

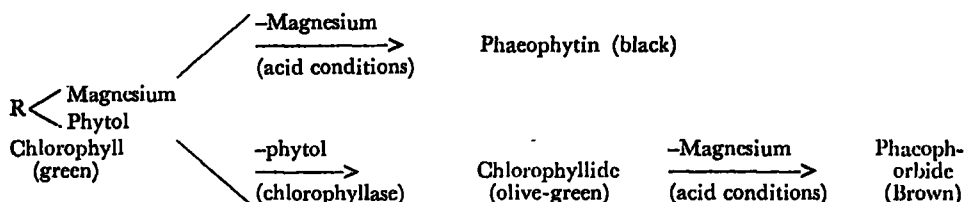
THE BLACKNESS OF TEA AND THE COLOUR OF TIP

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The investigations described here indicate that one of the main factors responsible for the appearance of black tea is the concentration of the transformation products of chlorophyll. These transformation products are phaeophytin and phaeophorbide—a high concentration of the former results in a black tea, whilst a high concentration of the latter makes it brownish. The relative concentrations of these products are determined by the method of manufacture as well as the initial concentration of chlorophyll in the flush prior to manufacture. Similar considerations apply to the colour of tip, and buds which contain chlorophyll at the time of plucking cannot be manufactured into silver tip, but will yield black or gold tip. The experimental evidence on which these conclusions are based is outlined, and the basis for certain practices in tea manufacture is discussed.

Introduction

An investigation was carried out to determine the factors which play a part in the determination of the blackness, and the presence or absence of silver tip, in low-country teas. Our findings suggest that blackness of tea and the colour of tip depend on the content of chlorophyll and its transformation products. Chlorophyll is a complex molecule containing magnesium and phytol (a long chain alcohol, $C_{20}H_{39}OH$), as an intergral part of its structure. Removal of magnesium from the chlorophyll molecule—a process which occurs in acid conditions—results in the formation of a black compound known as phaeophytin, the amount of which should influence the degree of blackness of tea. However, another reaction may occur concurrently with this process, where the removal of phytol, and not of magnesium, is the first step in the transformation of chlorophyll. This removal of phytol is effected by an enzyme, chlorophyllase, which occurs universally in green leaves. The product of this enzymic reaction is chlorophyllide, which is olive-green in colour, and retains the magnesium atom in its structure. Removal of this magnesium atom from chlorophyllide yields a brown compound, known as phaeophorbide, and the presence of this compound would be expected to impart a brownish colour to the teas. The changes which chlorophyll can undergo during manufacture may, therefore, be summarized as follows:—



It is seen from the above that blackness or brownness of teas could be dependent on whether phaeophytin or phaeophorbide predominates in the finished product. This, in turn, depends primarily on the activity of the enzyme, chlorophyllase. If conditions are favourable for the activity of this enzyme, the result will be brownish teas. The total chlorophyll content in the flush is obviously, also of importance, because the higher the chlorophyll content the greater will be the contribution made by its transformation products to the appearance of the made tea. On the other hand, the complete, lack or presence in negligible quantities, of chlorophyll would be

expected to lead to the absence of colour in the manufactured product. The developing bud contains much less chlorophyll than the formed leaf, and there is evidence that the colour of tip is determined by the chlorophyll content, prior to processing, of the bud.

Methods

Extraction procedure

Samples of tea (black and brownish), and of tips (black, gold and silver), were continuously extracted in Soxhlet extractors, using ether and chloroform as solvents. Extractions were continued for 72-96 hours until the solvent layer was no longer coloured.

Separation of chlorophyll and its transformation products

Separation of chlorophyll and its transformation products, (phaeophytin, chlorophyllide and phaeophorbide), was effected by thin-layer chromatography on plates coated with cellulose using petroleum ether; n-propanol; acetone (90 : 0.45 : 10) as developing solvent. Phaeophytin was identified by comparison with an authentic marker obtained from Messrs Fluka AG, Switzerland. Chlorophyll, chlorophyllide and phaeophorbide were identified by their R_f values and characteristic fluorescence in ultraviolet light.

Results

Experiment 1—Comparison of ether and chloroform extracts of black tea

The extracts of black tea obtained by continuous extraction with ether were green in colour, whilst those with chloroform were black. A comparison of the two extracts by thin-layer chromatography gave the results depicted in Figure 1A.

The major difference noticed in the two extracts was the very high amount of phaeophytin in the black chloroform extract and the very small amount of this pigment in the ether extract. This difference suggested that the blackness of the former extract was due to the presence of phaeophytin. Furthermore, the residual tea left after extraction with chloroform was brown in colour, whilst the residue from the ether extract was black, indicating that chloroform but not ether, extracted the compounds that were responsible for the blackness of tea. It should be mentioned here that there were other differences too in the chloroform extract, but these are probably not directly connected with the subject of this paper.

Experiment 2—Comparison of a black tea with a brown tea

Chloroform extracts of a black tea and a brown tea were chromatographed for comparative purposes (Figure 1B). It was seen that the black tea extract contained a larger amount of phaeophytin, whilst the brown tea contained a larger amount of phaeophorbide.

Experiment 3—Comparison of extracts of black, gold and silver tip

Visual examination of the ether extracts of black, gold and silver tips showed that those of black and gold tip were green whilst that of silver tip was a very much paler green in colour. Quantitative estimations of the absorption values at 665 m μ of the extracts revealed that the value for black tip was 1½ times that for gold tip, and 5 times that for silver tip. These results indicated that there was a decrease of chlorophyll pigments from black through gold, to silver tip.

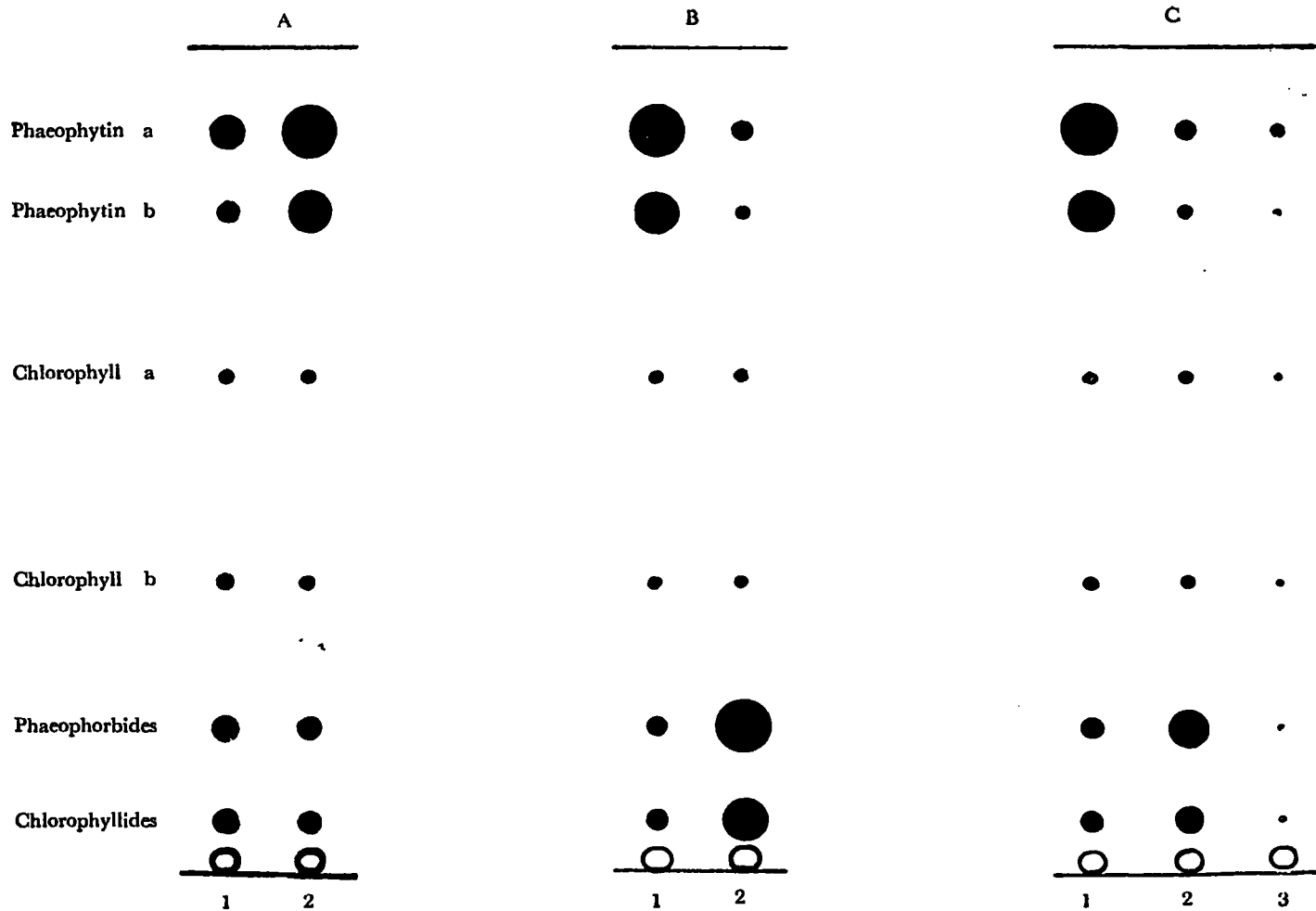


FIGURE 1—Phaeophytins and phaeophorbides of made tea

A—comparison of ether (1) and chloroform (2) extracts of black tea

B—comparison of chloroform extracts of a black tea (1) and a brown tea (2)

C—comparison of chloroform extracts of black (1), gold (2), and silver (3) tips

Note—Natural chlorophyll consists of chlorophyll a and chlorophyll b in the approximate proportions of 3:1

Chloroform extracts of black tip were black in colour, whilst those of silver tip were almost colourless by comparison, with gold tip showing an intermediate colour. Thin layer chromatography of the extracts gave the results depicted in Figure 1C.

Here again the results show that blackness is determined by phaeophytin content, because black tip had by far the highest concentration of this pigment.

Polyphenols and amino-acids in black, gold and silver tips

	Total polyphenols	Vanillin-reacting polyphenols	Total amino-acids
Black tip	285	218	20
Gold tip	255	205	19
Silver tip	295	247	19

All Values expressed as mg/g dry weight in terms of D—Catechin for polyphenols, and β -phenylalanine for amino-acids

Methanol extracts of tips were analysed for polyphenols and amino-acids, and gave the results summarized in Table 1. It is seen that there were no significant differences between the quantities of either of these groups of compounds, and it is therefore considered unlikely that the colour of tip is due to the way that juices are distributed over the hairs (Keegel 1965). If this were so, black and gold tip would be expected to contain higher concentrations of these compounds.

Discussion

Figure 1A showed that blackness of tea is due to the presence of phaeophytin, Figure 1B that brownishness is due to phaeophorbide, and Figure 1C that the "silveriness" of tip is due to the absence of either of these pigments.

Consideration of these findings provides a possible explanation of several observations and practices in tea manufacture. The extreme blackness of low-country teas may be due to their higher content of chlorophyll as compared to up-country teas, and might also provide a rational basis for the selection of darker-leaved clones for propagation in the low-country. It is evident that the higher the content of chlorophyll in the flush, the greater will be the probability of obtaining high concentrations of phaeophytin which will in turn, make the tea blacker. The practice of watering and re-firing grey teas in order to obtain a blacker product may also now be explained as being due to conversion of the residual chlorophyll in the grey teas to phaeophytin, since this conversion of chlorophyll occurs quite readily in the presence of acidified water.

The conversion of chlorophyll to chlorophyllide by chlorophyllase, however, leads ultimately to the formation of phaeophorbide which would make the tea brown. This sequence of reactions probably occurs more readily under conditions of heavy rolling, rotorvaneing, CTC or Clivemeare manufacture, since all these processes allow a more intimate contact of the enzyme with its substrate, when compared with conditions of light rolling with conventional manufacture. This would explain the comparative brownishness of rotorvane, CTC and Clivemeare teas and also the practice of light rolling in the low-country, where appearance is of paramount importance. In this connection the higher values of chlorophyll reported in fully fermented rotorvane and CTC teas (Wickremasinghe *et al* 1965), may have, in fact, been a measure of chlorophyllide, since the spectrophotometric method used would have failed to distinguish between these two pigments. If this were so, firing would lead to the formation of phaeophorbide and so account for the brownishness of rotorvane and CTC teas when compared to conventionally manufactured teas. It

is also of interest that analysis of a sample of Japanese green tea showed that chlorophyllide and phaeophorbide were completely absent in this product, and this could be attributed to the inactivation of chlorophyllase during the steaming stage of green tea manufactured.

The colour of tips is also probably dependent on the chlorophyll content of the bud at the time of plucking. It was observed in teas containing black tip that the bud unfurled on brewing, whereas it remained 'tight' in those with silver tip. This suggested that the former contained buds in a more advanced stage of development which had probably already formed chlorophyll. On this basis it would seem that shorter intervals between plucking rounds might give teas containing a higher proportion of silver tip, since it is not possible to manufacture silver tip from buds which already contain chlorophyll.

The increase of blackness on storage may again be due to the slow transformation of residual chlorophyll in the made teas to phaeophytin, and the increased blackness of teas fired at high temperatures may be due to an acceleration of this transformation process.

Experiments designed to make practical use of these findings are being carried out in collaboration with the Technologist, but it is still too early to make any definite suggestions regarding useful methods for increasing the blackness of tea.

Summary

- 1 — Evidence is presented that the blackness of tea is due to phaeophytins and brownishness to phaeophorbides.
- 2 — The type of changes undergone by chlorophyll, *ie* whether it is converted to phaeophytin or phaeophorbide, is determined by the conditions of manufacture.
- 3 — The colour of tip is determined by the content of chlorophyll in the bud prior to processing.
- 4 — Some observations and practices in manufacture are discussed.

Acknowledgments

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