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Optimising Fermentation Time in Black Tea Manufacture*

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ABSTRACT

A comparative study using in-line theaflavins analysis (ILTF), theaflavins of made-tea analysis (TFMT) and tasters' evaluations, to optimise fermentation during tea manufacture, was carried out. All methods obeyed a quadratic relationship with time. On average, the optimum fermentation times were 107·7, 135·3, 136·2 and 147·4 min for ILTF, TFMT, taster D and taster E, respectively. Linear relationships between different methods had good correlation coefficients but TFMT and tasters' evaluations related best. In the absence of a taster, TFMT can be used to optimise fermentation time in tea processing.

INTRODUCTION

Tea is manufactured from the young, tender plucked leaves of *Camellia sinensis* (L.) O. Kuntze. Post-harvest stages in tea manufacture have a major effect on the quality of the final product (black made tea). It is important that the proper procedure is followed to obtain the best quality from the leaf. Four main post-harvest steps are involved in tea processing. First, there is a withering step, which involves loss of moisture, accompanied by the softening of the leaf to allow proper

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comminution for the next stage (fermentation) and formation of some aroma compounds. Secondly, the leaf is comminuted, breaking down the cellular matrix and structure, thus allowing the enzymes and catechins to mix. Thirdly, with a proper supply of oxygen, the comminuted leaf undergoes fermentation and, finally, the tea is fired, i.e. the fermented leaf is subjected to high temperature to remove moisture and denature the enzymes, thus stopping fermentation.

Fermentation in black tea manufacture is a critical step in processing. Most of the important chemical transformations occur during this stage. Notably, the polyphenols (i.e. catechins or flavanols) undergo polyphenol oxidase-initiated reactions leading to the formation of mainly two groups of compounds; namely, theaflavins (TF) and thearubigins (TR). The formation of these two groups of compounds is competitive (Robertson, 1983). At the start of fermentation the rate of formation of TF is similar to that of TR (Robertson, 1983). At later stages, the situation changes and possibly some TF is transformed to TR. The amount of TF formed determines brightness (i.e. the quality aspect which produces clear liquor with good coppery colour, as opposed to dull colour) and briskness (the degree of pungency), while thickness, or the mouth feel of the liquor, and colour of the infusion (which may be red or brown with varying intensities) are largely determined by TR content. During fermentation, some flavour compounds are also developed (Bhatia, 1964).

To realise high prices in teas it is important, in tea manufacture, to produce teas which have an optimum balance of TF and TR as dictated by market demands. A market that prefers brisker and brighter tea will require tea with a higher TF:TR ratio, while a market looking for thicker and coloury tea will require tea with a slightly lower TF:TR ratio. During manufacture of black tea, the TF:TR ratio can be changed by varying fermentation time. Normally during this time, the tea goes through four stages. At the initial stage, the tea is under-fermented. During this time not enough TF or TR has been formed. In the next stage, the tea has a high TF:TR ratio. The taste of the tea at this point is very brisk and it has maximum brightness due to the formation of maximum TF. In the subsequent stage of fermentation, the TF:TR ratio slightly decreases. This is due to the fact that TR continues to be formed, while formation of TF is competing less effectively with the transformation of TF to TR. The tea, at this stage, has its maximum thickness and colour. If fermentation is allowed to proceed past this stage, the tea produced normally tastes flat (i.e. lacks briskness) and muddy (i.e. produces dull liquors resulting from over-fermentation). Much of the TF is now transformed into TR; hence, the loss of brightness. The only teas suitable for sale are those fired (dried) at either the second or third stages of fermentation. Thus, provided all the manufacturing procedures are carried out correctly, it is important to determine the time to start firing, to stop fermentation, in order to obtain the best quality tea. Whether to stop at the second or third stages of fermentation is largely dependent on the market where the tea is to be sold.

Visual assessment of 'dhool' (fermentating comminuted leaf) by factory personnel has been used with a lot of success to determine optimum fermentation time. However, due to its subjectivity, other methods have been developed, with varying success, to optimise fermentation time. Such methods include: monitoring of reduction in the epigallocatechin gallate (EGCG), concentration in the process of fermentation (Bhatia, 1960), measuring the extent of colour change during fermentation (Roberts & Chandradasa, 1982), measuring formed TF, TR and thearubigin polymers (TRP) during fermentation (Takeo, 1974) and an in-line TF method of analysis of TF development during fermentation (Cloughley, 1979, 1980). Owuor (1984) reported preliminary results of comparative methods of optimising fermentation time. The in-line TF analysis method (ILTF) (Cloughley, 1979, 1980), determination of TF contents of the made teas (TFMT) after different fermentation times and tasters' evaluations of the teas were the methods used. The curves obtained in the earlier study were eye-fitted and although there were significant implications, no firm and definitive conclusion could be reached because regression analysis of the data was not carried out. In this paper the regression analysis results of the data and the implications therefrom are reported and discussed.

MATERIALS AND METHODS

Seedling stock 47, clones 6/8, 7/3, 7/14, 31/8, 31/11, 54/40, 47/1, 100/2, 108/82, 301/4, 301/5 and 301/6 from Botany Department Clonal Field Trials at the Tea Research Foundation of Kenya, Kericho (altitude, 2178 m above mean sea level and longitude, 0° 22′ south) were used. Methods were the same as those reported earlier (Owuor, 1984) except for the regression analysis and the use of an additional taster in some experiments (see Tables 2 and 3 for experiments using two tasters).

A quadratic regression programme was used to determine the relationship between fermentation time and ILTF method, TFMT analysis and tasters' evaluation.

The relationship between any two methods of optimising fermentation time was determined using a linear regression programme.

RESULTS

The percentages of significant experiments are listed in Table 1 for the different methods of optimising fermentation. The relationships were usually statistically significant up to $P \leq 0{\cdot}001$. Occasionally, the relationships were not significant. Where there was a significant relationship at $P \leq 0{\cdot}05$, the equation was used to determine the optimum fermentation time. The optimum fermentation time, as assessed by any of the methods, was defined as the time when there was a maximum value for the measurements being made, followed by decline, i.e. point of inflexion on the curves from the generated quadratic equations. The optimum fermentation times, as assessed by the different methods, are presented in Table 2. When the optimum fermentation time fell outside the maximum fermentation time in the experimental design and when the quadratic equations were not significant, the data were omitted in Table 2. On average, optimum fermentation times were 107·7, 135·3, 136·2

TABLE 1
The Distribution, With Time, of Significance Levels of Quadratic Regressions of Different Methods of Assessing Optimum Fermentation Time

Method	*Total number of experiments*	*Percentage experiments significant at LSD*		
		0·05	*0·001*	*NS*
ILTF	25	92	92	8
TFMT	25	96	92	4
Taster D	25	88	81	12
Taster E	8	100	100	0

NS, r not significant at $P \leq 0{\cdot}05$.

TABLE 2
Optimum Fermentation Time (min) as Assessed by Different Methods

Exp. No.	*Clone*	*TFML*	*ILTF*	*Taster D*	*Taster E*
785	31/8	NS	112	150	
789	100/82	134	116	140	
792	100/5	123	125	155	
797	54/40	141	108	142	
800	7/14	—[a]	125	168	
802	74/1	165	109	159	
803	31/8	171	124	NS	
805	7/14	151	109	NS	
806	74/1	137	111	157	
808	31/8	145	99	149	
810	30/4	113	97	129	
814	ST 47	105	113	—[a]	
819	301/5	120	NS	133	
826	301/6	104	NS	NS	
831	301/5	97	76	113	
834	310/4	106	82	120	
838	31/8	147	113	65	
840	31/8	132	105	129	144
841	31/8	138	123	140	136
844	31/8	140	103	133	147
847	7/3	133	115	131	155
850	31/8	143	110	126	156
854	6/8	—[a]	112	152	151
857	31/11	178	96	143	137
861	31/8	137	94	127	154
Mean		135·3	107·7	136·2	147·4

[a] Optimum fermentation time outside experimental time.
NS, r is not significant at $P \leq 0{\cdot}05$.

and 147·4 min for the ILTF and TFMT methods, taster D and taster E evaluations, respectively.

The different methods of optimising fermentation time were related by linear regression equations. Table 3 presents the correlation coefficients of such relationships. For each set of correlations, the standard deviation (SD) from the average correlation coefficient is presented as a percentage of the mean.

TABLE 3
Correlation Coefficients or Linear Regression Equations for Different Methods of Optimising Fermentation Time

Exp. No.	*Clone*	*TFNT vs ILTF*	*TFMT vs Taster D*	*ILTF vs Taster D*	*TFMT vs Taster E*	*ILTF vs Taster E*	*Taster D vs Taster E*
785	31/8	0·55	0·98	0·59			
789	108/82	0·88	0·91	0·86			
792	100/2	0·97	0·97	0·93			
797	54/40	0·85	0·97	0·85			
800	7/14	0·35[a]	0·98	0·86			
802	74/1	0·72	0·99	0·77			
803	31/8	0·89	0·96	0·92			
805	7/14	0·72	0·69	0·78			
806	74/1	0·79	0·79	0·72			
808	31/8	0·57	0·97	0·55			
810	301/4	0·77	0·86	0·66			
814	ST 47	0·89	0·72	0·80			
819	301/5	0·41[a]	0·85	0·10[a]			
826	301/6	0·37[a]	0·79	0·12[a]			
831	301/5	0·77	0·90	0·54[a]			
834	301/4	0·61	0·89	0·46[a]			
838	31/8	0·86	0·95	0·87			
840	31/8	0·85	0·95	0·90	0·95	0·69	0·86
841	31/8	0·92	0·97	0·94	0·49	0·86	0·89
844	31/8	0·70	0·95	0·72	0·96	0·67	0·93
847	7/3	0·90	0·89	0·95	0·85	0·74	0·92
850	31/8	0·82	0·95	0·91	0·92	0·71	0·85
854	6/8	0·68	0·70	0·69	0·48	0·63	0·89
857	31/11	0·48[a]	0·90	0·61	0·81	0·42[a]	0·87
861	31/8	0·46[a]	0·39[a]	0·65	0·90	9·46[a]	0·90
Mean		0·71 (26·2)	0·91 (8·5)	0·71 (32·1)	0·89 (6·2)	0·64 (22·3)	0·88 (3·1)

[a] r, Non-significant at $P \leq 0{\cdot}05$.
Numbers in parentheses are standard deviations expressed as per cent of the mean.

DISCUSSION

Tea sales are usually based on tasters' evaluations. The best indicator of high quality tea is therefore the tea taster. Factory personnel therefore make efforts to produce teas which are considered best by the tea tasters.

For their evaluations, the tea tasters obtain guidance from the demands of the tea markets for which they are catering. It is consequently not uncommon to find some tasters preferring brisker teas to thicker and more coloury teas, and vice versa. In optimising fermentation time, it is considered best that either a tea taster be used to judge the qualities of made teas or a method equivalent to the tea taster be used.

The optimum time of the ILTF method was, on average, ahead of that of tasters D and E by 28·5 and 39·7 min, respectively (Table 2). If this method is used to optimise fermentation time under our conditions of manufacture, care must be taken to give the tea an extra 35 min, on average, of fermentation. This difference in time varied from day to day and with the type of tea being manufactured (Table 2). The TFMT method of analysis also lagged in optimum fermentation measurement, compared with the ILTF method, by 27·6 min on average. Even in Malawi where the ILTF method has been recommended for use in factories (Cloughley, 1979, 1980) a lag of 25 min exists (Hilton, 1975).

Optimum fermentation, as assessed by taster D, was slower than that assessed by the TFMT method by only 0·9 min. It is therefore apparent that taster D preferred brisker and brighter teas with highest TF contents. Optimum fermentation time, as assessed by taster E, was the longest, i.e. 147·4 min on average. The difference between average optimum fermentation time, as assessed by taster E and the TFMT method, was 12·1 min. This implies that taster E preferred more TR (Hilton & Palmer-Jones, 1975) and slightly less TF in tea, i.e. taster E preferred thicker and more coloury teas.

The best alternative method to using a tea taster to determine the optimum fermentation time would be that which has the best linear relationship to tasters' evaluations. Table 3 gives the coefficient values (r) of such correlations. It is noticed that, although the ILTF method related well to the tasters' evaluations, the standard deviation was very large, indicating that the method is unreliable. The TFMT method, however, related better to both the tasters' evaluations and the standard deviation of the mean correlation coefficients was low. Therefore, in the absence of a taster or a reliable scientific method that would best estimate optimum fermentation time in the manufacture of Kenyan black teas, the TFMT method appeared to be the best alternative.

There is a further implication in these results that deserves discussion. The difference between the pattern of TF production and destruction, as measured by the two different TF analysis techniques, was considerable. In the case of ILTF, there was a definite peak and a considerable loss of TF during the latter stages of fermentation. In the case of TFMT measured on manufactured tea, the peak was less obvious and there was very little loss of TF after this peak. This suggests that, during the final stages of fermentation of the 'dhool', there are either chemical changes in the TF (causing it not to be measured by the ILTF method) or physical changes (causing it not to be extracted by the ILTF method) and that these changes are reversed by firing (so that the more TF was extracted and measured in the case of processed tea). Whatever the cause of this difference, it is possibly the reason why the peak obtained by the ILTF method does not show the optimum fermentation time correctly.

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