**International Journal of**
**Research in Chemistry and Environment**
Available online at: www.ijrce.org
**ISSN 2248-9649**

***Research Paper***

# Effect of Leaf Withering Duration, Maceration types and Aeration Duration on the Quality of Black Tea of Clone TRFK 306 (Kenyan Purple Tea)

***Kilel E. Cherono[1], Wanyoko J.Kanyiri[2], Faraj A.Kipruto[1] and Ngoda Peninah[1]**
[1]Egerton University, Njoro, Department of Dairy and Food Science and Technology, P.O Box 536 -20115, Egerton, KENYA
[2] P.O BOX 996-20106, Molo, KENYA, former address, KALRO- Tea Research Institute, P.O Box 820 -20200, Kericho, KENYA

**(Received 17th March 2017, Accepted 27th March 2017)**

***Abstract:*** *TRFK 306 is a tea clone rich in anthocyanin giving the leaves a purple coloration and it is of assamica cultivar. It was developed in Kenya by the Tea Research Foundation of Kenya, currently Tea Research Institute and has since been released for commercial utilization. This type of tea clone just like any other tea clone can be processed into any type of tea (green, black, Oolong, white, yellow) depending on choice and preference of the processor. Since the clone was released for commercial utilization in 2011, processors are still not sure how best to process this new tea clone. The current study investigated the effect of processing method, withering and aeration durations on the quality of black tea from TRFK 306. TRFK 6/8 was used as a reference standard because of its proven black tea quality. Orthodox and Cut Tear and Curl (CTC) methods of processing were used in both tea clones. Withering was done at room temperature and varied at an interval of five hours, starting at five hours up to twenty hours. Within each withering regime, aeration was varied at 30 minutes interval from 30-90 minutes. Experienced regular tea tasters did the sensory evaluation by describing the liquor colour, body, strength, briskness and infusion colour then the researchers analysed and interpreted the description using a predetermined scale. Theaflavins, thearubigins, total colour, brightness percentage was analysed using UV spectrophotometer. The results showed that CTC teas had relatively higher black tea quality parameters than the orthodox teas irrespective of the tea clone. Within each processing method, TRFK 306 had better quality than TRFK 6/8. Aeration time had more pronounced effect on quality than withering duration. TRFK 306 processed through CTC and withered for ten hours and aerated for 90 minutes produced the best black tea according to the analysed quality parameters, while TRFK 6/8 produced best tea at twenty hours withering and 90 minutes aeration. For orthodox teas, TRFK 306 produced best tea at twenty hours withering aerated for 90 minutes while TRFK 6/8 produced best tea at fifteen hours withering and 60 minutes aeration. It was concluded that TRFK 306 produces better black tea than TRFK 6/8 based on the chemical parameters analysed.*

**Keywords:** aeration time, Cut Tear and Curl, orthodox, TRFK 306, withering time.



## Introduction

Tea is made from the tender shoots of *Camellia sinensis* L.O Kuntze. Tea was first introduced in Kenya from India in 1903 and in the 1930's commercial planting began [1]. Planted tea area in Kenya has grown [2] from a mere 21,448 hectares in 1963 to over 203, 006 hectares by 2014. Kenya being a major black tea exporter earns more foreign exchange from it than from other agricultural produce. Young shoots of tea leaves can be processed in different ways/methods depending on the processors choice. According to [3], there are three main types of teas; Green, Oolong and black teas. Kenya basically produces black Cut Tear and Curl (CTC) teas though product diversification is being promoted to enhance sales and consumption of tea.

The Tea Research Foundation of Kenya developed an Assamica tea cultivar rich in anthocyanin coded TRFK 306 whose leaves have a purple coloration [4]. Anthocyanins are phenolic materials, and along with catechins have medicinal effect. Purplish red tea results from an inherited reaction to unfavourable hot and humid environmental conditions, providing the tea tree with a mechanism for fighting scorching ultraviolet rays. In order to resist damage from this shortwave radiation, tea leaves produce anthocyanin, which can reflect away a portion of the ultra violet light hitting the leaves [5]. With the introduction of TRFK 306, many processors seek information on how best to process the new clone. We carried out a study where the new clone (TRFK 306) and TRFK 6/8 were processed in two methods; CTC and orthodox. Both withering and aeration durations were varied since these processing steps has great influence on quality of black tea.

Withering and aeration are critical steps in tea manufacture. The physical change associated with withering is a loss of moisture from the tea leaves which leads to changes in cell membrane permeability. Chemical wither involves breakdown of proteins into amino acids and other chemical changes take place. Short chemical wither period favour the formation of theaflavins and thus liquor brightness increases [6]. [7] in their study found out that, reduction of normal withering time of 12 hours from traditional method to four hours in the modified method induced some favourable biochemical changes for enhancement in brightness and flavour quality in black tea infusion. Chemical wither for longer period produced liquor with better flavour quality and fuller cup characters [7]. Optimal fermentation duration should be established for every cultivar at different temperatures for production of high quality black teas [8].

The current work investigated the quality parameters of black CTC and Orthodox teas from TRFK 306. TRFK 6/8 was used as a control since it is a reference clone at the Tea Research Institute, Kenya. TRFK 306 is a new purple tea clone in Kenya and was commercialised in Kenya in 2011 and not much research on its manufacturing method has been done. Previously these authors studied other various purple leafed teas which are yet to be released for commercial utilization, except TRFK 306 including some green tea clones processed as CTC teas with uniform withering and aeration time [9]. Theaflavins, thearubigins, total colour, brightness percentage were investigated of all the products made and sensory evaluation done on those products processed through CTC method.

## Material and Methods

### Tea manufacture

The samples for analysis (both TRFK 306 and TRFK 6/8) were plucked from Timbilil estate of Tea Research Institute, Kericho (0˚22' South, 35˚21' East, elevation 2180m above mean sea level). The freshly plucked tea leaves were spread in withering troughs and allowed to wither for specific durations (5, 10, 15 and 20 hours) as desired. The withered tea leaves were then divided into two where some were processed as CTC teas and others as Orthodox teas. The withered tea leaves for CTC processing were put through the mini CTC machine and macerated three times to expose the enzymes for aeration and to get the required dhool. For orthodox teas, hand rolling was done by skilled workers for 20 minutes after the desired withering time.

Within each withering time, aeration was done at specific durations of 30, 60 and 90 minutes at controlled temperatures (22$^{o}$C for both wet and dry bulb temperatures) then tea drying was done using a Fluid Bed Drier (Tea Craft, UK). Drying was done initially at 120$^{o}$C to arrest the enzymatic reactions. When the aerated leaves had turned black, the temperature was lowered to 100$^{o}$C to avoid burning the tea. The drying time took 30 minutes. The unsorted and non graded teas were then packed in well labeled aluminum lined sachets and kept for future chemical and sensory analysis. There were 72 samples in total because each treatment was in triplicate, for example, teas withered for 5 hrs and aerated for 30 minutes were three samples.

### Determination of plain black tea quality parameters

### Determination of dry matter

2 ± 0.05 g of milled samples were weighed and heated in an oven at a temperature of 103 $\pm$ 2$^{o}$C for at least 8 hours to constant weight. The percentage dry matter was then calculated when all the moisture has been removed. Dry matter determination was necessary since all the parameters are expressed on dry weight basis.

### Reagents

The reagents were obtained from Sigma Aldrich through Kobian Kenya limited in Nairobi. Reagents used included; Isobutyl methyl ketone (IBMK), Flavognost reagent, ethanol, oxalic acid, distilled water, methanol, ethyl acetate, disodium hydrogen orthophosphate (1%). Water used was always double distilled and all the solvents used were of HPLC grade.

### Determination of theaflavin content in black tea using Diphenylboric acid 2- amino acid ethyl ester (Flavognost reagent)

Flavognost method was used to determine total theaflavins content [10]. A tea infusion was prepared by adding 375 ml of boiling distilled water into a tared vacuum flask with 9 g black tea then agitated in a mechanical shaker for 10 minutes. It was then filtered through a cotton wool into a flat bottomed flask. Tea liquor of 10 ml was pipetted into a test tube and 10 ml double distilled iso- butyl methyl ketone 4- methyl-penta-2-one (IBMK) added then shaken for 15 minutes and the test tube was left to stand to allow two layers to separate. From the upper layer, 2 ml was pipetted into a test tube and then 4 ml ethanol and 2 ml of diphenylboric acid 2-amino- ethyl ester were added and shaken for exactly 2 minutes. The colour was allowed to develop by letting the test tube stand for exactly 15 minutes and then absorbance (A) read quickly at 625 nm. The machine was first set with blank Ethanol/IBMK (1:1 v/v) before reading the samples.

$$\text{Theaflavin } (\mu\text{mol/g}) = A_{625} \times 47.9 \times \frac{100}{DM}$$

Where DM = Dry matter

**Rapid method for estimating thearubigins in black tea (Roberts's method)**

The Roberts's method was used to determine total thearubigins [11]. A tea infusion was prepared by adding 375 ml of boiling distilled water into a tared vacuum flask with 9 g black tea (the loss in mass at 103°C of 2 g of black tea sample by the method of ISO 1573 1980 (E) is determined) then agitated in a mechanical shaker for 10 minutes. It was then filtered through a cotton wool into a flat bottomed flask and allowed to cool to room temperature. Pipetting into a separating funnel under a fume-cupboard of 6 ml of the cooled infusion was done before adding 6 ml of 1 % (w/v) aqueous solution of anhydrous disodium hydrogen orthophosphate.

The mixture was vigorously shaken for one minute after adding 10 ml of ethyl acetate which does extraction then settling was allowed to take place. Two layers formed after settling and the lower layer was drained off carefully. Then 5 ml of ethyl acetate was added to the ethyl acetate extract containing theaflavin fraction in the separating funnel before drawing 10 ml of the extraction into a 25 ml volumetric flask. Methanol was used to top up to the mark and E1was obtained whose optical density was measured using 10 mm cell.

From the cooled tea infusion prepared above, 1ml was mixed with 9 ml of distilled water and made up to 25 ml in a volumetric flask with methanol, E2 was obtained whose optical density was also measured as E1 above. Still from the cooled tea infusion prepared above, 1ml was pipetted into a 25 ml volumetric flask and 8 ml of distilled water was added before adding 1ml of aqueous 10 % oxalic acid. Methanol was used to top to the mark and E3 was obtained ready for optical density measurement.

Optical densities of E1, E3 at 380nm and E1, E2 at 460nm using the 10 mm cell was measured.

Calculation of thearubigins,

$$\text{TR\%} = 7.06\,(4E3 - E1) \times DM\%$$

Total colour was calculated as shown. At 460nm:

$$\text{Total Colour\%} = 6.25 \times 4E2 \times DM\%$$

(Roberts method)

$$\text{\% Brightness} = \frac{E1}{4E2} \times 100$$

**Determination of total colour (TC) by Flavognost method**

From the cooled tea infusion prepared above, 5 ml was pipetted into a 100 ml conical flask and 45 ml of distilled water added then thoroughly mixed by shaking. The absorbance was read at 460 nm after zeroing with distilled water as blank (E4).

$$\text{TC} = \frac{E4 \times 10/DM}{100} = \frac{E4 \times 1000}{DM}$$

**Sensory evaluation**

Five grams of the sample was transferred to an infusion cup and boiling distilled water added, covered and left to steep for five minutes. This was then filtered into an infusion bowl and the residue (infusion) collected on the infusion cup lid. Both the liquor and infusion were then tasted accordingly. The liquor was sipped by the taster with a spontaneous breath which brought the liquor in contact with the tongue and other parts of the mouth, sensitive to astringency and flavour. There were 72 samples and they were tasted by at least three experienced regular tasters in six different tea factories in Kisii County, Kenya. Each tea taster was given a sheet and requested to taste and make individual comments without the influence of the other tasters. The tasters were allowed to describe the teas using the usual terms used in tea tasting and then the researchers analysed and scored using a scale which was developed and described by [12], with modification where the highest score denoted the best. The score ranged from 1-5.

**Statistical analysis**

Completely randomized design with three replications was adopted for this study. Data analysis was done using General Linear Model of Statistical Analysis System software (SAS, version 9.1.3). Least significant difference (LSD) test was used to separate means.

**Results and Discussion**

The study investigated quality of black tea from TRFK 306, a purple tea clone in Kenya which has been released for commercial utilization. Clone TRFK 6/8 was used as a reference standard in the study since it is used in Kenya as a quality standard clone in most trials because of its high quality. Withering hours varied with five hour interval from five hours to twenty (20) hours for both clones and processing method of CTC and orthodox were used. Within each withering regime, aeration was varied with thirty (30) minutes interval from 30 - 90 minutes. Along the x-axis in the figures we have withering/aeration time representing the above combination.

So we have for example, 5//30 representing five hours withering and 30 minutes aeration, 5//60 representing five hours withering and sixty minutes aeration and so on and so forth up to 20//90 representing twenty hours withering and ninety minutes aeration. The clones are represented by 306 and 68 for TRFK 306 and TRFK 6/8, respectively. The processing methods are represented by CTC and ORTHO for CTC and orthodox respectively. In the figures we have 306ORTHO, 306CTC, 68ORTHO and 68CTC representing TRFK 306 processed through orthodox method and CTC and TRFK 6/8 processed through orthodox and CTC respectively. This explanation replaces key against each figure/graph which could otherwise have been verbose and lengthy.

**Total theaflavins content (TF)**

The results of theaflavins expressed in µmoles/g are presented in fig. 1. It can be observed that, black tea from both clones processed through orthodox method (rolling) has lower theaflavins than teas processed through CTC maceration. This could be because during CTC there is full maceration hence more surface area for reaction and oxidation of catechins and consequently more theaflavins. On the other hand, in rolling (orthodox), the tea leaves are left almost whole and there is less release of biochemical for oxidative reaction and hence less theaflavins. Black orthodox tea from TRFK 306 showed higher theaflavins than orthodox teas from TRFK 6/8 [13].

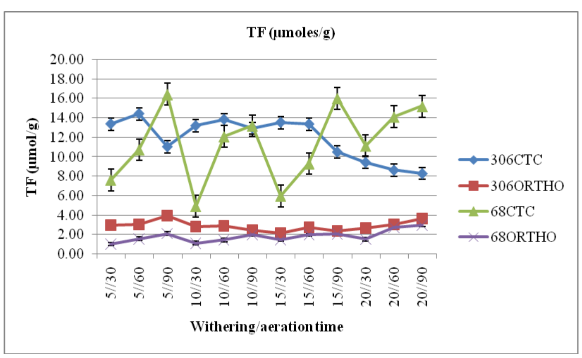


**Figure 1: Effect of processing method (CTC and Orthodox), withering durations (5-20 hours) and aeration time (30-90mins) on total theaflavins concentration in µmol/g of TRFK 306 and TRFK 6/8 tea clones. Key CTC- Cut, Tear and Curl, ORTHO stands for Orthodox**

These results agrees with [14] findings where they found out that, higher levels of theaflavins were recorded in orthodox black tea from purple shoots compared to black tea made from green shoots. CTC teas from TRFK 306 had higher TF especially in teas withered up to 15 hrs and aerated for 30 and 60 minutes than TRFK 6/8 but lower TF when withered for 20 hrs withering. TRFK 6/8 on the other hand had relatively higher TF at 90 minutes aeration time irrespective of the withering hours than TRFK 306.

These are good findings especially for Kenya who is leading in black CTC tea export. The purple clone can still be processed into black tea. The effect of withering duration was noticeable between the clones. TRFK 306 had higher theaflavins for shorter withering duration and reduces with increasing withering duration especially for CTC teas as the thearubigins slightly increase. This could be because of oxidative degradation of theaflavins to form thearubigins [15]. TRFK 6/8 had noticeable increasing theaflavins with increasing withering duration and aeration time.

**Total thearubigins (TR)**

Black orthodox teas from both clones had lower levels of thearubigins than black CTC teas. This is expected because there is more surface area for oxidative reaction in CTC teas than in orthodox teas. CTC teas from TRFK 6/8 and TRFK 306 and orthodox teas from TRFK 6/8 showed noticeable effect on aeration duration where there was a gradual increase in thearubigins with increase in aeration time. This might have led to increased liquor body (thickness) in CTC teas of both clones, fig. 7. The increase in thearubigins with aeration time concurred with other researchers [15] [16]. Thearubigins increases with increase in withering time up to a certain level [17].

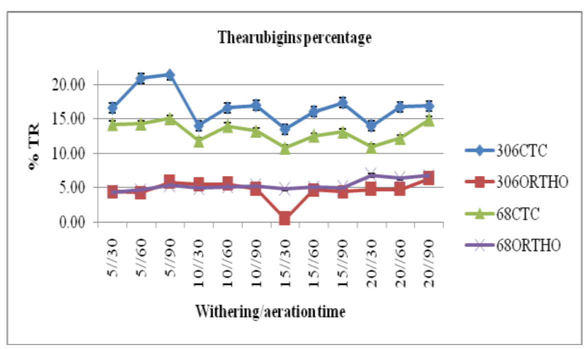


**Figure 2: Effect of processing method (CTC and Orthodox), withering durations (5-20 hours) and aeration time (30-90mins) on thearubigins percent of TRFK 306 and TRFK 6/8 tea clones. Key CTC- Cut, Tear and Curl, ORTHO stands for Orthodox**

**Total colour (by Roberts and Flavognost) and liquor brightness**

The results are presented in figure 3, 4 and 5. The teas processed via orthodox method of both clones had lower total colour than black CTC teas. This could be due to the theaflavins content variations. The higher the theaflavins the better the colour [9]. Brightness percentage results are presented in fig. 5. The brightness percentage of TRFK 306 processed by CTC method showed significant effect ($P<0.05$) on withering time and aeration. TRFK 306 CTC and orthodox teas had generally higher brightness in all the 30 minutes aeration time in all the withering duration relative to longer aeration time except for five hours withering. This could be because of noticeable lower levels of thearubigins in 30 minutes aeration especially in CTC teas. The brightness for CTC teas from TRFK 306 increases after ten hours wither and was highest at fifteen hours wither and thirty minutes aeration but decline on subsequent longer withering time. These results concurs with [18] who noted that theaflavins contribute to brightness and long fermentation times produced more colour in black tea at the expense of brightness. Orthodox teas from TRFK 306 had a similar trend except for five hours wither with thirty minutes aeration which showed relatively lower brightness percentage [18].

The decrease in brightness with increase in aeration time for CTC teas from TRFK 306 could be due to the increase in thearubigins with increase in aeration time and decrease in theaflavins with increase in aeration time. Theaflavin is responsible for black tea brightness and briskness [19]. Black CTC teas from TRFK 6/8 aerated for 30 minutes had relatively lower brightness percentage with respect to other longer aeration time except for teas withered for twenty hours and aerated for thirty minutes (20//30).

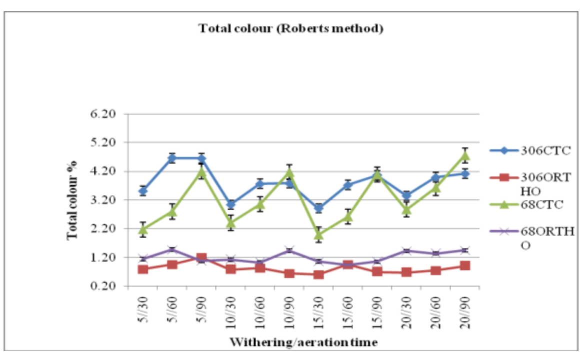


**Figure 3: Effect of processing method (CTC and Orthodox), withering durations (5-20 hours) and aeration time (30-90mins) on total colour percent by Roberts method of TRFK 306 and TRFK 6/8. Key CTC- Cut, Tear and Curl, ORTHO stands for Orthodox**

This could be because of lower theaflavins at thirty minutes aeration time for teas processed through CTC relative to longer aeration time. Black orthodox teas from TRFK 6/8 showed increasing brightness with increase in aeration time within a specific withering time. This could be due to the increase in theaflavins level with increase in aeration time, fig. 1.

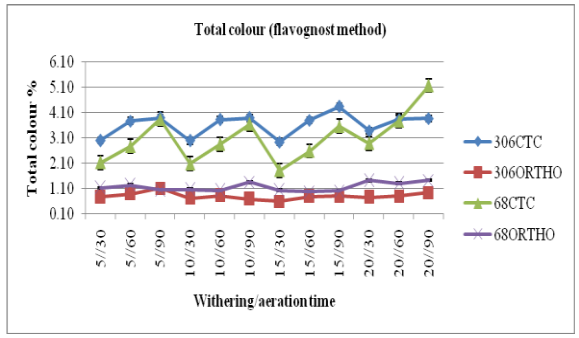


**Figure 4: Effect of processing method (CTC and Orthodox), withering durations (5-20 hours) and aeration time (30-90mins) on total colour percent by Flavognost method of TRFK 306 and TRFK 6/8. Key CTC- Cut, Tear and Curl, ORTHO stands for Orthodox**

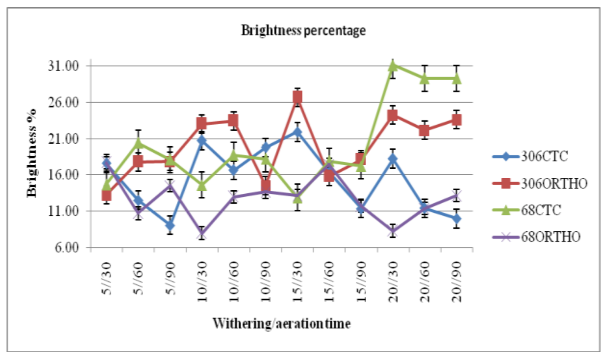


**Figure 5: Effect of processing method (CTC and Orthodox), withering durations (5-20 hours) and aeration time (30-90mins) on brightness percent of TRFK 306 and TRFK 6/8. Key CTC- Cut, Tear and Curl, ORTHO stands for Orthodox**

**Sensory evaluation:** Since CTC teas showed higher theaflavins, thearubigin contents and total colour than orthodox teas, they were subjected to organoleptic analysis using experienced tasters to further confirm the suitability of making black tea from TRFK 306. The results are presented in fig. 6 - 10. Each product was tasted and it's liquor colour, liquor body, liquor strength, liquor briskness and infusion colour was described by every taster then scoring was done using a score scale developed by [12] with modification where the highest score denoted the best and vice versa, scale of 1-5. This was necessary since during sensory evaluation of black tea, the tasters' judgment is usually based on the colour, strength, briskness, flavor and overall quality of the tea [10]). The teas were coded such that the taster never knew which clone or the treatment the teas have been subjected to for objective results.

**Liqour colour:** This denotes the brightness of the liquor, the brew itself. The liquor can be coppery bright as in TRFK 6/8 if optimum manufacturing conditions are applied, it can also be dull which is not desirable. The levels of theaflavins and thearubigins influences the liquor brightness such that the higher the theaflavins the brighter the teas and the higher the thearubigins the duller the teas since theaflavins are known to contribute to briskness and brightness of tea liquor whilst thearubigins are responsible for the colour and body of the liquor [20].

TRFK 306 results showed there was a significant difference at $p < 0.05$ among the products produced by varying withering and aeration time. Product of ten hours wither and aeration of thirty minutes (CTC10//30) had liquor colour score of 2.83 and the highest while withering for twenty hours and aerating for ninety minutes (CTC 20//90) had the least liquor colour score of 1.69. It was not conclusive here that the significant difference ($p < 0.05$) was due to withering duration, it is however noticeable that aeration time affects the liquor colour. Within each withering regime (5, 10, 15 and 20 hours), the liquor colour decreases with increasing aeration time such that teas aerated for thirty (30) minutes had better liquor colour than teas aerated for ninety (90) minutes (Figure 6). This could be because the thearubigins influences liquor colour hence brightness negatively [21] and from fig. 2 it can be noted that teas aerated for ninety minutes had more thearubigins than teas aerated for thirty minutes.

Effect of withering and aeration time on liquor colour was observed in black CTC teas from TRFK 6/8 with significant difference at $p < 0.05$, fig. 6. Liqour colour was found to improves with increasing aeration time and withering hours especially after ten hours of wither up to withering hours of twenty and aeration time of sixty minutes (20//60). The liquor colour declined after 20//60 and teas withered for twenty hours and aerated for ninety minutes (20//90) recorded second lowest liquor colour score of 2.55, teas withered for ten hours and aerated for thirty minutes (10//30) had the lowest score of 2.47. This could be because it had the lowest theaflavins with 4.89µmol/g, fig. 1. Theaflavins contribute to liquor colour, strength, briskness though other components such as thearubigins, caffeine and volatile compounds also have some effects according to [22].

Theaflavins improved with increasing aeration time from these results, however, high thearubigins, affects the liquor colour negatively [9] [16], [20]. Teas withered for twenty hours and aerated for ninety minutes from TRFK 6/8 showed low liquor colour because it had high thearubigins, even teas withered for five hours and aerated for ninety minutes had high thearubigins and consequently lower liquor colour.

**Liqour body**: This indicates the thickness of the liquor, the thicker the liquor the better the quality and light thin liquors are not preferable. Thearubigins formed during fermentation contribute to the mouth feel (thickness) and colour (reddish brown) of the tea [23]. Liqour body results of black CTC teas from TRFK 306 are presented in fig. 7. Though there was no significant difference in liquor body at $p < 0.05$, from the figure, it can be observed that there is noticeable effect on aeration time where the liquor body improves with increase in aeration time. Within every withering regime, ninety minutes aeration had better liquor body for teas from TRFK 306. This could be because of higher thearubigins (TR %) at every ninety minutes aeration time since thearubigins are responsible for thickness and colour of both the liquor and infusion [24]. Teas withered for five and ten hours and aerated for ninety minutes (5//90 and 10//90) had relatively higher scores of liquor body and 5//90 had the highest TR% of 21.41%, fig. 2. Liqour body for teas from TRFK 6/8 also improves with increasing aeration time irrespective of withering duration, with ninety minutes aeration time having better liquor body across the withering regime. Teas which had been withered for ten and fifteen hours and aerated for ninety minutes (10//90 and 15//90) had the highest score of 3 in liquor body. This trend is following the TR% trend in Fig. 2, where ninety minutes aeration time had relatively higher TR % across the entire withering regime.

**Liqour strength**: There was a significant difference in liquor strength at $p < 0.05$ in both black CTC teas from TRFK 306 and TRFK 6/8, fig. 8. Teas from TRFK 306 which were withered for five hours and aerated for thirty minutes had the highest liquor strength score of four (4) as shown in fig. 8. This could be due to the high level of theaflavins as shown in fig. 1. The strength, however, decreases sharply with increase in aeration time and withering up to ten hours wither and sixty minutes aeration (10//60) time.

This is unexpected and it calls for more research so as to demystify this. The strength however improves rapidly with increasing withering hours and aeration time up to twenty hours withering time and sixty minutes aeration time (20//60). This can be linked to the increase in theaflavins because the higher the theaflavins, the stronger the cup [9] [22]. The high liquor strength score of 20//60 treatment could be because of high level of TRs since TRs contribute to the strength and colour of tea liquor [25]. Teas from TRFK 6/8 showed significant difference at $p < 0.05$ in liquor strength. Teas aerated for longer aeration, sixty and ninety minutes have better liquor strength irrespective of duration of withering than teas aerated for thirty minutes. Teas withered for fifteen minutes and aerated for ninety minutes had relatively higher theaflavins (Figure 1), and consequently relatively higher liquor strength score of 3.67 and those withered for ten hours and aerated for thirty minutes recorded the lowest theaflavins value of 4.89µmol/g, fig. 1 and consequently the lowest score of 1.77 in liquor strength.

**Liqour briskness**: There was no significant difference ($p< 0.05$) on liquor briskness with withering and aeration time, for both clones. TRFK 306 teas which were withered for twenty hours and aerated for sixty minutes and teas withered for fifteen hours and aerated for ninety minutes had relatively higher liquor briskness score of 3.61 and 3.44, respectively, fig. 9. Teas from TRFK 306 which were aerated for sixty minutes had relatively higher theaflavins and consequently relatively higher briskness. TRFK 6/8 teas withered for ten hours and aerated for thirty minutes and those which were withered for fifteen hours and aerated for sixty minutes had relatively higher liquor briskness score of 4 each fig. 9. Liqour briskness increased with increasing withering and aeration time for TRFK 6/8 teas though not significant at ($p< 0.05$). This could be because of higher theaflavins with increase in withering and aeration time (figure 1).

**Infusion colour:** There was significant difference ($p< 0.05$) on infusion colour of teas from TRFK 306 with teas withered for shorter time having less bright infusions than teas withered for longer time but there was no significant difference ($p< 0.05$) for teas from TRFK 6/8 on the infusion colour. Fig. 10 depicts scores of infusion colour of black CTC teas from both TRFK 306 and TRFK 6/8. Teas from TRFK 306 withered for five hours and aerated for thirty and ninety minutes scored low in infusion colour, with a score of 2. This could be because of high thearubigins since thearubigins are responsible for thickness and colour of both the liquor and infusion [24]. Teas from TRFK 306 withered for twenty and ten hours and aerated for thirty minutes had relatively lower thearubigins as shown in fig. 2 and consequently scored relatively higher in infusion colour with scores of 3 and 2.9, respectively. Teas from TRFK 6/8 aerated for ninety minutes had relatively higher theaflavins, fig. 1 and consequently scored high in Infusion colour, fig. 10. Though theaflavins influences infusion colour positively [9], these results reveals that thearubigins has more effect on infusion colour of TRFK 306 while theaflavins have more effect on infusion colour in TRFK 6/8 teas.

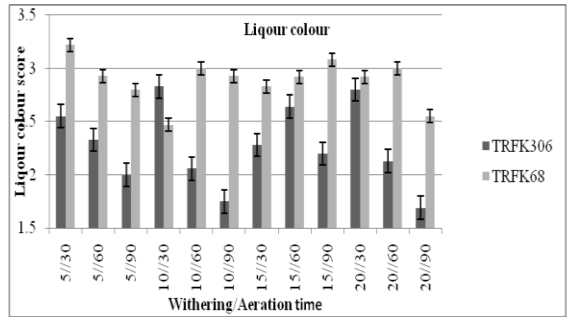


**Figure 6: Effect of withering durations (5-20 hours) and aeration time (30-90mins) on taste scores on liquor colour of CTC teas from the studied clones**

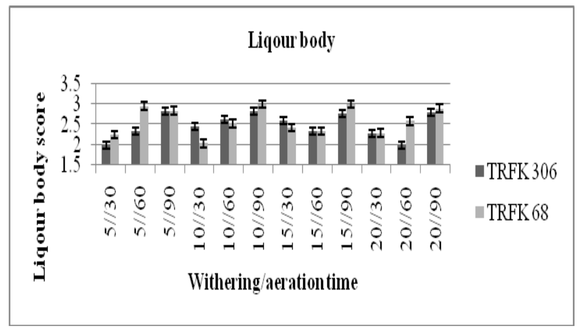


**Figure 7: Effect of withering durations (5-20 hours) and aeration time (30-90mins) on taste scores on liquor body of CTC teas from the studied clones**

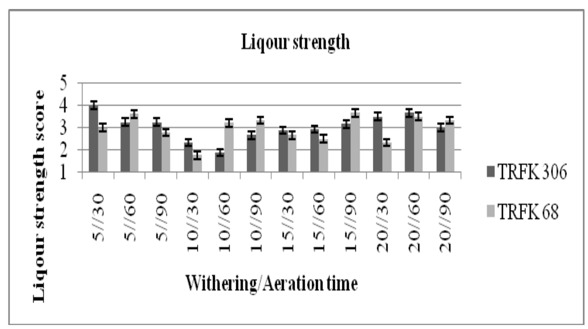


**Figure 8: Effect of withering durations (5-20 hours) and aeration time (30-90mins) on taste scores on liquor strength of CTC teas from the studied clones**

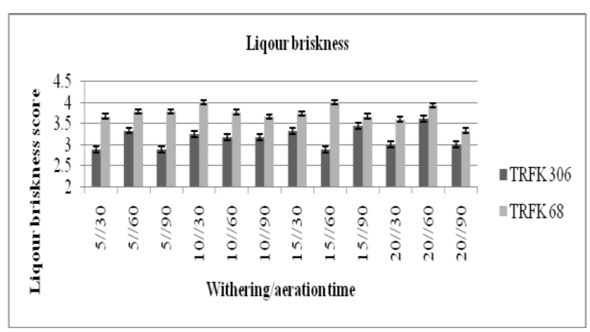


**Figure 9: Effect of withering durations (5-20 hours) and aeration time (30-90mins) on taste scores on liquor briskness of CTC teas from the studied clones**

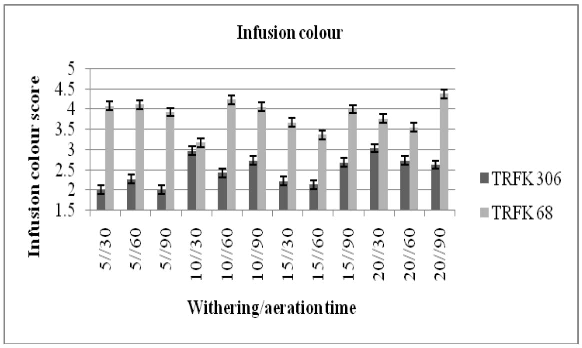


**Figure 10: Effect of withering durations (5-20 hours) and aeration time (30-90mins) on taste scores on liquor infusion colour of CTC teas from the studied clones**

**Conclusion**

Quality of black CTC teas from TRFK 306 is best produced with shorter withering duration of between 5-10 hours. The best quality parameters of teas from TRFK 306 can be obtained when withered for ten hours and aerated for ninety minutes. Fifteen hours wither can be used but aeration time should not exceed sixty minutes. TRFK 6/8 black CTC teas on the other hand are best produced at ninety minutes aeration time irrespective of withering time. Black orthodox teas from TRFK 306 are best produced using twenty hours withering time and aeration of ninety minutes, based on the chemical quality parameters obtained. Black orthodox teas from TRFK 6/8 also require longer aeration time but withering for fifteen hours and aerating at sixty minutes produces best quality parameters. CTC teas produce better quality black teas than orthodox teas. TRFK 306 produces better quality black teas than TRFK 6/8 based on the chemical quality parameters analysed, irrespective of processing method. However, it scored relatively low in tea tasting and this could be because TRFK 306 is still new in the market and should probably be described using different terminologies from those used with the green clones.

**Acknowledgement**

The authors acknowledge the Institute Director, Dr. David Bore and Centre Director, Dr. Samson Kamunya for providing equipment, the chemical reagents and the raw materials used in the study and for granting us permission to publish this work. The authors also appreciate the technical support of staff from Tea Processing and Value Addition Programme of the Tea Research Institute, Kericho.

**References**

1. Watts R., Improving farmer's income. *Africa Farming and Food Processing*, **9:** 26-28 **(1999)**

2. Anonymous, Annual bulletin of statistics. International Tea Committee (London) **(2015)**

3. Hicks A., Current status and future development of global tea production and tea products, *AU. J. l of Tech.*, **12(4):** 251–264 (**2009)**

4. https://www.worldoftea.org/cultivar/trfk-306/ visited on 28th Feb 2017.

5. Jansen M.A.K., Gaba V. and Greenberg B.M., Higher plants and UV-B radiation balancing damage, repair and acclimation. *Trends in Plant Sci.*, **3 (4)**:131-135 **(1998)**

6. Obanda M. and Owuor P.O., The effect of chemical wither duration and dryer type on quality of black tea manufactured in a commercial factory. *Tea*, **13(1):** 50-61. (**1992**)

7. Baruah D., Bhuyan L.P. and Hazarika M., Impact of moisture loss and temperature on biochemical changes during withering stage of black tea processing on four Tocklai released clones. *Two and a Bud*, **59(2)**: 134-142. **(2012)**

8. Asil M.H., Rabiei B. and Ansari R.H., Optimal fermentation time and temperature to improve biochemical composition and sensory characteristics of black tea. *Austra. J. of Crop Sci.*, **6(3)**: 550-558 **(2012)**

9. Kilel E.C.,Wanyoko J.K., Faraj A.K. and Wachira F.N., Plain black tea quality parameters of purple leaf coloured tea clones in Kenya, *Int. J. Res. Chem. Environ.*, **3 (3 July)**, 81-88 (**2013**)

10. Hilton P. J., *Tea. In: Ency .of Indust. Chem. Analysis. Snell, F.D. and Ettre, L.C.* **18:** 455-516 **(1973).** John Wiley, New York.

11. Roberts E.A.H. and Smith R.F., Phenolic substances of manufactured tea.11. Spectrophotometric evaluation of tea liquors, *J. Sci. Food Agri.*, **14:** 689-700 **(1963)**

12. Kilel E.C., Wanyoko J.K., Faraj A.K. and Wachira F.N., Variation in theaflavins and catechins contents in processed leaf from the purple tea varieties in Kenya, *Tea,* **33 (2),** 95-104 (**2012**)

13. Owuor P.O. and Reeves S.G., Optimizing fermentation time in black tea manufacture, *Food Chem.*, **21**, 195 **(1986)**

14. Joshi R., Rana A and Gulati A., Studies on quality of orthodox teas made from anthocyanin-rich tea clones growing in Kangra valley, India, *Food Chem*., **1**; 176:357-66 (**2015**)

15. Robertson A., The chemistry and biochemistry of black tea production, the non volatiles. In K. C. Wilson & M. N. Clifford (Eds.), Tea: Cultivation to consumption (pp. 555–601). **(1992)**. London, UK: Chapman and Hall.

16. Ngure F. M., Wanyoko J. K., Mahungu S. M. and Shitandi A.A., Catechin depletion patterns in relation to theaflavins and thearubigin formation, *Food Chem.,* **115 (1):** 8-14 **(2009)**

17. Ullah M.R., Gogoi N. and Baruah D., The effect of withering on fermentation of tea leaf and development of liquor characters of black teas, *J. of the sci. of Food and Agric*., **35 (10):**1142-1147 (**1984**)

18. Owuor P.O., Obanda M., Nyirenda H.E. and Mandala W.L., Influence of region of production on clonal black tea chemical characteristics. *Food Chem*.,**108**, 263-271 **(2008)**

19. Borah A., Gogoi T. P., Gogoi M. K., Kalita M. M., Dutta P., Das P.J and Tamuly P., Biochemical approach to the study of chemical basis of stress during tea processing. *Two and a Bud.* **59(2):** 74-77 **(2012)**

20. Hilton P.J. and Ellis R.T., Estimation of the market value of Central African tea by theaflavins analysis. *J. Sci. Food Agric*., **23**: 227-232 **(1972)**

21. Obanda M., Owour P.O. and Mangoka R., Changes in the chemical and sensory quality parameters of black tea due to variations of fermentation time and temperature. *Food chem.*, **75**: 395-404 **(2001)**

22. Owuor P.O., Can theaflavins content alone be adequate parameter in black tea quality estimation? A review, *Tea*, **3**: 36-40 **(1982)**

23. Biswas A.K., Sarkar A.R. and Biswas A.K., Biological and chemical factors affecting the valuations of North-East Indian Plains teas. II. Statistical evaluation of the biochemical constituents and their effects on briskness, quality and cash valuations of black teas. *J. Sci Food Agric*., **22 (4):**196-204 (**1971)**

24. Biswas A.K., Sarkar A.R., and Biswas A.K., Biological and chemical factors affecting the valuations of North East India planters. III. Statistical evaluation of the biochemical constituents and their effects on colour, brightness, and strength of black teas, *J. Sci. and Food Agric*., **24**: 1457–1477 **(1973)**

25. Tomlins K.I., Mashingaidze A. and Temple S.J., Review of withering in the manufacture of black tea, TRF QNL **122**, 12-20 **(1996)**