leaf becomes flexible and the shoots can now be twisted or rolled without breaking or becoming damaged into pieces. Withering increases the hydrolytic activity due to water loss, which increases hydrolysis and tea extract activity (Belitz et al., 2009). Ultimately, this activity catalyzes the oxidative reaction, which is mainly responsible for the quality of the product (Belitz et al., 2009; Fard et al., 2015). Withering brings about biochemical changes in tea leaves. To acquire the improved aroma, flavor, and other benefits in black tea, the proper withering of leaves is exceedingly important (Ravichandran and Parthiban, 1998).

Various ingenious withering systems, namely trough withering, tunnel withering, tat withering, and drum withering systems have been in use. Of these, the trough withering system is most commonly used in tea manufacturing factories. In most of the factories mainly two types of trough, open trough and enclosed trough, are commonly used (Sanyal, 2011), as shown in Figure 2 and 3, respectively.

In open troughs, leaves are spread at a particular

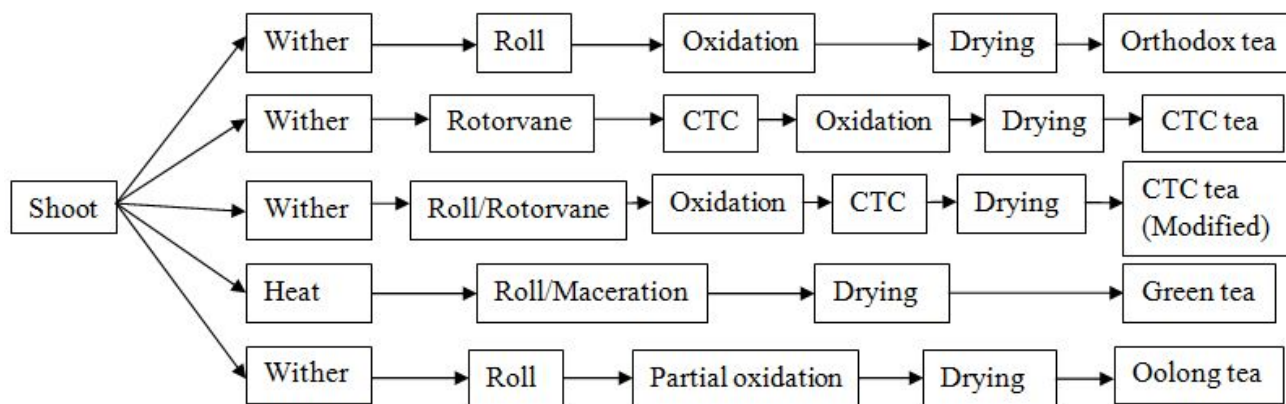


Figure 1. Major steps in tea manufacturing and the corresponding types of tea.



Figure 2. Open trough withering system (Source: Koomber Tea Estate, Goodricke Group Limited, Silchar).



Figure 3. Enclosed trough withering system (Source: Koomber Tea Estate, Goodricke Group Limited, Silchar).

thickness and air is blown in an upward direction from the bottom to the top layers, and in this way, the bottom layers of the leaves become withered. In order to minimize leaves handling and to reduce leaves damage by avoiding the leaves turning operation, the provision is made to move the fan both in forward and reverse directions. Therefore, the leaves in the upper layer also become withered as air is drawn into the leaf bed. However, during the reverse rotation the fan efficiency is drastically reduced to about 60% as compared to the efficiency in the forward direction, thus consuming more power (Sanyal, 2011).

In the case of using an enclosed trough, leaves are spread enclosed by the raised sides of the trough and a cover on top of the bed is used. In this system, a fan is forcing air only in the forward direction, and simultaneously air is passing through both the top and bottom of the leaves using a damper. As the handling of the leaves is less, the chances of leaves damage in enclosed troughs are much lower. In addition, the leaves do not get affected from the sudden variation in conditions of the outside environment. However, open troughs are still more popular in tea processing factories because they are

more convenient for loading and unloading, and it is easier to inspect the progress of the withering process (Sanyal, 2011).

Types of withering

There are mainly two types of withering: chemical withering and physical withering (Baruah et al., 2012; Fard et al., 2015). Both withering processes are equally important and it is difficult to get good aroma and flavored tea from un-withered or unevenly withered leaves (Bhatia, 1962; Saijo, 1977; Dev Choudhury and Bajaj, 1980; Takeo, 1984; Baruah et al., 2012).

Chemical withering

Chemical withering begins immediately after the tea leaves are plucked from the bushes. Chemical withering is independent of the rate of moisture removal and is a function of temperature and time. During the process, the complex chemical compounds are breaking down into simpler compounds. The dehydration shock during

chemical withering triggers enzymatic ripening and produces floral flavor in the tea leaves (Sakata et al., 2004). It is reported that for making good quality black tea proper chemical withering is highly necessary (Bhatia, 1962; Saijo, 1977; Dev Choudhury and Bajaj, 1980; Takeo, 1984). The optimum duration for chemical withering has been reported to be 14 h (Ullah, 1984). Experimental studies have shown that the withering time beyond 20 h leads to the deterioration of the quality of black tea (Owuor, and Orchard, 1989), and hence, withering time should be limited to 18 h (Owuor and Orchard, 1992; Omiadze et al., 2014).

Physical withering

Physical withering refers to the removal of moisture from the tea leaf. During this process, the turgid leaf becomes flaccid. This process also leads to the concentration of sap in the cells of the tea leaf. The desired level of moisture can be removed by passing air through the piled leaves. Studies have shown that during physical withering the moisture content of green leaves is reduced to 60-70% (Yamanishi, et al., 1966; Omiadze et al., 2014, Jabeen et al., 2015). Time, temperature, and relative humidity are the major factors affecting physical withering (Obanda et al., 2004). Tocklai (Tea Research Association, Assam, India) has reported that physical withering requires shorter duration as compared to chemical withering. Thus, physical withering is regulated at a slower rate for a longer period to achieve withering in the same duration as that required for chemical withering. This can be regulated by monitoring the airflow rate and changing the air temperature during withering of tea leaves.

Biochemical changes during chemical withering

Chemical withering plays a vital role in increasing the level of caffeine content (Sanderson, 1964), polyphenol oxidase activity (Ullah and Roy, 1982), amino acids, and sugars (Owuor and Orchard, 1989; Tomlins and Mashingaidze, 1997). Chemical withering results in the reduction of chlorophyll content (Wickremasinghe, 1975) and leads to the formation of different kinds of volatile flavor compounds (Mahanta and Baruah, 1989; Ravichandran and Parthiban, 1998). The breakdown of proteins into amino acids during chemical withering is one of the most important biochemical changes occurring during the process (Hussain et al., 2006).

Proteins and amino acids

Amino acids are formed during withering by approximately 1.2% breakdown of proteins and are involved in aroma formation. This breakdown occurs because of the peptidase present in the tea shoots (Bhatia, 1962; Perera and Wickremasingh, 1972; Motoda, 1979; Sanyal, 2011). Peptidase increases the levels of free amino acids particularly those of glutamine, glutamic acid, aspartic acid, valine, serine, lysine, alanine, threonine, phenylalanine, and tyrosine (Senderson and Graham, 1973; Tomlins and Mashingaidze, 1996; Panda, 2011; Sanyal, 2011). Phenylacetaldehyde, which is formed and reduced to alcohol, is reported to be involved in the improvement of tea aroma. In contrast, formaldehyde, acetaldehyde, isobutyraldehyde, isovaleraldehyde, 2-methylbutanal, and methional are reported to cause poor flavor in tea (Senderson and Graham, 1973). The partial breakdown of proteins to amino acids acts as a precursor for aroma.

Carbohydrates and simple sugars

There is a conversion of carbohydrates to simple sugars during withering. Simple sugars content increases and carbohydrate content gradually decreases (Roberts, 1962). Simple sugars formed from the breakdown of carbohydrates react with amino acids to produce the flavor in black tea (Dev Choudhury and Bajaj, 1980; Sanyal, 2011).

Lipids and fatty acids

During the withering process, lipids and fatty acids are broken down into simpler compounds and volatile compounds are formed. There are mainly two types of fatty acids: saturated fatty acids and unsaturated fatty acids. It has been previously reported that the levels of saturated fatty acids decrease during withering, but their effects on black tea aroma are unknown (Selvendran et al., 1969; Wright and Fishwick, 1979). Whereas, the effects of unsaturated fatty acids on black tea aroma are much more documented, and the aroma formed from the breakdown of unsaturated fatty acids contributes to a negative odor effect. It has been reported that grassy aroma released from the withering trough is the result of aroma compounds produced from fatty acids (Takeo and Tsuchida, 1980; Tomlins and Mashingaidze, 1997).

Catechins and enzyme activity

Moisture removal during withering leads to an increase in

the concentration of cell sap. As a result, the concentration of enzymes increases and results in the formation of high molecular units from low molecular subunits. The withering of tea leaves activates the activity of catechol oxidase of phenol oxidase. Consequently, the oxidative reactions take place, which are responsible for the quality of black tea (Omiadze et al., 2014). Catechin content decreases during withering (Bokuchava and Skobeleva, 1980) and theaflavins (TF) and thearubigins (TR) (Omiadze et al., 2014) are formed. TF and TR are the key parameters for brightness, briskness, color, and strength of black tea.

Volatile flavor compounds (VFC)

During withering, the levels of amino-acid derived aldehydes like methyl butanol, phenyl-acetaldehyde, and *n*-hexanol increase, but carotenoid levels decrease (Panda, 2011). VFCs highly influence the quality and aroma of black tea. There are mainly two types of VFC: Group I VFC, such as hexanal and E-2-hexenal, and group II VFC, such as linalool and geraniol. Group I VFC imparts inferior aroma, whereas group II VFC contributes to a positive effect on aroma. Research indicates that withering reduces the total amount of group I VFC, and increases the total amount of group II VFC (Sanyal, 2011; Zheng et al., 2016).

Chlorophyll

A high amount of chlorophyll content is not desirable during black tea production. It has been reported that high chlorophyll content at the time of fermentation and drying produce inferior liquor quality with a grassy aroma (Tomlins and Mashingaidze, 1996; Sanyal, 2011). About 15% of chlorophyll degradation has been reported to occur during withering (Sanyal, 2011). Although high chlorophyll presence induces inferior liquor quality, degradation of chlorophyll is recommended by proper withering, but high levels of chlorophyll degradation should be avoided. The conversion of chlorophyll to phaeophytin during fermentation and drying results in the black color of the CTC tea (Dev Choudhury and Bajaj, 1980; Taylor et al., 1992; Tomlins and Mashingaidze, 1997; Sanyal, 2011).

Caffeine

Caffeine is a very good stimulator of the central nervous system (Sanyal, 2011). The creaming property of black tea is an indication of caffeine content. Sufficient withering is

highly necessary to form a good amount of caffeine in black tea. Teas with low levels of caffeine content show inefficient creaming properties (Roberts, 1963; Bhatia, 1964; Dev Choudhury and Bajaj, 1980; Tomlins and Mashingaidze, 1997), and these types of teas do not receive good market value. Normally physically withered leaves show comparatively more caffeine concentration than forced physically withered tea leaves (Senderson and Graham, 1973; Dev Choudhury and Bajaj, 1980; Bhuyan and Mahanta, 1989; Tomlins and Mashingaidze, 1997; Sanyal, 2011). Generally, in tea processing factories during rainy days, the withering process is achieved with the application of hot air, and this makes the tea incapable of showing good creaming liquor. Therefore, it is always preferred to wither tea leaves normally below 38°C (Dev Choudhury and Bajaj, 1980).

Carotenoids

Carotenoids get degraded and volatile flavor compounds are formed during withering and fermentation (Hazarika and Mahanta, 1983; Sanyal, 2011). Carotenoids are the yellow pigments present in the green leaves, which assist with photosynthesis. Carotenoids degradation was found to be more significant during physical withering as compared to chemical withering.

Roles of withering in different types of tea processing

The withering step plays a vital role for quality black tea manufacturing (Dev Choudhury and Bajaj, 1980). At the same time withering is less important for producing plain teas, which are mainly produced in Kenya and Malawi, (Hilton, 1975; Owuor and Orchard, 1989; Orchard, 1991). However, it is recommended that there should be less handling of tea leaves during withering to minimize cell damage, so that negative effects on the subsequent step of oxidation can be avoided (Sanyal, 2011). Nevertheless, turn over treatment of leaves along with solar withering is found to be necessary for the development of aroma constituents in pouching tea. Research suggests that the withering process should be carried out below 38°C for quality black tea, but for oolong tea, withering at 40°C results in more volatile compounds compared to normally withered leaves at ambient temperature. The withering step is not performed during production of green tea.

Effects of withering on other processing parameters in black tea production

Maceration/rolling

Experiments indicate the problem in processing over-withered as well as under-withered leaves. The over-withered leaves become hard and cause the maceration device or roller to get blunt if not used for an optimum period. This results in additional fiber content in the final product; further, the likelihood of over-fermentation followed by over-firing of the final product increases. On the other hand, it is reported that the rotor vane and CTC machine become clogged if an excessive amount of moisture is present in withered leaves (Owuor et al., 1987). There is no specified degree of withering; it depends on requirements, leaf quality, and ambient weather condition. However, 68-72% of moisture content is recommended for maceration (Choudhury, 1970; Tomlins and Mashingaidze, 1997).

Fermentation (oxidation)

Even fermentation depends on proper withering, most importantly on physical withering. Uneven withering or less withering and excessive moisture content reduce the aeration and temperature control, which results in uneven fermentation (Sanderson and Graham, 1973; Tomlins and Mashingaidze, 1997). Over-withering also should be avoided, as it hinders the enzymatic activities that are responsible for color, brightness, aroma, and other quality attributes.

Drying (firing)

Excessively withered tea may burn during drying, as less amount of moisture is present in the dhool. At the same time, less or uneven withering should be averted as the wet dhool has a tendency to clump and stick to the surface of the dryer bedplate especially in fluidized bed dryers (Owuor and Orchard, 1992; Tomlins and Mashingaidze, 1997).

Storage of manufactured tea

The withering of tea leaves for short duration reduces the conversion of TF to TR, and tea made from short duration-withered leaves deteriorates more rapidly. Previous studies recommend that for long-term storage, special attention should be given to physical withering. Insufficient withering of tea leaves causes the greenish color in manufactured tea.

Fundamentals of good withering

For high quality tea production, even and proper withering are essential. Even and proper withering depend highly on the plucking (picking) standards, leaf handling, and transportation. Compact leaf handling and packing increases the leaf temperature followed by significant decrease in TF content. After plucking, if the leaves are kept in a basket for a long period, the degradation of TF to TR increases. Eventually, this may have adverse effects on the brightness, briskness, and other quality parameters of manufactured tea. As recommended, the optimum ratio of TF and TR should be 1:10 for mellow liquor and bright infusion. If the TF and TR ratio is less than 1:10, it results in raw liquor and green infusion, whereas a ratio of more than 1:10 gives soft liquor and dark infusion (Sanyal, 2011; Jolvis Pou, 2016). Therefore, careless handling, delayed transportation, leaves damage, compaction in basket for long duration, and over exposure to sunlight should be avoided to control all aspects of quality deterioration (Sanyal, 2011). Only because of poor handling from plucking until arrival to the factory, about 25% of the market value of manufactured tea can be lost (Burton, 1995; Wilkie, 1995).

Conclusion

About 75% of total world tea production is processed as black tea and withering is one of the major processing steps for making quality black tea. Withering involves both physical and chemical changes and plays a vital role for the development of quality attributes of black tea. Generally, the trough withering system is used to carry out the withering process, involving open trough or enclosed trough systems. During the process, the moisture content of the tea leaves is usually reduced to 60-70% wet basis and the leaves turn from turgid to flaccid. This further results in an increase in the concentration of cell sap. Chemical withering brings about the breaking down of complex chemical compounds into simpler compounds. Biochemical changes occurring during chemical withering include changes in the concentration of proteins, lipids, carbohydrates, volatile flavor compounds, chlorophyll, caffeine, carotenoids, catechins, and enzyme activities etc. Results from previous studies indicate that the withering duration of 14-18 h is optimum. The withering operation has great effects on the subsequent processing steps (maceration, rolling, fermentation, drying, and storage). Furthermore, the withering process can be influenced by standards of plucking, handling and transportation, ambient conditions, time, and

temperature. Therefore, it is necessary to understand the various aspects of withering process and control the process parameters to ensure high quality of manufactured tea.

Conflict of Interest

The authors have no conflicting financial or other interests.

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