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THE EFFECT OF RELATIVE HUMIDITY AND TEMPERATURE ON MOISTURE SORPTION BY BLACK TEA

S. Jayaratnam and D. Kirtisinghe

(Tea Research Institute of Sri Lanka, Talawakele, Sri Lanka)

The moisture content of high-grown BOP (1500-650μ) and Dust grade (780-275μ) were determined at 21°C and 32°C at various relative humidities.

The moisture sorption isotherm patterns were found to be sigmoid as has been previously found for other foods. The concept that is widely held that tea would neither lose nor gain moisture when stored in air at 60-65% relative humidity is shown to be invalid. It was found that tea stored at a relative humidity between 10 and 45% was the least likely to deteriorate.

Moisture sorption investigations of BOP and Dust grades at 21°C and 32°C were been used to evaluate the constants of the linear form of Henderson's equation.

INTRODUCTION

Dried black tea can absorb moisture from the atmosphere. Keegel (1956) estimated that in packing, storage and transit, black tea absorbed about 3% (w/w) of moisture. The regulation of this moisture level at 3% is considered by the trade to be important in retaining the freshness and flavour of tea. Rockland (1957; 1960; 1961) has shown the existence of optimum moisture level not only above, but also below which food products deteriorate rapidly. At very low moisture levels autooxidative reactions can account for most of the degradative reactions. At intermediate levels of moisture, enzyme reactions have an important effect while at high levels, the growth of microorganisms are chiefly responsible for the degradative reactions. Apart from moisture, the stability of tea during storage is also affected by the presence of light (Wickremasinghe and Perera 1972).

Several equations have been derived (after Henderson, 1952) to describe moisture sorption isotherms on account of their importance in governing food product stability. The present work was carried out to investigate the sorption of moisture by black tea in order to determine whether the observations made on other foods are applicable to tea.

EXPERIMENTAL

Sorption measurements were made from two grades of high-grown tea from the Tea Research Institute of Sri Lanka, St Coombs, Talawakelle (1200 m amsl) ranging in size from 650-1500μ for the BOP grade and 275-780μ for the Dust grade, at various humidities and at temperatures of 21° and 32°C. Saturated salt solutions, giving known relative humidities (rh) on equilibriation, were placed in desiccators which were then used as constant humidity chambers. When low humidities (12%) were required, these chambers were desorbed with silica gel and calibrated paper hygrometers were used to read their approximate rh. The saturated salt solutions were then allowed to equilibriate for 14 days with the atmosphere inside the constant humidity chambers, with their lids tightly closed before use. The moisture content in the tea samples were determined by moisture oven technique (Ceylon Standard 28).

The initial moisture content of the samples used for the adsorption series of experiments were in the region of 4%. At this level of moisture, at rh below 32.3%, desorption occurred. These samples were therefore dried initially in an oven at 70°C for approximately 4 h to bring the moisture content down to about 1% before placement in the constant humidity chamber for determining adsorption characteristics.

The growth of microorganisms was observed in the samples placed in the constant humidity chamber of 100% rh. The desiccator, the distilled water used for the experiment, the aluminium containers for placing the tea and the tea itself were first sterilized by autoclaving at 1.05 Kg cm^{-2} for 15 min, and the transference of the tea to the aluminium container and the distilled water to the desiccators were done in a room sterilized by uv radiation. This sample was allowed to remain for a month after which it was assumed to have equilibriated with its surroundings and the moisture content was then determined.

For the desorption series of experiments the same samples of BOP and Dust were first allowed to absorb moisture slowly upto about 20%. They were then placed in the constant humidity chambers prepared as before and the equilibrium moisture levels in the made teas were determined on desorption. The adsorption and desorption hysteresis curves were determined initially with the constant humidity chambers maintained at 21°C. These experiments were then repeated with the constant humidity chambers maintained at 32°C, with a fresh set of samples. Samples were assumed to have reached equilibrium with its surroundings when there was no gain or loss in weight between the moisture readings taken on two successive occasions, taken at least 5 days apart.

RESULTS AND DISCUSSION

The moisture sorption characteristics of the BOP grade at 21° and 32°C are presented in Figs 1 and 2 respectively, while Figs 3 and 4 give the corresponding values for the Dust grade. Each point plotted on these curves is the arithmetic mean of readings of moisture content made on duplicate samples after the samples attained equilibrium conditions with its surroundings. Individual readings differed from the mean values by $\pm$ 0.4% for the teas exposed to the lowest rh of 2% and the maximum variation observed was $\pm$ 1.2% at 100% rh. The moisture sorption isotherms showed a characteristic sigmoid pattern.

Henderson (1952) developed the following equation for describing sorption phenomena.

$$1 - rh = e^{-kM^n} \qquad \ldots\ldots\ldots\ldots(1)$$

where rh = relative humdity

k = factor, varying with material

M = equilibrium moisture content, dry basis

and n = exponent varying with material

This equation could be transformed to the linear form:

$$\log\log\left(\frac{1}{1 - rh}\right) = n\log M + k' \qquad \ldots\ldots\ldots(2)$$

$$\text{where } k' = \log_{10} \left(\frac{k}{2.303} \right).$$

The values of log M and log log $\left(\frac{1}{1-rh}\right)$ for the adsorbtion series of BOP and Dust at 21 and 32°C are given in Table 1.

TABLE 1 — *Values of the constants in the linear form of Henderson's equation, for adsorbtion data of BOP and Dust at two temperatures*

Grade	Temperature	n	k′	Correlation Coefficient
BOP	21°C	1.90	-2.24	+0.98*
Dust	21°C	1.85	-2.21	+0.99*
BOP	32°C	1.85	-2.06	+0.96*
Dust	32°C	1.75	-1.99	+0.98*

*Significant at $P<0.001$

Further analysis revealed that regression coefficient obtained for both BOP and Dust grades at a particular temperature, did not differ significantly ($P<0.05$). Therefore, grouping all adsorbtion data corresponding to the two grades at each temperature and finding a common regression coefficient, the following equations are obtained:

$$\log .og \left(\frac{1}{1-rh}\right) = 1.87 \log M - 2.23, \text{ BOP and Dust at } 21°C$$

$$\log \log \left(\frac{1}{1-rh}\right) = 1.80 \log M - 2.30, \text{ BOP and Dust at } 32°C.$$

Desorption too could be described by a relationship of the form given by Henderson but with different values for the constants from the equations governing adsorption. Equations obtained for desorbtion are as follows:

$$\log \log \left(\frac{1}{1-rh}\right) = 2.32 \log M - 2.85, \text{ BOP at } 21°C$$

$$\log \log \left(\frac{1}{1-rh}\right) = 3.10 \log M - 3.69, \text{ Dust at } 21°C$$

$$\log \log \left(\frac{1}{1-rh}\right) = 2.99 \log M - 3.53, \text{ BOP at } 32°C$$

$$\log \log \left(\frac{1}{1-rh}\right) = 3.37 \log; - 3.84, \text{ Dust at } 32°C.$$

In each case the correlation coefficients were significant at $P<0.001$.

A single equation for desorption for any two grades at a given temperature could not be found as the regression coefficients were significantly different ($P<0.05$).

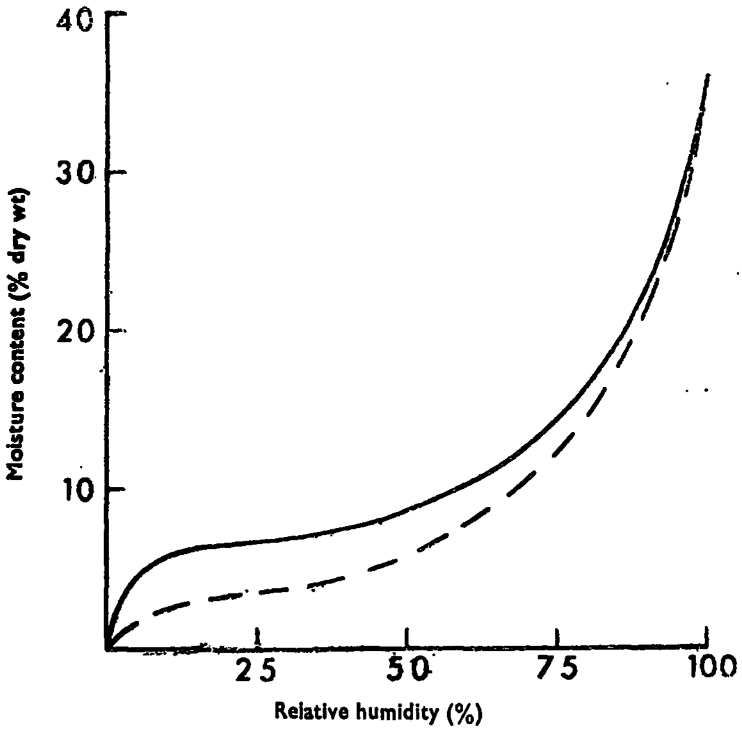

FIG. 1—*Diagrammatic representation of moisture sorption by BOP at 21°C—Unbroken line—desorption, broken line—adsorption.*

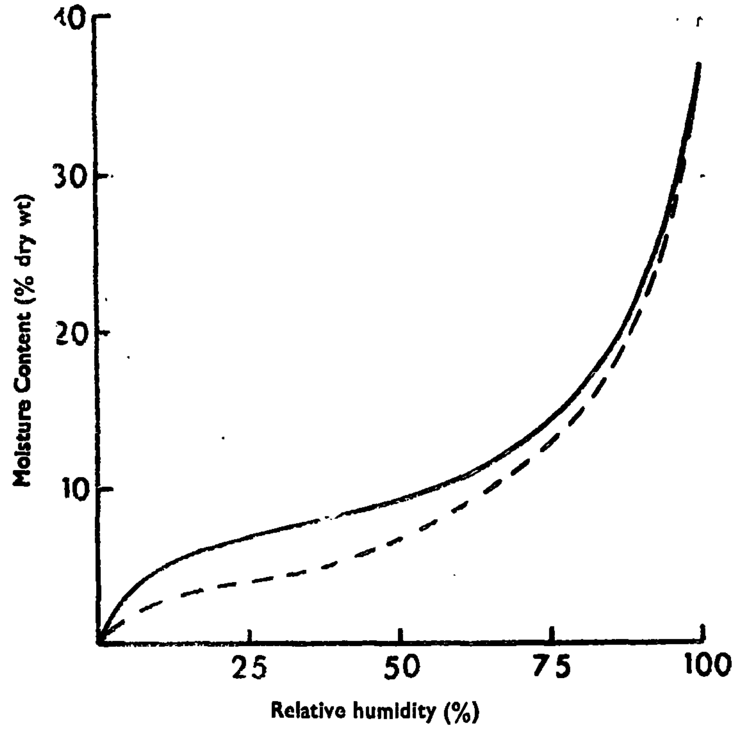

FIG. 2—*Diagrammatic representation of moisture sorption by BOP at 32°C—Unbroken line—desorption, broken line—adsorption.*

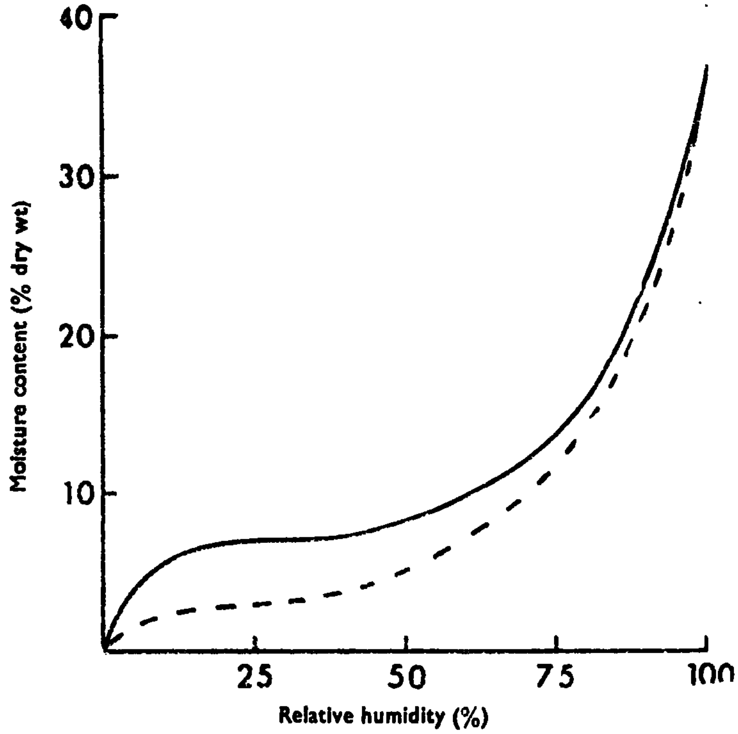

FIG. 3—*Diagrammatic representation of moisture sorption by Dust at 21°C—Unbroken line—desorption, broken line—adsorption.*

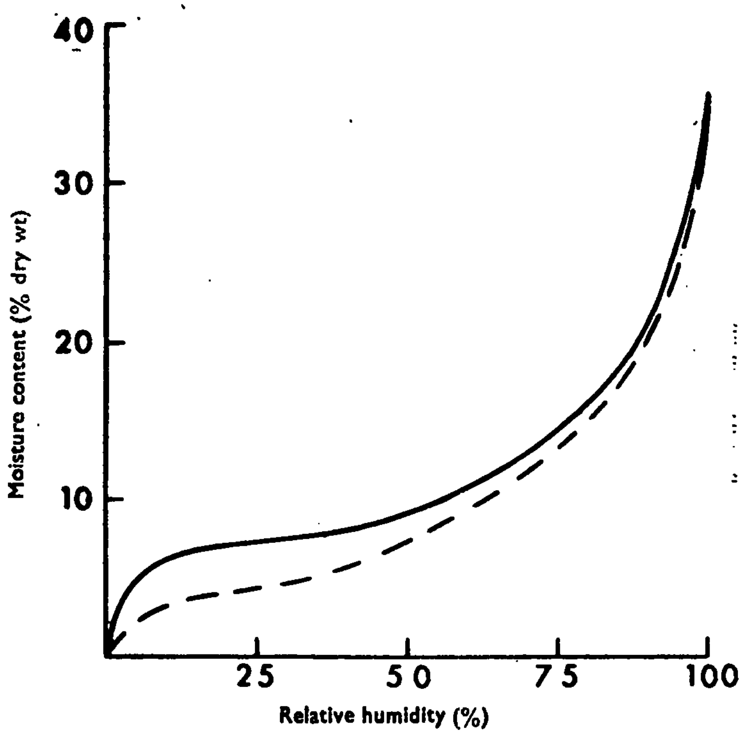

FIG. 4—*Diagrammatic representation of moisture sorption by Dust at 32°C—Unbroken line—desorption, broken line—adsorption.*

The concept that is widely held that tea would neither lose nor gain moisture when stored in contact with air at 60-65% rh (Keegel 1956) has been shown to be invalid. It has been demonstrated instead, that the moisture content of any sample will equilibriate with the surrounding atmosphere at any rh.

It is also seen from Figs 1 to 4 that the moisture level of tea cannot be kept under the 6% figure that is deemed necessary to keep a tea from undergoing rapid change, unless it is stored in an atmosphere whose rh is under 45%, a figure not easily attained under storage conditions in the tropics. This would therefore emphasize the importance of storage under air tight conditions.

It has been shown (Rockland 1969) that some food products have both upper and lower limits of moisture content outside which rapid degradative reactions are known to take place. In tea only the upper 6% moisture level has hitherto been recognized but it now seems likely that a lower limit of around 2% is also present for tea. Tea tasters complain of a 'bakey character' of overdried teas, but it is possible that this unpleasant character usually associated with a tea whose moisture content is exceptionally low, is the result of autooxidative reactions which are known to take place in other food products at very low levels of moisture. It is, therefore, important that a tea should not be stored in an atmosphere with less than about 10% rh.

The fact that it has been possible to describe all the adsorption data by a single regression coefficient in the Henderson equation means that total adsorption appears to be independent of particle size within the range of experimentation, *ie* 275-1500 μ. It is, however, dependent on temperature. The mechanism of description appears different from that of adsorption, depending both on particle size and temperature.

CONCLUSIONS

The total amount of moisture adsorbed by a tea on reaching equilibrium with it surroundings is dependent on temperature and relative humidity but is independent of particle size (within the size range 275-1500μ). Desorption phenomena, however, appear to be dependent on particle size within the range investigated, but, like adsorption phenomena, are dependent on temperature. The best conditions for the storage of tea is in surroundings whose rh is within the range of 10-45%.

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