CHEMICAL BASIS OF LIQUORING CHARACTERISTICS OF CEYLON TEA

PART II. RELATIONSHIP BETWEEN THE COMPOSITION OF THE TEA LIQUORS AND THE VALUATIONS FOR THE LIQUORING CHARACTERISTICS OF BLACK TEA

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Introduction

Several attempts have been made by various workers to relate the constituents of the green leaf, of the made tea, or of the brewed liquors, to the tasters' valuation of the made tea. Evans (1929, 1930) showed a positive relationship between the soluble solids, the tannin, the acid-soluble tannin, and the non-tannin content of the made teas and the market value of these teas. Lamb (1937) showed that an increase in the theotannin content of the made teas manufactured from the leaf plucked at different ages from pruning gave an increased valuation for the made teas at the Colombo and the London markets. On the other-hand, Harrison & Bose (quoted from Wood & Chanda, 1957) found no correlation between the valuations of the teas made from different quality jats (Assam) and their soluble solids, polyphenols, caffeine, phosphate and potash content. Quite recently, the Indian Tea Association has been carrying out an investigation of the "chemical basis of quality" with a view to relating the constituents of the green leaf as well as those of the made teas to the tasters' valuation for their liquoring properties (Wood and Chanda, 1957, 1958, Bhatia and Chanda, 1959). The conflicting reports are mainly due to the complexity of the problem and the lack of fundamental knowledge of the different tea constituents responsible for the characteristic liquoring properties of the tea. Furthermore, the investigators have to depend upon the valuation of the tea tasters for assessing the relationship between the constituents of the liquors and the liquoring qualities of the tea even though the tasters valuation is influenced by such non-chemical factors as the grade, the appearance, and the current market demand for the particular tea.

In Ceylon, the teas produced at different elevations vary in the technique of the manufacture to suit the particular market to which the teas are sold. The tea districts of Ceylon are situated at elevations from almost sea level to over 7,000' AMSL; they are also situated in two distinct climatic regions namely the South-West and the North-East monsoon zones; consequently, there are large variations in the type of teas produced not only in various parts of Ceylon but also during different seasons of the year. The quality teas are produced mostly in up-country areas while the coloury teas are produced at lower elevations. On the other hand, the flavoury teas are confined only to the up-country regions and the North-East monsoon zone; these again are produced only during a short but favourable period of the year. These conditions which lead to the production of teas with widely differing characteristics are of great advantage for the study of the relationship between the constituents of the tea liquors and the valuation of their liquoring properties.

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The investigations reported in this paper were undertaken with a view to relating some individual as well as groups of constituents of the tea liquors to the valuation of the liquoring properties as judged by a number of Colombo tasters.

Materials and Methods

1. *Collection of samples of Black Tea:*

One pound samples of ungraded made teas were obtained from the following estates every month between December 1958 and December 1959.

Estate	Elevation (ft AMSL Appx)	Climatic Zone
Palmgarden	200	South West
Ingiriya	150	,,
Kirimetiya	3200	,,
Endane	1300	,,
St Coombs	4500	,,
Pedro	6000	,,
Gonakelle	3000	North East
Nayabedde	6100	,,

These estates were chosen to represent widely differing tea production conditions.

2. *Tasters' valuation:*

All the tea samples were valued by a single firm of tasters at Colombo. A few sets of the samples were also tasted independantly by other firms. The scheme adopted for tasting was the same as that reported by Keegel (1959) except that the quality and the character of the liquors were valued separately and that the valuations for the grade and the appearance were ignored. The samples were sent to the tasters under code numbers which differed for the teas sent every month from a particular source of manufacture.

3. *Chemical Analysis of the tea liquors:*

Each of the teas was prepared for chemical analysis as follows. Six batches of 6.75 g of each tea were infused in 420 ml boiling distilled water for exactly 5 minutes. They were stirred thoroughly at the beginning and at the end of the period of infusion. The extract was filtered immediately through a Whatman No. 4 filter paper. The extracts from three batches were combined for one set of determinations while the combined extract of the other three batches was used for the duplicate analysis. Suitable aliquots of the extract were drawn for the determination of (1) soluble solids, (2) mineral constituents, (3) total oxidisable substances, (4) acid-soluble oxidisable substances, (5) free volatile organic substances, (6) hydrolyzable volatile organic substances, (7) absorption of light, (8) theaflavins, (9) caffeine and (10) non-caffeine nitrogen.

4. The determination of the soluble solids, the mineral constituents, the caffeine and the non-caffeine nitrogen was carried out according to standard analytical procedures (A.O.A.C. 1945). The total oxidisable substances and the acid-soluble oxidisable substances (soluble in appx. 0.5 N hydrochloric acid) were determined according to the iodimetric method of Shaw (1935), but the time of reaction was legthened from 15 to 90 minutes. The free volatile organic substances (substances volatile in steam) and the hydrolyzable volatile organic substances (substances hydrolysed at the room temperature at a pH of 11-12 and volatile in steam) were determined by oxidation with dichromate. The absorption of light was determined in the SPEKKER photoelectric colorimeter without using any filter. The theaflavins, soluble in ethyl acetate, were purified by successive washes with 2.5 per cent sodium bicarbonate solution, 0.1 per cent sulphuric acid and distilled water, and the extinction coefficient of the solution determined at 460 mμ in a Bechman DU model spectrophotometer.

Results and Discussion

This investigation was confined to Ceylon teas manufactured by the orthodox techniques. All leaf used for the manufacture of these teas was obtained from seedling plantings.

In relating the chemical constituents of the liquors to the tasters' valuation for flavour, only those teas which were produced during the flavoury season were considered.

1. The Liquoring characteristics

1. 1. *Comparison of the valuation for the liquoring characteristics:*—Comparison of the valuation for the liquoring characteristics of similar teas by tasters of eight firms are shown in Table 1.

TABLE 1.—*The relationship between the valuations of taster* (1) *for the liquoring characteristics and those of seven other tasters* (2 *to* 8) *for same teas* (*Results expressed as correlation coefficients*)

Relationship between the valuation of	LIQUORING CHARACTERISTICS					
	Infused leaf	Colour	Strength	Quality	Character	Flavour
Taster 1 and Taster 2	+0.91	+0.87	—	+0.95	+0.95	Non flavoury tea
,, ,, 3	+0.82	—	—	+0.95	+0.97	+0.99
,, ,, 4	+0.90	—	—	+0.82	+0.80	+0.93
,, ,, 5	+0.91	—	—	+0.95	+0.91	+0.76
,, ,, 6	+0.86	+0.74	+0.72	+0.81	+0.85	Non flavoury tea
,, ,, 6	+0.85	—	—	+0.72	+0.71	—do—
,, ,, 7	+0.95	—	—	+0.93	not valued	—do—
,, ,, 8	+0.90	—	—	+0.87	+0.90	—do—
Correlation coefficient (r) at 5% level of significance	0.71	0.71	0.71	0.71	0.71	0.71

These results show that the tasters were generally in close agreement in their valuation for the infused leaf, the quality, the character and the flavour. On the otherhand there was much disagreement between the valuations of the different tasters with regard to the colour and the strength of the liquors. Bhatia and Chanda (1959) have made statistical study of different tea tasters' reports. In their report they state that "As far as the individual liquor characteristics are concerned, the tea tasters are not always in agreement. In fact, statistical analysis brings out the fact that either some of the liquor characters mean different things to different

tasters or that the thresholds in respect of these characters may be different." The results obtained in this investigation, though limited, appear to show that such disagreements exist only in regard to the valuations for the colour and the strength.

1.2. *The inter-relationship between various liquoring characteristics*:—The inter-relationship between various liquoring characteristics of the teas as valued by these tasters are shown in Table 2.

TABLE 2.—*The inter-relationship between various liquoring characteristics*
(Results expressed as corelation coefficients)

Liquoring Characteristics	TASTER 1	2	3	4	5	6	7	8	9
Quality and Character	+0.97	+1.00	+0.99	+0.78	+0.97	+0.86	+0.98	not reported	1.00
Quality and infused leaf	+0.90	+0.90	+0.87	+0.79	+0.98	+0.88	+0.80	+0.92	+0.85
Quality and flavour	+0.86	No flavour	+0.98	+0.85	+0.97		No flavour		—
Quality and strength	—	—	+0.96	+0.78	—	—	—	—	+0.87
Quality and colour	-0.34	—	—	+0.74	—	—	—	—	—
Strength and colour	+0.42	—	—	—	—	—	—	+0.92	—
Correlation coefficient (r) at 5% level of significance	0.20	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71

These results indicate that the quality of the liquors is positively related to the character, the colour of the infused leaf, the flavour and probably to the strength. In short, it appears that the quality of the tea is related to the best of *all other* liquor characteristics and includes the appearance of both the infused leaf as well as that of the made tea. This is borne out by the several definitions of quality in tea which have been published of which the following are examples:

(*a*) Bradfield and Penney (1944) refer to "the quality of a black tea infusion as judged by the taste, colour and the creaming down of the liquor";

(*b*) Trinick (1953) has defined quality as "the essential characteristics of a good tea";

(*c*) Harler (1956) describes quality as a term "used in a general sense to denote desirability or in a special sense to denote a special blend of characteristics which may include both taste and aroma. Quality in its special sense, is inherent in the leaf and is present at some periods of the season and markedly in some types of bush";

(*d*) Eden (1958) has defined quality as "a general integration of desirable characteristics"; and

(*e*) Keegel (1958) mentions that "in its broadest sense this term (quality) is used to describe all the characteristics of a tea, inclusive of its appearance. It is however commonly used to denote the presence of some desirable characteristic in the liquor which distinguishes the fundamental difference between an up-country and a low-country tea in Ceylon".

The relationship between the quality and the colour of the liquors was found to be neither consistent nor significant. This is in conflict with the generally accepted view that the colour "is indirectly connected with quality" (Keegel, 1958). In Ceylon up-country teas which are manufactured for the maximum production of quality and flavour give light liquors while low-country teas give coloury liquors but lack quality. These two liquoring characteristics usually appear to be produced at the expense of each other. Evidently further work remains to be carried out to establish the relationship between quality and colour in tea liquors.

2. *The relationship between the composition of the tea liquors and valuation for the liquoring properties.*

The analytical data on the chemical composition of each tea liquor was compared with the corresponding valuation reported by the tea tasters. A summary of the results, expressed as the number of the tasters whose valuations correlated with the chemical quantities at less than five per cent level, are presented in Table 3. The maximum number of comparisons has been shown in the last column of the table.

The following paragraphs discuss the results shown in Table 3.

2.1. *Soluble solids:*—The soluble solids content of the Ceylon tea leaf appears to increase during the process of normal withering, but if withering is prolonged for more than 24 hours these constituents decrease (Ramaswamy, 1959, 1962, Evans, 1929). The increase in the soluble solids is mostly due to the formation of water-soluble pectic substances (Ramaswamy 1959) and the formation of amino-acids from the leaf proteins (Evans, 1929). But such increases are very nearly compensated for by the respiratory losses of carbohydrates during withering (Evans, 1929). During the various processes of tea manufacture, however, there is a rapid loss of the soluble constituents mostly due to the formation of insoluble and complex condensation products of the oxidised tea catechins (Ramaswamy, 1959, 1962).

TABLE 3.—*The relationship between the composition of the tea liquors and the valuation for the liquoring properties*

(Results expressed as the number of tasters whose valuations showed significant correlation at $P = < 5\%$ level)
(The nature of the correlation is shown within brackets)

Liquoring properties valued by the tasters	COMPOSITION OF THE TEA LIQUORS										
	Soluble solids	Mineral constituents	Total oxidisable substances	Acid soluble oxidisable substances	Free volatile organ substances	Hydrylisable volatile organic substances	Absorbtion of light	Theaflavins	Caffeine	Nitrogen other than caffeine nitrogen	Maximum possible
Quality	5 (+)	8 (−)	7 (+)	8 (+)	4 (+)	0	0	8 (+)	3 (−)	5 (−)	8
Character	3 (+)	7 (−)	5 (+)	7 (+)	2 (+)	0	0	7 (+)	2 (−)	5 (−)	7
Infused leaf	3 (+)	8 (−)	7 (+)	6 (+)	3 (+)	0	0	7 (+)	3 (−)	3 (−)	8
Strength	4 (+)	0	0	0	0	0	1 (+)	0	0	0	8
Colour	0	1 (+)	0	1 (−)	1 (−)	0	2 (+)	2 (+)	1 (+)	1 (+)	8
Flavour	4 (+)	4 (−)	2 (+)	4 (+)	1 (+)	1 (+)	0	4 (+)	1 (−)	4 (−)	4

The tasters' valuations for the quality, the character, the infused leaf, the strength and the flavour of the liquors were generally found to increase as the soluble-solids content of these liquors increased. The average composition of the soluble-solids content of the liquors from all the tea samples investigated is shown in Table 4.

TABLE 4.—*The composition of the soluble solids of Ceylon tea liquors (Average of 102 tea samples)*

Constituents	Composition as % soluble solids
Total oxidisable substances expressed as % Theotannin (Shaw, 1935)	52.57
Caffeine	8.55
Nitrogen × 6.25	7.02
Mineral constituents	11.57
Undetermined	20.29

The undetermined constituents of pectic substances, dextrins, sugars, condensed polyphenols, *etc.*

Among the various constituents of the soluble solids, the caffeine, the nitrogenous substances and the mineral constituents were generally found to be present to a larger extent in poor quality teas than in the high quality teas. It may, therefore, be presumed that the quality of the teas would generally increase as the constituents belonging either to the prolyphenolic group of substances or the carbohydrate derivatives increased. The results shown in Table 3 indicate that the polyphenolic group of substances (total oxidisable substances, and acid-soluble oxidisable substances) appeared to be more closely related to the quality than were the carbohydrate derivatives estimated, namely the water-soluble pectic substances determined as hydrolysable volatile organic substances.

2.2. *Mineral constituents:*—The tasters' valuation for the quality, the character, the infused leaf and the flavour was found to decrease as the mineral constituents of these liquors increased. The tasters' valuation in this respect were unanimous. These results are in conformity with our earlier findings (Lamb, 1941, 1950) where it was shown that the mineral content of up-country teas (quality teas) was lower than that of the low-country teas (low quality but coloury teas).

2.3. *Total oxidisable substances:*—The tasters' valuation for the quality, the character, the infused leaf and to a lesser extent the flavour appeared to increase as the total oxidisable substances of these liquors increased. These results are in conformity with the findings of Evans (1930) and Lamb (1937) who found that the market value of the Ceylon teas increased as the tannin content of the made teas increased. For the most part, the oxidisable substances represent the unoxidised or partly oxidised polyphenolic constituents of the liquors together with smaller amounts of other easily oxidisable organic constituents. As was shown in Table 4, these substances constitute the major fraction of the soluble-solids content of the liquors which also showed a positive relationship with the quality. It has been shown (Ramaswamy, 1962), that the rate of oxidation and condensation of the tea

polyphenols increases as the length or the temperature of fermentation increases. The variations in the content of the oxidisable substances found in the liquors from the different types of Ceylon teas are, therefore, likely to be due to the differences in the temperature, humidity, period of fermentation, *etc.*, in factories situated at different locations or in factories using different manufacturing techniques in order to produce teas for a particular buying market.

2.4. *Acid-soluble oxidisable substances:*—The tasters' valuation for the quality, the character, the flavour and to a lesser extent the infused leaf, increased as the acid-soluble oxidisable substances of these liquors increased. The valuation of practically all the tasters gave highly significant correlations. These results were, once again, in conformity with the findings of Evans (1930).

2.5. *Free volatile organic substances:*—The tasters' valuation for the quality, the character, the infused leaf and to a lesser extent the flavour appeared to increase as the free volatile organic substances of these liquors increased.

2.6. *Hydrolysable volatile organic substances:*—The tasters' valuation for the flavour generally appeared to increase as the hydrolysable volatile organic substances increased. However, the valuations of the majority of the tasters did not show significant correlation with these constituents. The hydrolysable volatile organic substances appear to be derived mostly from the water-soluble pectic substances of the liquors as reported earlier (Ramaswamy, 1959), where it was shown that the presence of these substances in clonal tea was related to the quality of the colones.

2.7. *Absorption of light:*—There appeared to be no significant correlation between light absorption and taster's valuations.

2.8. *Theaflavins:*—The theaflavins (which impart the golden yellow colour to the liquor) consist of theaflavin and theaflavin gallate. These substances are formed during the rolling and fermentation of the leaf from the tea catechins after their enzymic oxidation. These constituents are subsequently transformed into the reddish-brown or dark-brown coloured products, *viz.* the thearubigins (Roberts, 1958). The theaflavins are, therefore, formed only after the leaf is damaged and the oxidation of the tea catechins begins to take place.

The tasters' valutations for the quality, the character, the flavour, and (with the exception of one out of eight tasters whose valuation could not be significantly correlated) the infused leaf, of the liquors were found to increase as the theaflavin content of these liquors increased. The results were highly significant.

The relationship between the theaflavin content of the liquors and the quality of the teas confirms our earlier findings (Ramaswamy, 1962) where it was shown that the ethyl-acetate soluble fraction of the liquors (consisting of mostly theaflavins) appeared to be directly related to the quality of the teas. Investigations on Indian teas have shown a similar relationship between the theaflavin content of the liquors and the colour of the teas (Wood and Chanda, 1957), but later results have shown that relationships between theaflavin content of these teas and tasters' valuations can vary widely for reasons which are only poorly understood (Wood and Chanda, 1958, Bhatia and Chanda, 1959). We have also encountered certain exceptions to such a relationship when the liquors from experimental teas were examined. For example, in general experimental teas made by processes which cause much leaf damage, such as the clivemeare process, the teas were found to contain more theaflavins than the teas manufactured by the orthodox methods even though the valuations of the former teas were generally lower than those of the latter teas,

Tocklai workers have also reported a higher theaflavin content in the teas manufactured by the C.T.C. process than in those manufactured by the orthodox methods (Wood and Chanda, 1958; Bhatia and Chanda, 1959). Typical results of comparative values of the theaflavin content of experimental teas manufactured by the orthodox or the Clivemeare techniques are given in Table 5.

TABLE 5.—*Comparative values of the theaflavin content of the liquors of teas manufactured by the orthodox and the Clivemeare techniques (St Coombs Factory)*

Theaflavin content expressed in arbitrary but comparable units.

Experiment No.	Manufacturing technique	
	Orthodox	Clivemeare
1	4.26	8.09
2	3.69	4.95
3	3.51	4.60

Evidently, the amount of the theaflavins present in the liquors, would probably not bear a direct relationship whith the quality, but its presence in relation to other constituents needs consideration. However, in Ceylon teas manufactured by the existing orthodox techniques on different estates, a close relationship was found to occur between the theaflavin content of the liquors and their quality, character, infused leaf and the flavour.

2.9. *Caffeine:*—The caffeine present in the green leaf does not appear to undergo any change during the various stages of tea manufacture.

However, there are indications to show that the caffeine content of the leaf increases as the degree of natural wither is increased (Ramaswamy, 1961). Wood and Chanda (1957) have reported a similar increase in the caffeine content of the leaf of Indian tea after withering under natural conditions for a period of about 24 hours.

The tasters' valuation for the quality, the character, the infused leaf and the flavour generally appeared to decrease as the caffeine content of the liquors increased; on the other hand the valuation for the colour appeared to be directly related to the caffeine content. However, the valuations of the majority of the tasters could not be significantly co-related to the caffeine content of the liquors. A negative relationship between the quality and the caffeine content of the liquors have been reported by Harrison and Bose (quoted from Wood and Chanda, 1957) who investigated the teas made from different quality jats in Assam.

2.10. *Nitrogen:*—The taster's valuations for the quality, the character, and the flavour were found to decrease as the nitorgen content of these liquors increased. The negative relationship found between the desirable characteristics in the liquors of a good quality tea and the nitrogen content of the liquors is in conformity with the findings of other investigators. Todd (quoted from Eden, 1958) investigated the

flush from green and from yellow-green tea bushes in East Africa and he found that the flush from yellow-green bushes had more water soluble solids and total oxidisable substances, but lower nitrogen content. The superiority of the teas made from the yellow-green bushes was confirmed by tasting assessments. Evans (1933) showed that teas from "no-nitrogen plots were superior to teas from double-nitrogen plots" in respect to colour, pungency and quality. Roberts (1949) showed that "the valuation of the teas (manured) were lower than unmanured tea due to fall in quality". Harrison and his associates (quoted from Eden, 1958) detected deterioration in quality when nitrogen application approached 120 lb of nitrogen per acre in Assam.

It is well known that the leaf from the initial plucks after pruning makes poor quality teas when compared with later plucks and the quality of the teas increases as the age from pruning increases. Evans (1930), reporting the results of his investigations on the composition of the leaf in relation to age from pruning, showed that the first few plucks after pruning were rich in nitrogen, but low in tannin and the soluble solids; but the subsequent plucks showed lower nitrogen and higher "tannin and soluble solids content. Haworth (1953) reporting results of his investigations on a number of T.R.I. clones showed that the leaf from the clones younger in age and pruning contained more nitrogen than that in clones older in age and pruning.

Summarising these findings, there is some evidence to show that a high rate of nitrogen supply to the tea bush may give rise to higher contents of nitrogenous compounds in the flush relative to the carbohydrate and/or the polyphenolic derivatives which may reduce the quality of the tea.

Summary

1. Results of preliminary investigations on the composition of the tea liquors in relation to their valuation as judged by a number of tasters at Colombo are reported; these investigations were carried out on Ceylon teas (manufactured by conventional factory methods) obtained from tea districts situated at different elevations and under different climatic conditions. The survey covered a period of 13 months during 1958—1959. The data collected were analyzed for various correlations by simple statistical methods.

2. The valuation of the various tasters for the liquoring properties of similar teas showed that the tasters generally agreed very well in their valuation of the liquors for their quality, character, colour of the infused leaf and flavour; on the other hand, there was much disagreement between the tasters concerning valuation for the colour and the strength of the liquors.

3. The valuation of the tasters for various liquoring properties of the teas indicated a highly significant and positive relationship between the quality, the character, the colour of the infused leaf and the flavour.

4. The desirable characteristics (particularly the quality, the character, the colour of the infused leaf and the flavour) of Ceylon tea generally appeared to be related to a *high content* (in the liquors) of (1) theaflavins, (2) soluble solids (3) total oxidisable substances and (4) acid soluble oxidisable substances. Most of these constituents are related to the polyphenolic constituents of the tea. The high quality teas were also found to be related to a low content (in the liquors) of (1) mineral constituents, (2) the nitrogenous substances other than caffeine and (3) probably caffeine.

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