STUDIES ON THE FIRING OF TEA.—III

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In previous articles [1] the results of experiments designed to find the best firing temperature have been described. Briefly, it was proved that 190°F gave the best all round teas, whilst firing at lower temperatures (160°F), although giving superior quality, pungency and flavour, did not ensure keeping qualities. These previous articles have described the technique of the experiments and it is only necessary to recapitulate in order to emphasise the fact that each conclusion is based on the results of at least 21 experiments carried out at all seasons of the year and involving either 42 or 63 days' manufacture according to whether two or three days' work is bulked for sampling. Each sample is drawn from the bulk of tea fired over two or three-day periods. The total number of samples dealt with in the course of obtaining the results described in this article was 654. All samples were tasted by a team of tasters, the personnel of which did not change to any appreciable extent so that differences due to personal factors were minimised. The samples were sent under a serial number so that the "team" were not even aware that they were from firing experiments.

The method of reporting has several times been described in *The Tea Quarterly*. Appearance, colour, strength, quality and pungency or flavour, if present, have all been marked separately and each sample valued on the market ruling at the time of tasting. A simple arithmetic average has been drawn up of each team result and all fractions disregarded. For instance, suppose the average mark for the strength of a sample was 10.5 compared to the 10 marks given to every standard then 10.5 would be regarded as 10 and the conclusion that there was no difference in the strength would be drawn from the result. If, on the other hand, the average was 11.2, it would be accepted that the team had found a real difference between the teas. Similarly in the valuations all fractions of less than 0.6 cent were regarded as having no significance.

These are very rigid tests and bring out only marked differences of practical importance.

Most of the teas were tasted in pairs, one being the standard, and never were more than three teas compared to the same standard. This makes for accurate tasting as a taster cannot be expected to remember all the features of each tea when working down a long row of cups with only one standard.

When describing the results of the experiments on the effect of firing temperature, the averages of the taster's analyses for each separate season were all tabulated. Since in the present results all the differences were in either strength or quality, and most of the seasonal differences were not significant, it is proposed greatly to simplify the tabulation of results and to give only the significant differences in the valuation for each complete series.

through the drier. In these experiments therefore the temperature was fixed at 190°F. and the load and air flow so adjusted that a moisture content of 3 per cent was obtained in about the normal time of 20 minutes. Low or high moisture contents were obtained by variation of firing time to give the figures required.

It is quite clear from Table I that 3-4 per cent is the moisture content associated with the best teas. Curiously enough firing to very low moisture contents apparently impairs keeping quality. This has been known in practice for some years but the usual explanation of "case hardening" does not fit the facts in this case. A condition to which the term "case hardening" may be an apt description may arise when teas are dried rapidly at high temperature, but a tea dried at 190°F. under

TABLE I

Comparison of valuations of teas fired to different moisture contents
(Based an 66 days' manufacture)

Moisture % * (On discharge from drier)	Comparative valuations based on Standard (Differences in cents.)	
	Fresh teas	Teas stored for two months
4 to 6	0	—1
3	Standard	
2	—1	—2
1 to 2	—2	—2

* Moisture contents were about 1 per cent higher when tasted. They absorbed moisture during the grading process. The very dry teas sometimes picked up more than 1 per cent during grading.

I. FIRING TO DIFFERENT MOISTURE CONTENTS AT 190°F.

In commercial drying at any fixed inlet temperature the moisture content depends mainly on the time taken to pass the tea standard conditions of air flow and load, dries at a fixed rate and the low moisture content is merely a result of length of drying. At the present moment there is no explanation which fits all the facts.

The moisture contents given in the table are the moisture contents at the moment of discharge from the drier. Teas fired to 3 per cent moisture content will pick up about 1 per cent during grading and storage (if storage conditions are good) and should be despatched at about 4.0 to 4.5 per cent.

The problem of what to do with teas which absorb more moisture than this now arises.

2. FINAL FIRING TEAS ORIGINALLY FIRED TO 3% MOISTURE CONTENT AT 190°F.

As the object of final firing is only to drive off a little excess moisture, neither high temperatures nor long periods of firing are necessary or desirable. Previous experiments have shown quite clearly that temperatures above 160°F. and times above 20 minutes are both detrimental to quality to some extent although the loss at 190°F. is small. On the other hand the moisture in tea when the material is comparatively dry at, say, 6 per cent is held tenaciously and is not readily lost to moderately hot air in short periods of time. Accordingly final firing was carried out at 160°F. for 15 minutes, both these figures representing minima for effective treatment.

The conclusion was therefore that final firing for 15 minutes at 160°F. is quite innocuous. The figures bracketed in the table indicate a slight deleterious effect immediately after final firing a tea containing 4 per cent moisture but this effect disappears after 2 months' storage and the tea is then slightly better for the final firing. For all practical purposes we can say that final firing, when unnecessary from the point of view of moisture content, does little harm or good. Normally when it is possible to determine moisture contents, unnecessary final firing would be avoided on account of additional cost, especially as no benefit is derived from it.

The next question is does a small rise in moisture content do any harm ? Table III displays figures which answer this question.

TABLE II

(Based on 44 days' manufacture)

Original firing to 3% at 190° F

Final firing 15 minutes at 160° F

Sample	Comparative valuations based on Standard (Differences in cents)	
	Fresh teas	Teas stored for 2 months
Original tea at 4%*	Standard	
Original tea after final firing	0 (−0.4)**	0 (+0.5)**

* The moisture content rose to 4 per cent after grading.

** The actual differences were too small to be regarded as significant.

Gain in moisture is shown to cause definite deterioration amounting to 2 cents. The fresh teas normally reached the tasters on an average of about two weeks after manufacture and even in this short time there was marked deterioration.

When teas gain moisture and start to deteriorate final firing can only be expected to arrest deterioration.

The loss of two cents in the value of fresh teas shown in Table IV agrees well with the previous table but equality with the standard after two months' storage is not so easy to understand.

Further to study the effects of final firing it is necessary to make a comparison of the teas containing 6-7 per cent moisture before and after final firing. Table V affords such a comparison.

TABLE III

(Based on 44 days' manufacture)

Sample	Comparative valuations based on Standard (Differences in cents)	
	Fresh teas	Teas stored for 2 months
Original graded tea containing 4% moisture	Standard	
Original tea allowed to absorb moisture up to 6-7%	—2	—2*

* This value was increasing but had not reached a significant. —3.0 in two months.

TABLE IV

(Based on 44 days' manufacture)

Sample	Comparative valuations based on Standard (Differences in cents)	
	Fresh teas	Teas stored for 2 months
1. Tea fired to 3% moisture at 190° F. and containing 4% after grading	Standard	
2. Above samples allowed to gain 6-7% moisture during storage in bins before packing. Final fired at 160°F. for 15 minutes before packing	—2	0

These results confirm previous findings and reveal that in spite of the increased moisture present no apparent harm has resulted from final firing. The effectiveness of the treatment is gauged from the fact that after two months' storage the final fired teas were valued two cents higher than the standard which had not been final fired.

These figures do not however offer any explanation of the curious result shown in Table IV where final fired teas reach equality with the standard 4 per cent moisture content tea after two months' storage. For further information on this point it is necessary to look into more detail at the tasters' opinions from season to season and it is possibly a case where some seasonal effect influences the effects of final firing. Table VI displays the average differences in the comparison with the standard worked out from each season.

TABLE V

(Based on 44 days' manufacture)

Sample	Comparative valuations based on Standard (Differences in cents)	
	Fresh teas	Teas stored for 2 months
1. Teas containing 6-7% moisture (fired at 190°F. to 3%)	Standard	
2. Above after final firing for 15 minutes at 160°F.	0	+2

TABLE VI

	Average difference, compared to standards, for each season (Cents)			
	Fresh teas		Teas stored for two months	
	(a) 6-7% moisture (originally 4%)	(a) Final fired to original moisture content	(a) 6-7% moisture (originally 4%)	(a) Final fired to original moisture content
Dry weather	0	+1	—1	+1
Inter Monsoon (April)	—1	+2	—1	+3
S. W. Monsoon	—1	—3	—3	—1
Inter Monsoon (Aug.)	—4*	—2	—3	0
N. E. Monsoon	—4*	—6*	—4*	—5
Average shown in Tables III & IV	—2.0	—1.6 *i.e.*, —2.0	—2.4 *i.e.*, —2.0	—0.4 *i.e.*, 0

* Market high but showing discrimination; differences therefore large.

The columns headed 6-7 per cent are the parallel details for Table III. Although at all seasons rise in moisture causes deterioration there are indications that in certain circumstances rise of moisture followed by final firing may improve teas. This process may be what is commonly known as "maturing." Under drier conditions in the dry weather, and the two inter-monsoon periods, (to a lesser extent in the August period between the South-West and North-East), this improvement following final firing is most marked. It is possible that underfermented particles of leaf under the influence of moisture may slowly oxidise and improve provided that the process is arrested by final firing before it leads to softness. On the other hand the deterioration which is so marked in the wet weather may be due to bacterial activity as observed by Benton in N. India.

The process of maturation is a very difficult one to investigate and has so far resisted all efforts to discover the exact conditions under which it takes place. The results obtained in these experiments will however afford new lines of investigation. Until the process is better understood it is obviously best to guard against rise of moisture during storage as far as possible in commercial manufacture.

3. THE TREATMENT AND HANDLING OF TEA AFTER FIRING

Having regard to the importance of moisture content and the prevention of excessive gain of moisture during operations subsequent to firing, the handling of tea after its discharge from the drier is a question of considerable importance. Fired tea should obviously be packed into boxes and denied access to air as soon as possible. Freshly fired tea gains moisture rapidly even in the comparatively dry atmosphere of the firing room and the sooner it is packed into boxes the less the gain in moisture will be. However, the question arises as to whether it is desirable to pack tea while it is hot since owing to its nature it is obviously likely to retain its heat for considerable periods. This question was accordingly investigated by further experiments. Four series of samples were examined.

(i). Samples fresh from the drier which had moisture contents averaging 2.6 per cent and temperatures of 160-165°F. as measured by a sensitive thermometer inserted into a bulk of the hot leaf. The firing temperature was 190°F.

(ii). Samples of leaf as in Section I which were spread out on a wooden table to cool off until they were just warm to the hand. The moisture contents then averaged 3.3 per cent and temperatures 85-90°F.

(iii). Samples as in Section I packed straight into boxes, carried and stored for grading on the following day. The moisture contents then averaged 2.7 per cent and the temperatures 100-115°F.

(iv). Samples as in Section II packed into boxes, covered and stored overnight. The moisture content was then 3.6 and temperatures 75-80°F.

The leaf packed hot retained its heat and showed very little rise in moisture content but the effect of such conditions on quality was of course open to grave doubts. On the other hand the cooled leaf already showed a gain of 1 per cent moisture before grading, as indicated by Section IV. The

tasters' opinions were very decisive and it was only considered necessary to repeat the experiment nine times.

The teas stored in the hot condition were sometimes reported as "bakey." Strength and quality in the case of the teas stored for two months were both marked down significantly.

types of tea drier are efficient, simple and by most standards economical, also more especially as they represent a considerable capital sum in installation costs, any radical change in the technique of tea drying is not to be expected in the very near future. Therefore, tea drying as it is, and not tea drying as it might be if different types of

TABLE VII

Sample	Comparative valuations based on Standard (Differences in cents)	
	Fresh teas	Teas stored for two months
1. Teas cooled before storing	Standard	
2. Teas stored in hot condition	—2	—3

In spite of gains in moisture therefore teas should be cooled before packing into boxes. The gain may be reduced by cooling in the dry atmosphere of the firing room and to prevent further gain during grading a hygrometric difference of 10°F. should be maintained in the grading room while work is in progress.

DISCUSSION OF RESULTS

The above results may be said to complete the experiments on the most practical considerations of firing tea in Ceylon. They have not revealed the necessity for any change in the technique of firing and, indeed, it would have been surprising if after about a century of experience in hundreds of commercial factories, a comparatively few experiments at the Tea Research Institute revealed some fundamental improvement in what is undeniably a comparatively simple industrial operation. In fact, it is doubtful whether firing by hot air will ever be superseded and as the modern machines were available, is of primary interest to the worker in applied science who is concerned with tea manufacture in Ceylon.

It is not to be imagined that since tea drying is a comparatively simple operation that there is not room for error and controversy. The number of possible permutations and combinations of temperatures, times, moisture contents and so on is very large and only systematic investigation can hope to establish the best set of conditions. Superimpose on these difficulties the questions of various possible ranges of temperature and time for final firing, and the range of moisture content for final packing. It then becomes even more obvious that to establish optimum firing conditions is a task of some magnitude which can only hope to succeed under conditions controlled by scientific methods. Such conditions have been established and it is now possible to say what are the optimum conditions for

firing Ceylon tea in a single operation. Temperature, time, moisture content and so on are no longer matters of controversy, fads and fancies as they have tended to be in the past. Firing at high temperatures and firing at low temperatures have alternately, in cycles of years, become fashionable and the apparent reason for some transient success. The novelty then faded out of general interest only to be rediscovered again some time later. Firing at exceptionally high or low temperature inevitably causes changes in the time of firing and other conditions, so it is never possible to say that the innovation is the primary cause of any apparent success.

One particular character in the green leaf may be accentuated by a change of firing method and market demands for this particular character may further contribute to transient improvement. More often than not, keeping quality suffers when firing conditions are extreme in any respect and during the course of years a set of what have become to be regarded as "normal" conditions has been evolved as a result of continuous trial and error.

SUMMARY OF RECOMMENDATIONS ON FIRING

The following are the optimum conditions for firing tea in a single operation in a standard type of tea drier in Ceylon.

1. Temperature 185-190°F.
2. Moisture content of discharged tea 3 per cent approximately (say 2.5 to 3.5).
3. Time through drier 20 minutes approximately (say 19 to 21 minutes).
4. As several times explained in *The Tea Quarterly*, one of the best indices of correct firing conditions is an exhaust temperature of 125-130°F. The range of exhaust temperature varies in different types of driers and also with the amount of moisture in the fermented leaf but the exhaust temperature of an endless chain type of drier working at 190°F. and turning out teas with 3 per cent moisture in 20 minutes should not vary outside this range. A tilting tray type of drier working under similar contions shows a depression of temperature every time the trays tilt which will be roughly every 3½ minutes on a 21-minute pulley. In this case the temperature falls to about 115°F. for a few seconds and rises to 120 within a minute. At the end of the cycle there is a rapid rise to 130°F. or slightly higher.
5. Moisture content after grading and storage prior to packing not above 4.5 per cent. Packed teas should not contain moisture exceeding 5 per cent.
6. Teas likely to exceed 5 per cent moisture content on packing should be final fired for 15 minutes at 160°F.
7. Teas hot from the drier should be cooled to a temperature just warm to the hand before storage or packing in boxes.

REFERENCES

1. *Tea Quarterly*, 1939, XII, p. 171.
Ibid 1940, XIII, p. 156.