

STUDIES ON THE ROLLING OF TEA.

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During the past four years many references have appeared in *The Tea Quarterly* and in the annual reports especially, in the latter, to our research on the fundamental principles of tea rolling.

The work involved is long and tedious; this is not very surprising, considering that rolling experiments have been carried out in factories in all parts of Ceylon by superintendents of estates and teamakers for the greater part of a century without any very definite conclusions having been reached. Even in the same district, the methods employed may be very diverse in different factories; there are a multiplicity of types of rollers and battens, and the type employed in any particular case does not, in general, bear any relation to elevation or district. Everyone familiar with the tea industry is aware of many paradoxical instances in connection with manufacturing methods, machines, and results. Neighbouring factories with almost identical equipment may get entirely different results, old factories with obsolete equipment sometimes do well where new factories fail, and from time to time new machines come on to the market with a record of very successful trials and fail miserably in general practice.

In short, a research worker contemplating investigations on tea manufacture finds little to guide him on his way, and before he has conducted many experiments will become aware of the innate conservatism of the tea trade of which he must be exceedingly wary.

Four years ago I found myself faced with such problems and since I did not possess any previous experience of the tea industry, I proceeded with an unbiased mind to study existing methods. It was perhaps fortunate that I had not received any prior instruction as such on tea manufacture because teamaking is a matter of many prejudices and to have acquired preconceived theories would have been a serious handicap. Experience gained from visits to factories in all parts of the Island led me to the conclusion that there was plenty of room for investigation of the principles involved in the use of the orthodox type of rolling machine. The ordinary roller appeared to have withstood the test of time in that, in more or less the same form, it dated back to the beginning of the industry in Ceylon and held its own against all new-comers such as the expressor, the C.T.C. machine and various forms of cutters.

Expensive machinery lying idle creates a lasting impression in the mind of a new-comer and does not encourage purely exploratory research and I decided to leave such matters alone at least until I had gained experience of existing methods. With regard to the use of rollers the only generally agreed principle seemed to be that it should be done in stages although there was no agreement about the length of each stage or roll, the pressure used for each roll, or on any of the other details of procedure.

The question then arose as to why the many hundreds, perhaps thousands, of experiments carried out by those engaged in the practice of teamaking had failed to give more exact information. It soon became obvious that, since under normal commercial conditions it was not usual to measure any of the mechanical constants, it was almost impossible to define any particular method of rolling. The utility of commercial experiments was therefore limited to the particular set of machinery on which they were carried out and, even then, the repetition of any particular set of conditions was often a matter of considerable difficulty. For instance, when I came to Ceylon, the actual pressure in terms of pounds weight had only just been measured and I assisted in what we believed to be the first attempt in Ceylon to measure the actual power consumed by a tea roller under working conditions. How therefore could any previous rolling experiments have been defined in such a way as to give results of general application?

I was, however, fortunate in arriving at what appeared to be the dawn of the scientific approach to rolling problems and also in having small-scale experimental rollers at my disposal, and one of the first tasks was to get these equipped with means of measuring the most important mechanical constants.

A variable speed electric motor with Kilowatt recorder was installed to drive each roller and, after a number of tests with spring pressure, the springs on the pressure caps were discarded and a system for adding weights to the cap was devised.

The outcome of these changes was that every experiment could be defined in terms of:—

1. Time.
2. Speed of roller.
3. Pressure applied in pounds weight.
4. Time and interval of application of pressure.
5. Total power consumed.

Furthermore, the Kilowatt recorder would give an exact record of variations of power during each rolling period which could be related to other records of pressure, speed, load, etc. It was, therefore, possible to keep an exact record of all the principal physical conditions of every experiment which could be repeated accurately whenever desirable.

Some considerable period elapsed before the new equipment was complete but since that time no effort has been spared to expedite our investigations on rolling. If we had been able to devote all our time to this branch of our duties progress would have been more rapid; other parts of the manufacturing process have however received attention and a large amount of analytical work arising out of Food and Drug Laws has been demanded by the Associations governing tea interests in Colombo and London. In spite of these handicaps, however, definite progress has been made. Interim reports have appeared in the Annual Reports for 1935, 1936 and 1937 and, prior to departure on leave, it is now my intention to summarise these reports, to state the practical conclusions which have emerged, and to indicate the future lines of work which will be carried on during my absence.

The methods of standardisation described above proved completely successful. Two similar battens were found to give exactly equal amounts of dhool under standardised conditions to a remarkable degree of accuracy. By this time the team system of tasting had been inaugurated, and teams in both London and Colombo were unanimous in their opinion that there was not any difference between teas made from the same lot of well bulked leaf under standardised conditions.

The next step was to compare teas made on an experimental roller under a fixed set of conditions with tea made from similar leaf on a full sized commercial roller. The commercial roller was equipped with an electrical drive and Kilowatt recorder while the battens and table were of the same type, the table on the experimental roller being in fact an exact scale reproduction of the commercial table. In the case of the full sized roller it was not possible to apply weights to the cap since it would have involved handling up to about 600 lbs. The spring on the pressure cap was therefore calibrated and a dial indicator made by Messrs. Marshall, Sons & Co. was used to indicate the spring compression in the weight.

Again, we were completely successful, the dhool out-turns, etc. being exactly comparable and the teas so made were found to be indistinguishable by both teams of tasters.

These experiments proved that our experimental results were applicable in practice and that commercial rolling could be standardised without any great difficulty. The independent drive and Kilowatt recorder are not essential and similar results may be obtained with a calibrated spring provided the speeds of the rollers are equal and constant.

The importance of this finding cannot be over-emphasised since it has been proved conclusively that haphazard methods of rolling may be avoided. A certain amount of experimental work will always be necessary, however, in tea factories if only for the reason that the Tea Research Institute cannot work out details for all the different conditions in all the various tea districts of the Island.

Such experiments can be put on to a definite basis and findings will be of much more value than those of rule of thumb methods. Whereas a century of vague and indefinite experimentation has failed to give any marked measure of agreement a decade of logical and organised trial must, if there is any reason at all about tea manufacture, afford specific information on which rolling methods can be based.

The preliminary results with the standardisation of rollers were published in 1935⁽⁵⁷⁾ and at the same time⁽⁶⁾ the necessity for attention to rolling programmes and the output of the rolling room in relation to firing capacity was pointed out. The time was opportune, for in the past two or three years several devices for standardising roller pressures have appeared on the market and general interest in rolling room organisation has been very marked. Factory organisation has received our fullest attention and support; the subject was discussed at the Conference in 1937 following a paper by Mr. F. J. Whitehead

who has shown much ingenuity in planning programmes applicable to almost all types of manufacture. This paper and discussion appeared in *The Tea Quarterly*;⁽⁷⁾ we also obtained an article on the same subject from Mr. G. K. Newton.⁽⁸⁾

Two devices⁽⁴⁾ for facilitating the working of rolling room organisation have been tested out in St. Coombs factory, and may be seen by visitors to the factory. We are also prepared to assist anyone wishing to draw up a suitable programme for their factory.

Standardisation and organisation of tea rolling has made remarkable strides in the past two years and neglect in any factory to give these matters the fullest consideration is to be deplored, not only because they enable a definite procedure to be adopted and adhered to (the alternative being haphazard manufacture) but because they are essential to the adoption of ideas resulting from further research on manufacture. Apart from organisation, standardisation of rolling methods in any particular factory cannot be achieved satisfactorily unless rolling methods are defined in terms of time, speed, pressure in pounds weight, batten type, and dhool percentage in relation to a certain mesh size, and it follows that real progress cannot be made until the majority of tea factories are in a position to carry out such methods accurately.

There can be little compromise in this matter and it should be widely realised that research is of little value if methods advocated cannot be practised accurately.

It is not as generally recognised as it should be that terms such as "Hard Pressure" and "Light Pressure," "Dhool Out-turn," etc. mean next to nothing at all unless the pressure is defined in terms of period of application and pounds weight, and dhool out-turn is defined in terms of mesh size (assuming efficient roll breaking and sifting). For instance, a type of batten that cuts rather than twists will give a large percentage of dhool passing through, say, No. 4 mesh with a very light pressure. If the spring on a roller cap is weak it may be fully compressed without giving a very large pressure and in such a case the full spring compression and the high dhool out-turn may give a misleading impression of hard pressure. Results will, however, be very different where a different type of batten that gives a low dhool out-turn even under really hard pressure is employed. To take the extreme opposite case to the above, the roller may have the second type of battens and the spring may be a powerful one; if somewhat inefficient sifting is carried out over No. 6 mesh, the dhool percentage separated may not be any higher than in the first case but there will be an enormous difference in results.

I am not exaggerating when I say that in the past, two such entirely different cases were in danger of being considered together under the same category. It is not surprising therefore that methods considered to be identical have given apparently paradoxical results.

The above postulations are germane to our experiments on batten types. Exhaustive tests have been carried out with three different batten types, all of which are common in Ceylon factories. In previous publications these types have been referred to as X, Y and Z for the simple reason that we wished to avoid premature statements about any well-known batten type. It is still my intention to avoid specific reference to batten types, but type X I shall call a cutting type and type Z a twisting type. My reason for doing this is the big difference in dhool out-turn under rigidly standardised conditions, standardisation including the mesh on the roll breaker and sifter. Figures from page 75 of the annual report for 1936 illustrate this point.

TABLE 1

Date	Batten	% Moisture in Withered leaf	% Out-turn of dhools 1 to 3 Total
3.9.36	X	59.3	46.5
	Z	59.3	27.3
15.9.36	X	56.4	47.7
	Z	56.4	24.9

The cutting type of batten produced almost twice the percentage of dhool that the twisting type produced, and the first conclusion we came to in batten experiments was therefore that there are big differences in the effect of battens. Recently we commenced investigations of a type of batten, very widely used, which is even more severe than type X and the danger inherent in reference to a batten type by name is very well illustrated by the enormous difference in performance when the battens on the door were changed. Aluminium battens on the door were substituted by similarly shaped and sized battens of teak and the result was that the dhool percentage fell as follows:—

	No Pressure	Pressure applied by first set of weights
Before alteration to door battens	21% dhool	29% dhool
After alteration to door battens	8% dhool	16% dhool

The battens still conform to standard types in commercial use and the makers offer both types of door battens, no distinction being drawn in name.

The indications are therefore that battens should be referred to by effect rather than by name since a particular name often covers a range of very different types. Very little in the way of standardisation of batten types has so far been achieved and, even when engineering firms offer a type constructed according to definite plans, several alternatives in detail may be offered and the battens may be further modified when repairs are effected. The first broad division in the classification of battens should be into cutting and twisting types and I shall adhere to this until it becomes necessary to subdivide into further classes of each type.

Having reached this conclusion, it is then necessary to follow up the effect of cutting and twisting battens upon quality. The first experiments along these lines gave rather startling results and I now give the valuation of the B.O.P.'s taken from the first three dhools described in Table I.

TABLE II

Date	Batten	Valuation (Average)	
		Colombo	London
3.9.36	Cutting type	78 cts.	15½ pence
	Twisting "	80 "	17 "
15.9.36	Cutting type	78 "	17½ "
	Twisting "	87 "	20½ "

Differences of 9 cents and 3 pence in B.O.P.'s justifies the description just given; such differences were indeed startling and we at once began to seek the reason. It was not hard to find since in one case the B.O.P. was taken from only approximately 25 per cent of the total charge, that being the percentage of the first three dhools, while in the other case the B.O.P. came from approximately 48 per cent of the total leaf. Such a large difference is however interesting in that it serves to illustrate the snags encountered in experimental work and as a warning against indiscriminate sampling. When a commercial scale experiment carried out in the course of normal factory practice gives contradictory results, the sampling should be examined carefully since it is obvious that even with

uniform leaf, differences in grade percentages, particularly selling grades, may have a considerable effect upon the average realised by an invoice.

It became necessary therefore to grade out the whole of the roller charges and to send all grades for valuation when making further comparisons between cutting and twisting battens. The question then arose as to how the comparison should be made since, owing to the big difference in dhool out-turn under standard conditions, large differences in grade percentages were inevitable if the same conditions were maintained for both rollers. We eventually decided to carry out the comparison under the following conditions with the hope that some definite pointers would emerge:—

1. Equal pressures and speeds.
2. Equal pressures and speeds to a predetermined big bulk out-turn.
3. Equal dhool out-turn.

The first experiment was particularly difficult to carry out because at the end of three rolls the bulk in the cutting type roller was reduced to 22 per cent and the remaining quantity was insufficient for a further roll.

TABLE III

	Cutting type	Twisting type
Dhool 1	14%	7%
2	29%	16%
3	35%	20%
Bulk	22%	57%

The pressures applied gave an already low dhool out-turn with the twisting type of batten and it did not appear as if any advantage would be gained by reducing pressure. The figures again illustrate the large differences which may occur between battens although for practical purposes they are perhaps rather extraordinary. However, we fired and graded out the teas in such a way as to get as much of the selling grades as possible and, in spite of the abnormal dhool out-turns and bulk percentages, the teas were very favourably reported on and the valuations were high as shown in Table IV.

TABLE IV
Per cent Out-turn of Grades and Valuations (Average).

Grade	% Out-turn		Colombo Valuation in cts.		London Valuation in pence	
	Cutting type	Twisting type	Cutting type	Twisting type	Cutting type	Twisting type
B.O.P.	66.7	36.7	87	92	17½	17½
F.P.	6.0	5.3	85½	91	18	17½
O.P.	3.7	5.6	78	80	16½	16½
B.P.	11.3	30.7	77	80	15½	15½
Pekoe	6.3	16.7	86	89	17	16½
Fannings	4.0	3.0	90	91	17½	16½
Dust	2.0	2.0	74	74	16½	15½
"Sale" Average			85	86½	17½	16½

The figures given in Table IV are of course averages for several experiments.

In this case, although the Colombo tasters still preferred the teas from the twisting batten, London did not make any difference in the B.O.P.'s and, on the whole, preferred the teas from the cutting batten. We are now finding that London and Colombo tasters often show a consistent difference of opinion and we shall no doubt have to take market differences into consideration in all our experiments. In both cases samples are tasted blind and the opinions over a series of these experiments are remarkably constant. Differences of opinion are consistent and obviously due to different market requirements. Reference to Table IV indicates that the grade percentages had a very marked effect on the "sale" average and in subsequent experiments these were adjusted to be as nearly equal as possible. The first series of experiments were, as already pointed out, rather abnormal but considered together with subsequent experiments afford some insight into general tendencies. The second series of experiments were designed to bring the total dhoole percentages and big bulk out-turn more into line with general practice.

Extra rolls were taken with the twisting type of batten so that the percentages of dhoole, bulk and therefore grades were as nearly equal as possible. Under these conditions the B.O.P. and the F.P. represented the greater part of the charge and attention was confined to these two principal grades as shown in Table V.

TABLE V

Grade	Colombo Valuations in cents		London Valuations in pence	
	Cutting type	Twisting type	Cutting type	Twisting type
B.O.P.*	77½	80	15½	16
F.P.*	80	81	15½	15½

* The B.O.P. and F.P. constituted the greater part of the tea.

We found that both Colombo and London tasters preferred the teas from the twisting type of batten; the valuations on the whole were lower since this series of experiments were carried out several weeks later, the season and markets having changed in the meantime. It is significant that Colombo tasters consistently preferred the teas from the twisting battens in all the experiments up to this point, no doubt on account of their fine appearance. The Colombo market undoubtedly attaches more importance to leaf standards than the London market; this point again emerged when experiments were conducted with the Clivemeare roller.

In the third series of experiments the comparison on a basis of equality in mechanical conditions was abandoned except in the speed of the roller, the pressures being adjusted to give equal individual dhool out-turns. The dhool out-turn to be aimed at in each roll was of course decided before-hand and followed the usual lines of a small dhool from the first roll, followed by increasing amounts taken from the later rolls. In this case very much heavier pressure had to be applied to the twisting batten in every roll compared to the cutting batten.

The grade percentages were again similar and the greater part of the leaf went into B.O.P. and F.P. grades. The valuations are shown in Table VI.

TABLE VI

Grade	Colombo Valuation in cents		London Valuation in pence	
	Cutting type	Twisting type	Cutting type	Twisting type
B.O.P.	76	74	16½	16½
F.P.	74	72½	16½	16½

Application of hard pressure to the twisting batten altered results considerably, for in this case its former advantage in the opinion of both Colombo and London tasters disappeared, Colombo

tasters actually preferring the teas from the cutting batten. This result was at once pursued further.

Two identical rollers equipped with the cutting type of batten were available and results from these under conditions of normal and heavy pressure were compared in a further series of experiments. In one case sufficient pressure was applied in a preliminary experiment to give an orthodox series of dhool out-turns which for the sake of clarity I will give in Table VII.

TABLE VII

Dhool 1	...	8%	Dhool 4.	...	20%
2	...	16%	5.	...	20%
3	...	25%	Big Bulk	...	10%

These figures were adopted as a standard and were adhered to throughout the whole series of experiments. The pressure used in this preliminary experiment served throughout in the roller having normal pressure application.

Full pressure was applied throughout in the other roller, and the dhool percentages taken in each roll were adjusted to the figures given in Table VII by the use of a suitable size of mesh in a separate roll-breaker. This of course involved many trials but finally we succeeded in arranging everything according to plan and the series of manufactures were carried out with a high degree of accuracy. As would be expected, the grade percentages obtained from the two lots of leaf rolled under such different conditions varied considerably; all grades were therefore submitted to the tasters for opinion. The average figures for the series are given in Table VIII together with a "Sale" average computed on the basis of the average for an invoice.

TABLE VIII

Grade	% Out-turn		Colombo		London	
	L. Press	H. Press	Valuation in cts. L. Press	H. Press	Valuation in pence L. Press	H. Press
B.O.P.	45.2	49.6	76	74	16½	16½
F.P.	14.0	2.5	75	72½	16½	16½
O.P.	5.7	5.5	75	73	15½	15½
B.P.	18.6	26.1	72	72	15½	15½
Pekoe	8.8	4.0	72½	71	16	15½
Fannings	5.8	9.2	74	72	16½	16½
Dust	1.9	3.1	69	69	15½	15½
Average :—			74½	73	16½	16

Taster's opinion was in this case unanimously in favour of the teas made from leaf which had been rolled under normal pressure as against what we may call "forced pressure."

A further practical conclusion consistent with the results of this whole series of experiments may therefore be drawn and is to the effect that forcing dhool out-turn by the application of heavy pressure is detrimental to quality. The reason for this appears to me to be fairly obvious and is concerned with the circulation of leaf during rolling. Tea rolling in the normal type of roller is essentially a twisting action and this cannot proceed unless the leaf circulates continuously. Application of pressure beyond a certain point, depending on the batten, tends to restrict circulation and will, if sufficient pressure is applied, arrest it altogether. When circulation is arrested, the leaf on the table is dragged round and round the battens and gives rise to greyish tea containing a high percentage of dust and fannings while the leaf in the roller jacket is compressed into cakes which seldom break up completely when the pressure is released. Frequent release of the pressure cap will mitigate this state of affairs to some extent but would not appear to be so effective as a steady lighter pressure which allows continuous circulation. Investigations on this particular point are now proceeding.

With regard to batten type it appears legitimate to conclude that the type I have called the twisting type is preferable to the cutting type under certain conditions. These conditions are well defined and then such a batten is not suitable for obtaining large dhool out-turns. The obvious solution to this difficulty is to use another type of batten when a high dhool out-turn is required, and, as the results I have quoted show, there is not any difficulty in obtaining a type of batten which I have termed the "Cutting" type which will give a high dhool out-turn without the application of pressure sufficient to impede circulation.

In actual commercial practice it is fairly common to find one type of batten used for early rolls and another for reducing big bulk. Experimental justification has therefore been found for this practice and it can be recommended where it is not already in use. A word of warning is however necessary at this juncture; where two different types are already employed it does not necessarily mean that they are the exact types I am referring to and, as I have already pointed out, methods resulting from research cannot benefit general commercial practice unless they are carried out accurately. Batten types are so very diverse that actual trials must be carried out to ascertain the class into which each installation falls; small differences in layout of battens may have a very marked effect upon their characteristics.

I will therefore endeavour to give a definition in terms as general as possible of the battens I have referred to as cutting and twisting types. Using No. 5 mesh in an efficient roll-breaker or sifter, the twisting type I have referred to would give no more than 8 per cent dhool for a 30-minute first roll with the cap just riding on the leaf, the spring being kept under a tension which is just perceptible during the pressure period. Pressure would be applied for eight-minute periods and the cap raised for 2-minute intervals. Under similar conditions the cutting type would give at least 14 per cent dhool and should be severe enough for all practical purposes.

This definition illustrates the difficulties involved in describing rolling methods with any degree of accuracy and I venture the opinion that before long it will be necessary in the interests of rationalism to speak of pressure in pounds weight and to relate it to the size of roller employed.

The results I have just described and the conclusions I have drawn from them merit careful attention when the question of the pressures to be applied in a rolling programme is being considered. When it is desired to improve liquors and increase in pressure is resorted to, great care should be taken to avoid defeat of the object in view by some secondary effect of the pressure increase. If for instance a cutting type of batten is employed the result of increased pressure will be a very large increase in dhool out-turn. A large dhool out-turn in the first two rolls means that a high percentage of the leaf only receives 30 minutes or one hour of treatment, whereas if the dhool out-turn is small a greater percentage of the leaf receives three or four rolls. Further if the high dhool percentage in early rolls is arrived at by short periods of extremely hard pressure on a cutting batten, the period of effective rolling is even shorter. For instance 20 per cent of first dhool may be arrived at by very hard pressure applied for five-minute periods, the interval between pressure periods being 10 minutes. In such a case the hard pressure will almost certainly defeat its own object in that the leaf is actually rolled under pressure for only 10 minutes per roll in which case 20 per cent of the made tea would have received only 10 minutes of rolling under pressure. If this process is described as "Hard rolling" it is surely a misnomer. On the other hand, the same dhool percentage could be arrived at with a twisting batten, employing moderately hard pressure for eight-minute periods with two-minute intervals. In this case the 20 per cent of tea arising from the first dhool would have received 24 minutes of rolling under pressure or $2\frac{1}{2}$ times as much as in the first case.

Obviously there are a large number of different combinations of battens, pressures and rolling periods which may be employed;

my object is to draw attention to the lack of definition in rolling programmes and I would suggest that in commercial practice more attention should be paid to batten effect, (i.e., twisting or cutting), pressure in pounds weight, and total pressure period.

In general it may be stated that much more pressure can be applied to a twisting type of batten without excessive dhool out-turn than to a cutting type of batten and that the pressure applied should never be sufficient to stop circulation of leaf.

Provided circulation of leaf in a roller is good, there is seldom excessive heat generation because the circulation of the leaf pumps air through the roller jacket and the leaf is cooled by conduction and evaporation. The dominant factor in heating is actually the state of the wither; a medium soft wither seldom allows much rise in temperature during rolling when circulation is good, while on the other hand a hard wither with a poor circulation will lead to very high temperatures during rolling which do not fall very readily when the cap is raised. Investigations of the effect of heat during rolling are in progress and experiments with cooling processes are being planned (Cf. Air conditioning) but it must be borne in mind that the heat may be only symptomatic of other troubles (as it is in animal fevers) and not the real cause of poor results. The old saying that "Heat is the enemy of quality" should not be followed blindly since, for instance, a certain amount of warmth in the leaf is essential for good fermentation and if this is not in the leaf when it is put on to the fermenting table the process may be unduly prolonged.

Before our rolling experiments had been in progress very long it appeared to me that the fundamental problem in rolling with the ordinary type of machine was how best to apply force to accentuate the twisting action. The only method of approach is normally by application of pressure to the cap and this is attended by difficulties with dhool out-turn and circulation. Once dhool of 5 mesh size is separated from the flush it appears to be impossible to get any further twisting action on such small particles.

It appeared to me that the ideal batten, at least for preliminary rolls, was one which would allow considerable pressure to be applied without excessive dhool formation and without restriction of circulation. An examination of the various types available was commenced in order to collect information on this matter; it is hoped that it will eventually be possible to design a batten which will meet these requirements and at the same time prevent throw-out.

The possibilities of alternative mechanical systems of rolling have, however, been carefully considered and in this matter we have been fortunate in making contact with Mr. Clive Meares.

Mr. Meares who has had considerable experience of the tea trade came to Ceylon with a new type of rolling machine and commenced experiments up-country. Shortly afterwards I had the opportunity through the kind services of Mr. Kenneth Morford of seeing these experiments and, as a result, suggested that the work should be continued at the Institute where facilities were more favourable for exploratory work of the nature involved.

At this point I should like to pay a tribute to Mr. Meares who, thinking over the subject of tea manufacture after retirement from the trade, formed definite ideas about the rolling of tea (see *The Tea Quarterly*, Vol. X, Part II), and came out from England at his own expense to test these ideas in practice. Mr. Meares has shown the courage of his convictions and has also been remarkably unbiased about results and I feel that the industry owes him a debt of gratitude whatever the outcome of the new method may be. During the first month of the experiments at St. Coombs we had the great benefit of Mr. Meares' personal assistance and advice and the fundamental principles of the method followed ever since were worked out during that period.

Briefly, the Clivemeare roller consists of two smooth, even speed, rollers which rotate in opposite directions. The gap between the rollers through which withered leaf is passed is adjustable and may be set as fine as 1/1000th of an inch. Leaf passing between the rollers is subjected, momentarily, to an enormous pressure and with full pressure may, in fact, be completely disintegrated. The time is not yet opportune to describe the experiments in full and if the method passes into general use the best way of disseminating information will undoubtedly be practical demonstration at St. Coombs.

The smaller the gap between the rollers, that is to say the higher the pressure employed, the brighter and more coppery are the resulting infusions and the stronger the liquors. As would be expected, however, complete disintegration of the leaf in rolling gives a very unorthodox appearance to the dry leaf and the aim and object of a year's experimentation has been to obtain as much improvement in infusion and liquor as is consistent with passable standards of dry leaf.

The difference between the requirements of the Colombo and London markets has been illustrated very forcibly by reports on teas from this particular series of experiments. The dry leaf standards demanded in Colombo are so severe that there does not at present appear to be much hope of success in that quarter. The blenders who buy on a large scale on the London market have, however,

shown a marked interest in Clivemeare teas and when we had succeeded in reaching a certain standard of appearance it was suggested that we should manufacture an invoice for sale in London.

As a result of many experiments a relatively satisfactory standard of dry leaf appearance has now been attained; the principle of the method being to take a softer wither than normal and to pass the withered leaf straight through the Clivemeare roller. Passage through the Clivemeare roller is followed by treatment with ordinary rollers with the object of imparting the familiar twist to the leaf and working the leaf into a state in which it will dry black. Unless the treatment following Clivemeare rolling is carried out along certain definite lines the leaf tends to dry brown instead of black with the result that it is practically unsaleable. Careful manufacture will, however, produce a tea which is almost indistinguishable from the normal product except to the expert eye. Some misgivings have been expressed about the preservation of Ceylon character and this aspect is receiving our closest attention; on the other hand the opinion has been expressed by equally unbiased authorities that Clivemeare teas have much brighter and more even infusions and that the liquors "have got the better quality that up-country Ceylon should have." An invoice of Clivemeare tea has now been manufactured and sent to London for sale on the open market; an invoice manufactured on alternate days by the normal method serving as a standard for comparison. Working on a commercial scale we succeeded in producing a satisfactory standard of leaf and preliminary reports have been very satisfactory. It may be possible to give further details in an appendix to this article* if the full reports are available before going to press. Meanwhile the grade out-turn may be of interest and was as follows:—

TABLE IX

Clivemeare manufacture		Normal manufacture	
		B.O.P.	59.3%
B.O.P.	54.2%	F.P.	19.8%
Pekoe	17.4%	O.P.	0.5%
Fannings	16.9%	B.P.	1.2%
Dust	8.2%	Pekoe	0.6%
B.M., etc.	3.3%	Fannings	13.0%
		Dust	3.2%
		B.M., etc.	2.4%

* Since this article was written these invoices have been sold. The reports received are discussed on page 118.—Ed.

Of the Clivemeare manufacture, B.O.P., Pekoe, Fannings and Dust were sent for sale and of the normal manufacture, B.O.P., F.P. and Fannings only were sufficient for shipment. The number of chests in each invoice was 54. To complete this account of our work with the Clivemeare roller I will quote some further observations made in my annual report for 1937.

"Some very interesting questions from the chemical and biochemical point of view have been raised by the Clivemeare process. One is apt to explain all improvements in rolling as due to 'more thorough expression of juice' which is very vague and is really only a roundabout way of restating the fact that improvements have taken place.

"When hard pressure is applied to leaf with the Clivemeare roller there is a most marked increase in colour and strength when compared with identical leaf manufactured on ordinary rollers. If this improvement were due entirely to a greater disruption of the leaf, it would be reasonable to expect that the liquor would contain a greater weight per cup of total solids in the case of the Clivemeare liquor than in the ordinary liquor. If such were the case, there would be a possible disadvantage in the Clivemeare leaf if the extra colour and strength in the first cup was merely a result of most of the soluble material passing into the brew and so exhausting the leaf that a second brewing would give a very watery liquor. In such a case there would inevitably be complaints from many consumers who want the utmost value for their money.

These considerations were put to the test on seven samples as follows:—

Sample No. 1 was St. Coombs ordinary commercial B.O.P.

" " 2 was a Clivemeare B.O.P., in which the withered leaf was put straight through the Clivemeare machine.

" " 3 was a Clivemeare B.O.P., in which the withered leaf had been rolled once in the ordinary way before putting through the Clivemeare machine.

All these samples were made from the same batch of green leaf.

TABLE X

Sample	% Extract	% Caffeine	% Theotannin Iodine method	Formalin method
No. 1 St. Coombs, B.O.P.	41.0	3.20	21.5	20.5
" 2 W.L. Clivemeare B.O.P.	38.2	3.08	21.1	20.3
" 3 R.L. Clivemeare B.O.P.	40.0	3.04	20.6	20.1

"The brew in this case aimed at complete extraction of the leaf, which was boiled for 30 minutes.

Sample No. 4 was again a commercial St. Coombs B.O.P.

" " 5 was a corresponding Clivemeare B.O.P.

" " 6 was a Diyanilakelle* B.O.P., which is well-known for its strong and coloury liquoring characters.

" " 7 was made from longer withered Diyanilakelle leaf by the Clivemeare process at St. Coombs.

"In this case the teas were brewed for 5 minutes using tasters' cups and scales.

TABLE XI

Samples	% Water-soluble matter extracted successively			Total
	1st brew (5 mts.)	2nd brew (5 mts.)	3rd brew (5 mts.)	
St. Coombs B.O.P. (Factory roller)	25.4	7.7	3.1	36.2
St. Coombs B.O.P. (Clivemeare)	26.1	7.3	2.5	35.9
Diyanilakelle B.O.P. (Factory)	26.3	8.6	3.5	38.4
Diyanilakelle B.O.P. (Clivemeare)	27.4	7.1	2.6	37.1

"Perusal of the figures appertaining to these seven samples indicate that the total soluble extract of the Clivemeare leaf is actually less than that of ordinary tea. To a slight extent, the relative amount of solids extracted in the first brew is higher than in the case of ordinary B.O.P. but this was not actually discernible to the eye, the Clivemeare leaf appearing to give the more coloury liquor in each of the three brews. The difference in the first brew was quite remarkable in the case of the short-withered St. Coombs leaf. We cannot, therefore, explain the action of the Clivemeare roller by the relative amount of soluble substance which it renders available for liquoring. The various substances which contribute towards colour and strength and other tea characters must be present in a better form or state although their total weights are of the usual order.

"This is in keeping with Mr. Clive Meare's own explanation which attributes the improvement of liquor and infusion to the short and complete nature of the rolling process which starts fermentation of all liberated substances at the same time. All the "Juice" therefore has the same fermentation both in regard to time and temperature.

* We are indebted to Mr. A. T. Sydney Smith for these facilities.

"The suggestion is, therefore, that the actual mechanism of the improvement is to be sought in the fermentation.

"Determination of the enzyme activity of carefully selected and bulked leaf after treatment in ordinary and Clivemeare rollers reveals a much higher activity in the leaf rolled in the Clivemeare roller. In the earlier experiments the residual potentially active enzyme in the fired tea was found to be twice the normal amount, which was consistent with certain difficulties in keeping quality experienced at this stage of the experiments. The fermentation of Clivemeare rolled leaf is markedly quicker than normal as would be expected from the high enzyme activity, and this appears to be, at least to some extent, responsible for the fine red colour of the infusions."

SUMMARY AND CONCLUSIONS

1. Prior to departure on leave I have collected together the principal results of the rolling experiments carried out during my first tour in Ceylon.

After making myself acquainted with the methods prescribed in Ceylon I came to the conclusion that definition of rolling methods as practised was impossible and devoted my energies to defining and standardising experimental methods.

2. The machinery installed for this purpose proved extremely successful and later experiments showed that results with the experimental equipment were comparable with and applicable to commercial methods.

Full support has been given to means for rationalising rolling including factory organisation in general, and attention is drawn to the fact that results of research cannot be made use of until commercial factories are able to standardise the rolling process.

3. The use of springs calibrated in pounds weight is strongly recommended.

4. A suggestion is advanced that battens should be classified into cutting and twisting types and the following general definition of these types is advanced with the reservation that in future all such definition will have to be made in terms of pounds weight of spring compression.

A. *Twisting type*—with No. 5 mesh in an efficient roll breaker not more than 8 per cent dhool after a 30 minutes' roll with pressure periods 8 minutes on and 2 off.

Cap just resting on leaf with spring under a tension which is just perceptible.

B. *Cutting type*.—A batten which gives more than 14 per cent dhool under the same conditions.

5. The percentages of selling grades obtained after sifting influence the results of rolling experiments to a considerable extent. Attention is drawn to this fact for consideration in commercial experiments carried out on estates.

6. Consistent differences in the requirements of the Colombo and London markets were encountered in the course of rolling experiments. The Colombo market pays particular attention to teas of fine appearance.

7. The application of heavy pressure to force dhool out-turn is undesirable. The explanation advanced is that very heavy pressure impedes circulation of leaf in the jacket and defeats its own object, since the principle of normal tea rolling is the twisting action to which the leaf is subjected and this cannot be provided correctly without circulation of leaf.

8. "Twisting" battens are preferable for early rolls. The "Cutting" type of batten should be used for reducing the bulk of the later rolls.

9. The state of wither is the principal factor involved in the generation of heat in the rollers. Hard withers cause the temperature to rise rapidly.

10. Preliminary results with a new type of roller called the "Clivemeare" roller have been very promising. The machine involves a different principle whereby the leaf is worked into a satisfactory state by direct pressure rather than by twisting. The fermentation of the leaf is initiated much more quickly than in the twisting process and this appears to account for the improvement in liquor and infusion.

REFERENCES

1. Annual Report, 1933, page 58.
2. Annual Report, 1933, page 59.
3. *The Tea Quarterly*, 1937, page 70.
4. This number, page 156.
5. Annual Report, 1935, page 68.
6. Annual Report, 1935, pages 60 and 61.
7. *The Tea Quarterly*, 1937, page 70.
8. *The Tea Quarterly*, 1936, page 109.