7 Review of withering in the manufacture of black tea

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INTRODUCTION

We have reviewed work published on the role of withering in black tea manufacture throughout the tea producing regions. It helps to direct and plan research and it also seems that many in the tea industry, with justification, are not sure of the role of withering and of the do's and dont's. Uncertainties often arise over the differences between a normal, physical and chemical wither and how these can be achieved. A knowledge of the biochemical changes in the leaf may help the factory manager to appreciate the implications of different methods of processing the leaf. This review may answer some questions and raise many more. However, for every publication advocating one method, it is usually possible to find another contradictory paper. Also, some of the findings might have been from a trial done only once and hence may not be repeatable. Your views would be much appreciated.

The role of withering is determined by its definition which is described as the changes that occur in the green leaf from the moment it is plucked from the bush to the time of maceration. As tea manufacturing technology evolves, the method and value of withering on black tea quality appears to be changing. In the production of flavoury teas where the tea is rolled, withering is considered vital for quality. For plain teas, such as those manufactured in Malawi, South Africa and Kenya (west of the Rift) the role of withering with respect to quality is less clear. Here, withering appears to be most important for processing reasons as follows:

- Maceration machines operate most effectively within a fairly narrow leaf moisture range
- Withering can be used as a means of storing the green leaf when leaf is very abundant or when it is short so that manufacturing can be effectively managed
- Unwithered leaf is difficult to ferment and dry

An aspect of withering now considered to be important is leaf handling in the field. Recent work in Malawi (*QNL 120*) suggests that up to 25% of the market value of tea can be lost before it arrives at the factory door if the leaf is poorly handled whilst in the field and during transit.

WITHERING METHODS

A number of withering methods have been described and these are outlined as follows:

- **Physical (Artificial) wither.** This is probably the most clearly understood. It refers to a loss in moisture and changes in cell membrane permeability which result in the leaf becoming flaccid. It is achieved by passing air through the leaf at ambient or above ambient by applying heat. Soft withers refer to minimal moisture loss whereas hard withers refer to much greater moisture losses. The physical wither is reported in the literature to take about 4 hours and with applied heat shorter times of 2 to 2.5 hours. In practice, however, it can be as rapid as 15 minutes when more heat (60°C) is applied or as long as 18 hours when the air is very humid.

- **Chemical (Storage) wither.** The term is perhaps misleading as it does not involve the addition of chemicals to the leaf. It refers to natural biochemical changes that occur inside the leaf that may or may not influence the quality of the made tea. These biochemical reactions are considered necessary for formation of the tea aroma which are more important for flavoury teas. A chemical wither is achieved by blowing air either intermittently or continuously at low flow rates through the leaf to keep it cool without losing moisture for between 4 and 18 hours.

Blowing air through the leaf is vital since temperature rises of 3°C per hour are considered common if air is not passed through. A very important role of this type of withering is in storing the leaf to assist in the factory management of leaf. Hence, chemical withering could also be referred to as storage wither.

- **Normal wither**. This refers to the traditional method of withering where air is blown through leaf (12 to 24 hours) until the desired moisture loss is reached. It is in effect a simultaneous physical and chemical wither. Heat may be applied on wet and humid days to remove moisture from the leaf.

- **Two-stage wither.** This refers to a chemical wither, used to store or hold the leaf, followed by a physical wither. The depth of the leaf bed may be greater than that used in troughs; the term tank withering has been used for the chemical wither stage. Heat may be applied during the physical wither stage which can be achieved in 2 to 2.5 hours or less.

- **Nil wither**. When green leaf is manufactured fresh.

The type of wither and its effect on made tea quality seems to differ between producing countries. For plain teas such as those produced in Malawi and Kenya (west of the Rift), tasters preferred teas that had been physically withered. In Kenya, the duration of chemical wither (0 to 18 hours) did not have any effect on quality. In other producing regions such as Assam, the chemical wither is considered necessary for producing full and round liquors and the duration could be reduced to 6 to 8 hours by holding the leaf at elevated temperatures between 30 and 37°C and passing air through. Some manufacturers in Kenya practice a two-stage wither, which starts with a chemical wither in which leaf is stored, followed by a short physical wither to lose moisture. Other manufacturers follow a nil wither but difficulties may occur during maceration, fermentation and drying because of the higher moisture content.

Changes occurring in the Green Leaf during the Physical Wither

Immediately after plucking, the fresh leaf starts to lose water as vapour. In the factory, the maximum initial drying rate has been reported to be 0.075 kg of water per kg of green leaf at ambient temperatures. As the degree of wither progresses, the permeability of the cell membranes in tea shoots increases and the leaf becomes more flaccid. During withering, some solid matter (3 to 4 per cent of the dry weight) in the leaf is lost through respiration in addition to the moisture initially present in the leaf.

The rate of loss of moisture during withering is related to leaf surface moisture, how often the leaf is turned, humidity of the air, altitude, air flow and whether heat is applied.

Processing Reasons for the Physical Wither

We need to remove moisture from the leaf so that it is easier to handle during processing and can affect the following stages:

- **Maceration:** For LTP (Lawrie Tea Processor) maceration, a target moisture content on a wet basis of 71 to 72% is desirable. CTC (cut-tear-curl) maceration can operate over a wide range of moistures; 68 to 72% is preferred. Excessive moisture in the green leaf may clog both the rotorvane and CTC rollers. The orthodox method requires leaf that has has had a harder wither to 60 to 66% moisture content and can be as low as 50% for the manufacture of Darjeeling. This is to ensure that the leaves are sufficiently flaccid for the rollers to produce the desired twist in the leaf.

- **Fermentation:** The physical wither is necessary for producing an even fermentation. Excessive moisture in the dhool reduces aeration and temperature control resulting in an uneven ferment. Too hard a physical wither may inhibit the enzyme activity essential for the formation of the brightness, briskness, colour and strength characteristics of tea.

- **Drying:** Too high a moisture content can affect the drying as the wet dhool will tend to form balls and stick to the bed plate of fluidised-bed driers causing uneven drying and off-flavours.

Some people report their results as moisture contents and others as percentage wither. These are not the same; moisture content refers to the quantity of moisture in the leaf on a wet basis, whereas percentage wither refers to weight loss in relation to the fresh weight.

To date there are no quick cheap and simple methods for measuring the moisture content of the green leaf. The best that many factories can do is to measure the moisture content of the dhool after maceration or to squeeze the leaf or dhool in the hand. At TRF(CA) an Electronics and Instrumentation Engineer is currently studying for a higher degree in the UK to find a technical and economical solution.

CHANGES IN THE BIOCHEMICAL CONSTITUENTS OF THE GREEN LEAF DURING WITHERING

Following plucking, many biochemical and physiological processes occur in the green leaf. During manufacture some of these processes will be altered and new processes commence. The known biochemical changes involved are the breakdown of proteins into amino acids, a decrease in lipid and fatty acids, carotenoids and chlorophyll, an increase in the caffeine content and changes in sugars, organic acids, enzyme activity and flavour volatile components.

Catechins and Enzyme Activity

In freshly plucked leaf, the catechins account for about 30 per cent (dry weight) of the green leaf and their content decreases during withering. Catechins form theaflavins (TF) and thearubigins (TR), mostly in the presence of polyphenol oxidase (PPO) and peroxidase (PO) enzymes, although recent work indicates that their formation can also occur without enzymes. The TFs and TRs are responsible for the brightness, briskness, colour and strength of black tea. The activity of the PPO enzyme has been reported to decrease during withering as a result of moisture loss but can be restored when the withered leaf was rehydrated although the degree of moisture loss has not been clearly defined. The activity of the enzyme is also reduced at temperatures above 35°C.

Proteins and Amino Acids

Protein accounts for 15 per cent (dry weight) of the green leaf. During withering, levels are reduced by approximately 1.2 per cent and the changes accompany an increase in amino acids which are thought to be involved in flavour formation. Some amino acids give rise to poor flavour while others can improve it.

Carbohydrates and Simple Sugars

Carbohydrates account for about 34 per cent (dry weight) of the green leaf. Simple sugars, formed from the breakdown of carbohydrates, increase during withering and may be incorporated into amino acids to form volatile flavour compounds.

Caffeine

Caffeine constitutes about 3 to 4 per cent of the unwithered leaf on a dry weight basis. Black teas with low levels of caffeine lack the ability to cream. The creaming properties of made tea are adversely affected by insufficient wither. Although caffeine is thought to increase during both chemical and physical wither, most of the increase occurs during the latter.

Lipids and Fatty Acids

Volatile compounds formed as a result of the breakdown of lipids and fatty acids (3 per cent dry weight of the green leaf) during withering are thought to have a detrimental effect on flavour. In particular, the strong grassy odour on the withering troughs is a result of the volatile compounds produced from fatty acids.

Carotenoids

Carotenoids are yellow pigments in the green leaf which assist with photosynthesis. During withering and fermentation they degrade to form volatile flavour compounds important in the aroma of tea. Their decline in concentration is more significant during the physical rather than the chemical wither.

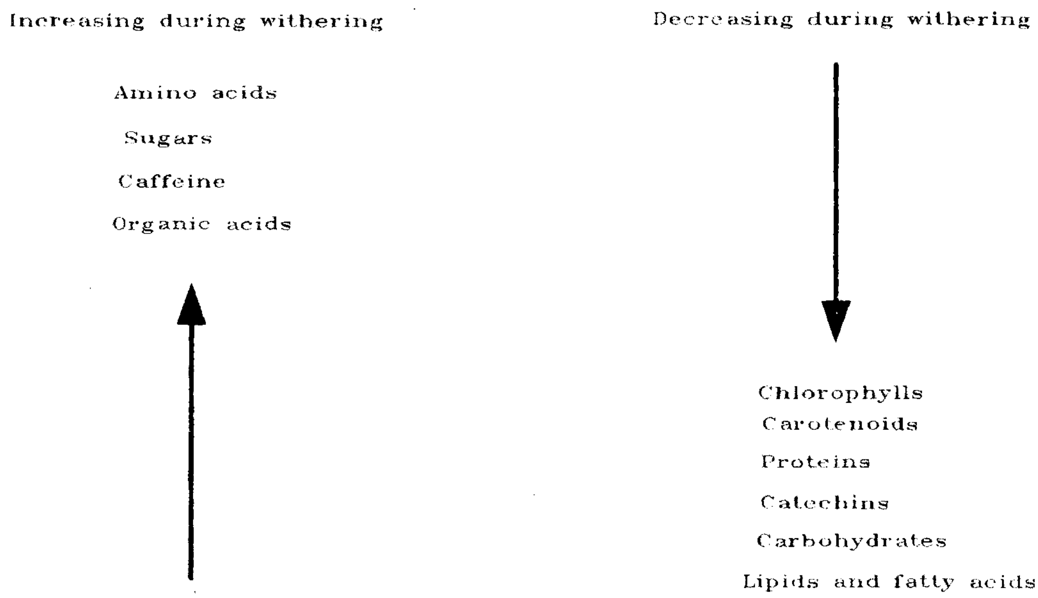
Chlorophyll

Chlorophyll is a green pigment essential in plants for photosynthesis. Teas with high chlorophyll may result in inferior liquors that have a grassy odour. Their concentration decreases during withering but their presence is however important as they breakdown during drying to contribute to the black colour.

Other Biochemical changes in the Green Leaf

Other changes have been recorded during withering but the effects which these have on quality are not known. These include an increase in organic acids and soluble inorganic phosphorous.

Generalised summary of Biochemical Changes Occurring in the green Leaf During Withering



INFLUENCE OF WITHERING ON THE BIOCHEMISTRY OF THE FERMENTATION PROCESS

Theaflavins (TF) and Thearubigins (TR)

TFs in tea are responsible for the briskness and brightness, while TRs contribute to the strength and colour. Unwithered leaf is associated with teas that are bright, brisk but thin and correspondingly the teas are higher in TF but lower in TR. Harder withers produce teas with less brightness but improved body; the TFs are lower and the TRs higher.

Volatile Flavour Compounds

Withering is thought to improve the aroma of tea. The aroma of black tea is complex, being composed of over 600 volatile compounds, none of which on their own have the characteristic aroma of tea. During chemical withering of plain Kenyan teas, the concentration of volatiles in the made tea decrease but the flavour improves because those compounds that impart an inferior grassy odour to black tea decline faster than those that impart a sweet flowery aroma.

METHODS FOR MONITORING THE BIOCHEMICAL CONSTITUENTS AS A MEANS OF QUALITY CONTROL DURING WITHERING

While many biochemical compounds in the green leaf and black tea have been studied, the measurement of most are time consuming, involve costly equipment and a high level of training and expertise. Also, for many, the exact relationship with quality is not known. Compounds that can be easily monitored in the leaf are the catechins and caffeine. Other parameters that could be simply measured but as yet have not been fully evaluated, are the acidity (pH), water potential, chlorophyll fluorescence and the chloroform test.

Flavour volatiles have until recently been difficult to monitor rapidly. A new type of detector, known as an 'electronic nose' now appears to offer the potential for monitoring the flavour volatiles during tea manufacture. The instruments can evaluate a tea sample in less than 5 min. As well as the potential for monitoring the leaf during withering, they may well be able to detect overfired odours during the drying stage. Current instruments are expensive but more affordable instruments are being developed.

INFLUENCE OF OTHER FACTORS ON WITHERING

Plucking Standards and Factory Withering

A study in Kenya on the influence of plucking standards on withering indicates that quality, as perceived by tasters, declined with coarser plucking standards and that, in general, the decline was least when only a chemical wither was employed.

Storage of Made Tea

Storage trials in Malawi have indicated that teas withered for more than 10 hours had the best keeping properties with respect to TF composition. Tea manufactured from short withers had the highest initial TF values but deteriorated more rapidly. A study in Kenya found similar results. For newly manufactured teas, tasters tended to initially prefer chemically withered teas but after five to six months storage there was a growing preference for hard physically withered teas, the chemically withered teas becoming bakey and greenish.

Packing Density of Made Tea

Studies in Kenya have shown that chemical withers tend to give teas of lower density but acceptable quality. However, the lower density may make tea difficult to sell.

Mechanisation of Leaf Handling and Withering

In factory withering, the green leaf is usually transferred to tats or withering troughs by hand. Withering has been mechanised in factories in Kenya and Assam. Such systems are reported to reduce labour costs and improve quality by reducing handling of the green leaf.

SUMMARY ON FINDINGS PREVIOUSLY REPORTED

These findings may be contradictory as they were carried out by different researchers in various countries. Some of the research may not have been carried out with sufficient replication, controls or other information which could permit useful conclusions.

Field Handling

This work has only been carried out in Malawi and might differ for other regions. For example, in Kenya the ambient temperatures are lower and the teas are slower fermenting, hence it would be expected that the build up of temperature in the leaf would be less.

- Temperatures of 30°C or above in the sack. and times longer than 3 hours in the field, may cause a significant loss in quality. The leaf tends to increase in temperature at a rate of 2 to 3°C per hour but is probably very dependent on many other factors yet to be monitored in detail, such as the presence of surface moisture, leaf damage, packing density, ambient temperature and location of sack on a trailer.

- Some degree of packing appears to be advantageous for quality. The use of net bags, enabling circulation of air in the leaf, rather than fertiliser sacks, can improve quality when leaf is densely packed and is likely to remain in the field for long periods.

- Damaged leaf, when made into tea, realised very low scores for briskness, brightness and colour of infusion when tasted by commercial brokers.

Withering

This is a summary of work carried out in several countries; the country(ies) where the studies were carried out are indicated in brackets.

Plain teas with no notable flavour (for Malawi, Kenya west of the Rift, South Africa)

- Physical withers were more important than chemical withers (Kenya, Malawi).

- Physical withers will reduce TF formation and hence brightness and briskness of the made teas whereas colour and strength are improved. The degree of moisture loss does not appear to be important.

- The duration of chemical or physical wither has little effect on quality and can be as little as four hours (Kenya). The optimum length of wither probably depends on the preference of the taster assessing the tea.

- Moisture loss could be achieved either by conventional means or by 2-stage withering (Kenya).

- Two-stage factory withered teas were of the same quality as normally withered teas. The duration of chemical wither (0 to 18 hours) at the second stage was not apparently significant (Kenya)

- Fresh leaf manufacture and chemical wither alone produced acceptable teas with only a slight quality drop compared to physically withered teas (Kenya).

- Withering at lower temperatures tended to produce higher quality and more aromatic teas (Kenya).

- Coarse plucked leaf benefits from a chemical wither only (Kenya).

- When the physical wither step was omitted (soft wither), the leaf was difficult to process, particularly at the drying stage with a decline in throughput (Kenya).

- Soft withers tended to give teas of lower bulk density but acceptable quality.

- Teas made from withered leaf appear to keep longer in storage than teas made from unwithered leaf (Kenya, Malawi).

Quality teas (Assam, Sri Lanka, Southern India)

- A normal wither of 12 hours was optimal for quality (Assam).

- Physical withering should be followed or preceded by a 16 to 18 hour chemical wither for producing full and round liquors (Assam).

- The chemical withering time can be reduced to 6 to 8 hours by holding the leaf at elevated temperatures between 30 and 37°C and passing air through (Assam).

- A wither bed thickness, up to 18 inches, was not critical if the leaf was carefully turned (Sri Lanka).

- Lower wither temperatures (10°C) produced good liquors with marked improvement in colour although only good quality leaf benefited (Southern India, Sri Lanka).

- Low temperatures (10 to 15°C) and shorter periods (about 12 hours) gave rise to teas of good flavour and quality (Sri Lanka).

- High temperatures (25 to 35°C) and longer wither periods (20 to 30 hours) resulted in teas with good colour but poorer quality and flavour (Sri Lanka).

- Long and high temperature withering reduced greenness.

CONCLUSIONS

While much has been reported on changes occurring in the factory stage of withering, until recently little was known about the importance of changes in the leaf when in the field and how this might influence subsequent stages in the manufacturing process. For plain teas, such as those manufactured in Malawi, it is now clear that much of the potential value of the tea could be lost before the leaf has arrived at the factory. Little is known about the influence of poor leaf handling on the quality of plain and flavoury teas manufactured in other producing regions or how it might affect the withering and fermentation of tea. For example, should the leaf that has been in the field for 10 hours and attained temperatures in excess of 40°C be treated in the factory in the same way as fresh leaf?

Withering involves both physical and chemical changes in the green leaf. The physical changes, such as rate of moisture loss, might easily be determined if the moisture content, mass of the fresh leaf, altitude and humidity are known and the air flow and any applied heat during withering can be closely controlled. Where space is important, costs may be reduced by utilising a two-stage system but this should be assessed on an individual factory basis. While much is known about the chemical changes that occur in the green leaf during withering, the tea manufacturers are still very dependent on tea tasters to measure quality. No rapid objective method yet exists to determine when the chemical wither has reached its optimum or when the leaf has reached its desired moisture content.

Withering practices differ with country and the type of tea being manufactured. For plain teas such as those from Southern Africa, the physical wither appears to be the most important for quality. For more flavoury teas a chemical wither was considered important

It might be thought that little work now needs to be done on withering but this could not be further from the truth. Many practical aspects of withering appear to hve been omitted or reported inconsistently, perhaps because researchers consider these unique to the factory where the work was conducted or because they did not fully appreciate the complexity of withering. Factors often omitted are the leaf condition, how frequently the fan ought to be turned on, plenum chamber pressure, airflow, bed loading, turning of the leaf, when and how much heat should be applied and how should wet leaf be treated as opposed to dry leaf. The factory manager needs to know these in order to ensure the leaf is correctly and evenly withered.

Table 1 shows the withering parameters reported by a number of researchers and illustrates the inconsistencies and the difficulties in making objective comparisons. While most have recorded the withering time and degree of wither, many factors are infrequently reported and some important ones such as leaf condition and turning of the leaf were not mentioned at all. Comparisons of the degree of wither are difficult because some record the degree of wither as a percentage of the fresh weight while others record the moisture content; the latter is preferred. It is hoped that future work will help to answer some of these questions.

Table 1: Survey of withering parameters measured by previous researchers

Author	Leaf condition	Withering time	Moisture content of fresh leaf	Degree of wither	Ambient temp	RH %	Bed loading	Air flow rate	How frequently the fans were switched on	Plenum chamber pressure	Turning of the leaf
A	no	no	no	per cent of fresh weight	no	no	no	no	no	no	no
B	no	yes	no	per cent of fresh weight	yes	yes	no	no	no	no	no
C	no	yes	yes	per cent moisture	yes	yes	no	no	no	no	no
D	no	yes	yes	per cent of fresh weight	yes	no	no	no	no	no	no
E	no	yes	yes	per cent moisture	yes	no	no	no	no	no	no
F	no	yes	no	no	no	no	no	no	no	no	no
G	no	yes	no	no	no	no	no	no	no	no	no
H	no	yes	yes	per cent of fresh weight	no	no	no	no	no	no	no
I	no	no	no	no	no	no	no	no	no	no	no
J	no	yes	no	per cent moisture	yes	no	no	no	no	no	yes
K	no	yes	yes	per cent moisture	yes	yes	yes	yes	no	no	no
L	no	yes	yes	per cent moisture	yes	yes	yes	no	no	no	no

SUGGESTED FURTHER READING

Johnson, A.L. (1990) Manufacture - Section 14, Tea Planters Handbook, Tea Research Foundation (Central Africa), P.O. Box 51, Mulanje, Malawi.

Wilkie, A.S. (1995) Leaf Handling Study, TRF QNL 120, 26-38.

Wilkie, A.S. (1996) Improvement of leaf handling, TRF QNL 121, 11-19.