MOISTURE ADSORPTION ISOTHERMS OF COPRA AT DIFFERENT TEMPERATURES

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ABSTRACT

The moisture adsorption isotherms of *tapahan* dried copra were determined at 22, 30 and 38°C. The isotherm of copra at different temperatures were of type III according to the BET classification. Equilibrium moisture content of copra at a given water activity increased as temperature decreased. The Henderson equation gave better fit of the adsorption isotherms of copra at each given temperature, followed by Oswin and Caurie equations, respectively. A modified Henderson equation can describe the effect of temperature on the adsorption isotherms of copra. The critical moisture contents of copra with respect to mold growth and aflatoxin production decreased as temperature increased. Aflatoxin production had higher critical moisture content than mold growth only.

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INTRODUCTION

Ninety percent of coconuts harvested in the Philippines are converted into copra. Philippine copra is produced using kukum dryers, native *tapahan* dryers and sun drying, resulting in three classes of copra. During storage of copra, there is extensive spoilage and loss through the action of microorganisms, chiefly fungi and specifically *Aspergillus flavus*. Industry sources place the spoilage to about 20% loss in production of oil and meal (UCAP, 1987). Hence, PCA (1992) recommended the use of *tapahan* dryers which produce copra with lower levels of aflatoxin as compared with those resulting from kukum- or sun-drying.

Copra is usually dried to around 5% moisture to be considered as a *resecada* grade. *Resecada* is the basis of trade for copra both in the domestic and foreign markets (PCARRD, 1983). Copra will either lose or gain moisture depending upon the relative humidity and temperature conditions of storage until it reaches its equilibrium moisture content (M_e) (Lozada, 1978). The relationship of M_e and equilibrium relative humidity or water activity (A_w) at constant temperature is known as the moisture sorption isotherm of the product (Henderson, 1952; Labuza, 1968).

The sorption properties of biological materials are of interest because of the influence of A_w on microbial, enzymatic, and chemical reactions and hence, on the storage stability of the products (Diamante, *et al.*, 1992). Coconut research literatures have very limited data on the sorption properties of copra at different temperatures (Bustrillos and Banzon, 1949; Pixton and Warburton, 1971; Tuason and Madamba, 1980).

This study was carried out to obtain the adsorption isotherms of*tapahan* dried copra at different temperatures. The experimental isotherms were fitted using published two-parameter isotherm equations (Boquet, *et al.*, 1978) and were modified to describe the temperature dependence of the isotherm data. Using published data on minimal A_w with respect to mold growth and aflatoxin production, critical moisture contents of copra were determined using derived isotherm equations.

METHODOLOGY

Adsorption isotherm determination

Freshly made *tapahan* dried copra with 15% (dry basis) initial moisture content (MC) was obtained from the Regional Coconut Research Center (RCRC), ViSCA, Baybay, Leyte. The copra was sliced into 2 mm thickness and dried further in a forced convection electric dryer at 60-70°C to reduce MC to about 1%. The dried copra was then placed in a conditioning chamber at 90% RH and ambient temperature to re-adsorb some moisture. About 50 g of copra slices were withdrawn from the chamber at various time durations. MC was determined in triplicate by drying each batch of sample in an air oven at 105°C for at least 15 hrs (Diamante, *et al.*, 1992). The A_w of the same batch of sample was determined in duplicate 20 g of copra for each A_w Meter (G. Luft, GmbH & Co.). The equilibrium of the sample inside the meters was for at least 6 hrs and temperatures for A_w were those of an airconditioned room (22±1°C) and a laboratory incubator (30±1 and 38±1°C). Due to the limitations of the A_w meters, only samples with A_w above 0.40 were obtained. Plots of equilibrium MC against A_w at different temperatures yielded the adsorption isotherms of copra.

Curve fitting of the adsorption isotherms

The experimental adsorption isotherms of copra were fitted with selected two-parameter isotherm equations reported by Boquet,*et al.* (1978). The best fitting equation based on high coefficient of determination (r^2) and low mean relative percentage deviation (MRPD) values (Lomauro,*et al.*, 1985; Diamante, *et al.*, 1992) was selected to model the isotherms at each given temperature.

The constants of the selected equations were related to temperature by linear, logarithmic, exponential and power regressions. The relationship with the highest r^2 was chosen as the temperature function for that constant.

Critical moisture content determination for copra

Using the derived isotherm equations and the minimal A_w of*Aspergillus flavus* for growth (0.78-0.80) and aflatoxin production (0.83-0.87) as reported by Beuchat (1981), the critical MCs of copra at different temperatures were calculated.

RESULTS AND DISCUSSION

Adsorption isotherms of tapahan dried copra

Figure 1 shows the adsorption isotherms of *tapahan* dried copra at different temperatures. The isotherms of copra were of type III according to the classification of Brunauer, Emmet and Teller (BET) (1938). Results showed that as A_w increased, the equilibrium MC also increased. The temperature had the usual effect predicted by the theory of physical adsorption: the quantity of sorbed water at a given A_w increased as the temperature decreased (Iglesias, *et al.*, 1975; Diamante and Munro, 1990; Diamante, *et al.*, 1992). The results agree with the data of Wolf,*et al.*, (1973) for paranut and pekanut, and Bustrillos and Banzon (1949) for copra.

The adsorption isotherms of copra from other workers and at almost the same temperatures (Bustrillos and Banzon, 1949; Pixton and Warburton, 1971) are presented in Figure 2. The isotherms of Pixton and Warburton (1971) at 25°C is within the 22 and 30°C isotherms of this study, but the

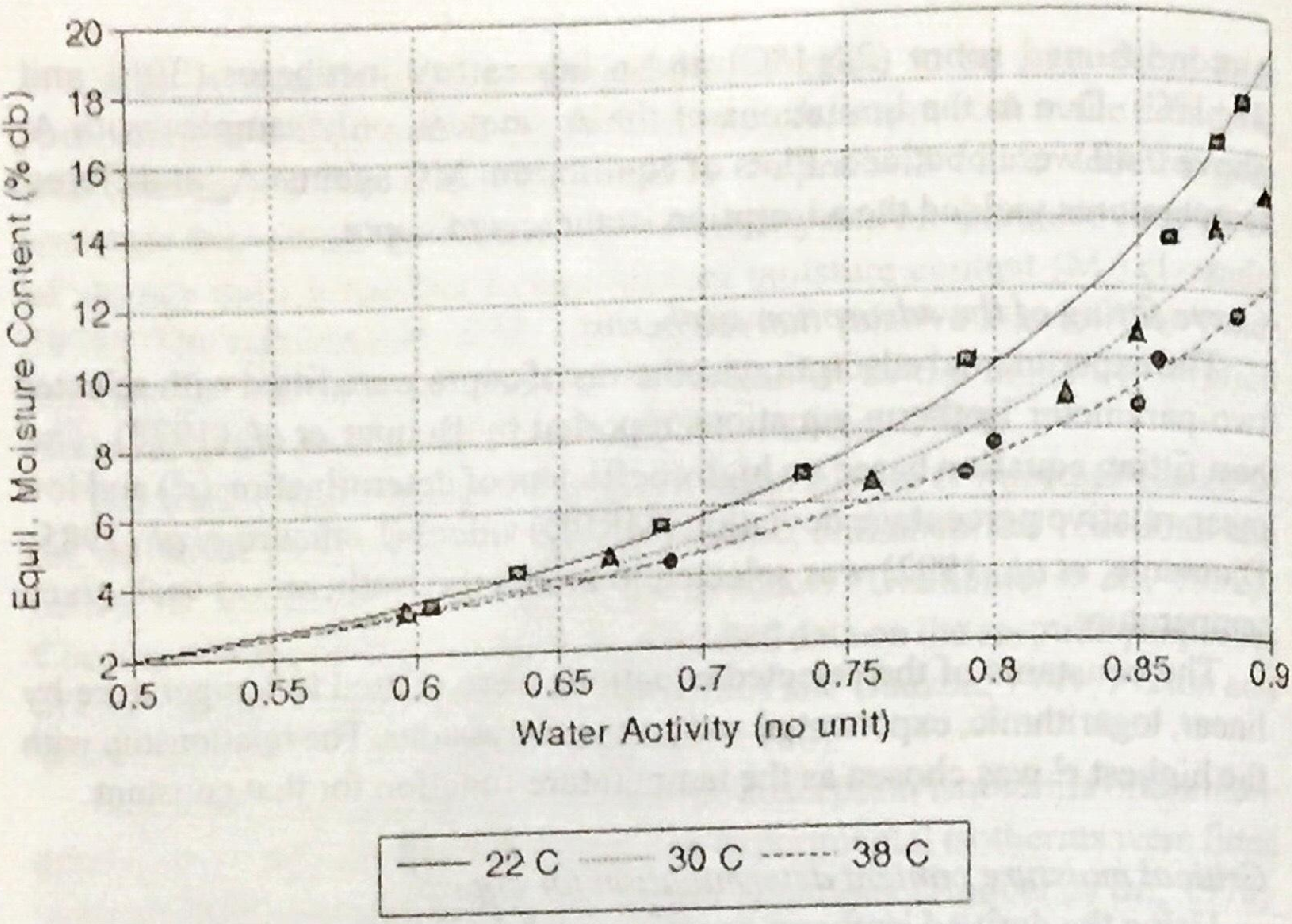

Figure 1. Adsorption isotherms of tapahan-dried copra at different temperatures.

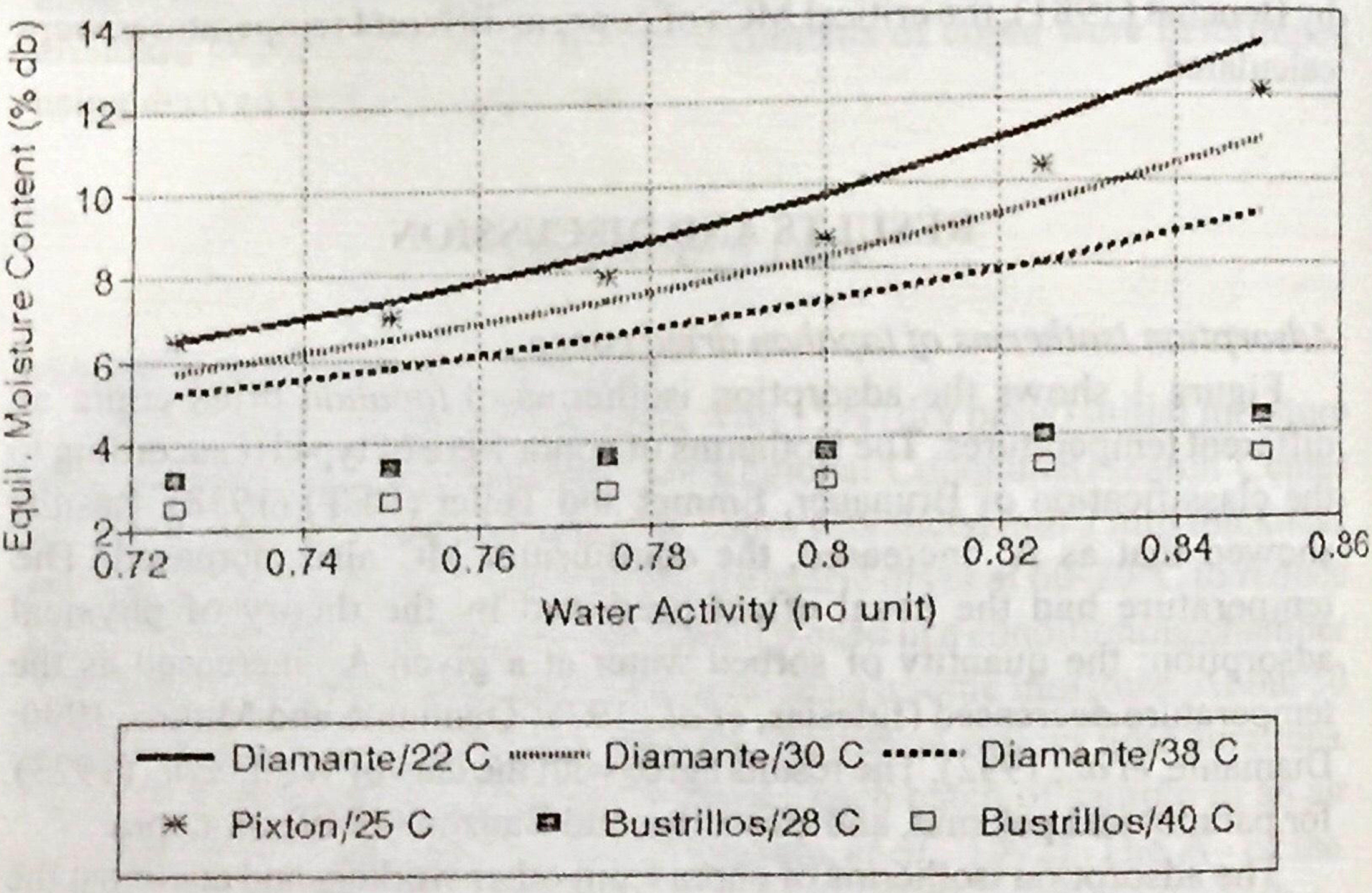

Figure 2. Adsorption isotherms of copra at different temperatures from this study and from Bustrillos and Banzon (1949); and Pixton and Warburton (1971).

isotherm of Bustrillos and Banzon (1949) at 28.5°C is relatively lower. Comparison of the isotherm at 38°C obtained from this study with that of Bustrillos and Banzon (1949) at 40°C again show a big difference. The difference of the data with that of Bustrillos and Banzon (1949) may be attributed to a number of factors. First, the temperatures of the isotherms were quoted as 28.5±3°C and 40±2°C, indicating that temperature control during the conduct of the experiment was not very good. Big temperature fluctuations will considerably affect the equilibration of the samples. Second, a close look at the data of Bustrillos and Banzon (1949) show a wide spread of the experimental points from the approximate curves of the isotherms. Lastly, the type of copra was not specified and may not be tapahan-dried copra after all. Hence, the sorption properties of the copra by Bustrillos and Banzon (1949) will be different from the data obtained.

Curve fitting of copra isotherms

The experimental isotherms were fitted with selected two-parameter equations from Boquet, *et al.*, (1978). Table 1 shows the r^2 for the different equations.

The Henderson equation gave consistently higher values of r^2 than the other equations. This is closely followed by the Oswin and Caurie equations, respectively. The MRPD values for the three equations were calculated and showed that the Henderson equation also gave consistently lower MRPD values (Table 1).

Table 1. Coefficients of determination (r^2) for the regression of the adsorption isotherms of copra using selected two-parameter equations from Boquet*et al.* (1978).

Isotherm Equation	Coefficient of Determinants (r^2) 22°C	30°C	38°C
CAURIE	0.994	0.988	0.985
	(4.26%)	(5.09%)	(3.27%)*
HALSEY	0.979	0.988	0.983
HENDERSON	0.992	0.994	0.989
	(4.09%)	(3.31%)	(2.41%)*
KUHN	0.987	0.978	0.975
OSWIN	0.984	0.992	0.986
	(5.91%)	(4.34%)	(3.28%)*
SMITH	0.990	0.978	0.981

* - mean relative percentage deviation (MRPD) values.

Table 2. Slopes (S) and intercepts (I) for regressions of the Henderson equation* to the adsorption isotherms of copra.

Temperature (°C)	Slope	Intercept	r^2
22	-0.74745	0.53691	0.992
30	-0.77998	0.59394	0.994
38	-0.85147	0.67152	0.989

*$\ln[-\ln(1-A_w)] = I + S \ln M_e$ (Henderson equation).

Boquet, *et al.*, (1978) found that the Oswin and Henderson equations best described the isotherms of a range of food proteins. Several nuts and oilseeds were found to be fitted well by the Oswin equation as reported by Lomauro, *et al.*, (1985), while Diamante, *et al.*, (1992) have shown that the isotherms of several types of milk protein (casein) were best described by the Henderson equation.

Temperature dependence of copra isotherms

Equations for predicting the effect of temperature on sorption isotherms of foods are important because of the limited data available at higher temperatures. These equations will enable the interpolation and extrapolation (with caution) of the limited data to other temperatures.

Table 2 shows the slopes and intercepts for regression of the Henderson equation to the adsorption isotherms for copra at different temperatures. Generally, the slopes (S) decrease with temperature while the intercepts (I) increase with temperature. The constants in Table 2 regressed with respect to temperature (T) and regression equation with the highest r^2 are:

$$I = -10^{(-0.20749 + 0.0035367\,T)} \quad (r^2 = 0.962)$$
$$S = 10^{(-0.40527 + 0.0060723\,T)} \quad (r^2 = 0.997)$$

Hence, the resulting modified Henderson equation with a temperature factor is:

$$\ln[-\ln(1-A_w)] = -10^{(-0.207 + 0.00354\,T)} + 10^{(-0.405 + 0.00607\,T)} \ln M_e$$

The MRPD values for the predicted isotherms using the Henderson and modified Henderson equations were calculated and shown in Table 3. The results were very similar for both isotherm equations which suggest that the

Table 3. Mean relative percentage deviation (MRPD) of Henderson and modified Henderson equations from the experimental adsorption isotherms of copra.

Temperature (°C)	Henderson Equation	Modified Henderson Equation
22	4.09%	4.10%
30	3.31%	3.53%
38	2.41%	2.48%

modified Henderson equation can describe the effect of temperature on the isotherms of copra. Diamante, *et al.*, (1992) also reported that a four-parameter Henderson equation with temperature factor can adequately describe the isotherms of different types of caseins at different temperatures.

Figure 3 shows the reproduced adsorption isotherms of copra at different A_w and temperatures using the modified Henderson equation. The plots were extrapolated beyond the A_w and temperature ranges of the experiments to show the effect of low A_w and higher temperatures on the adsorption isotherms. Results suggest that the equilibrium MC of copra is affected by temperature when A_w of copra is above 0.60.

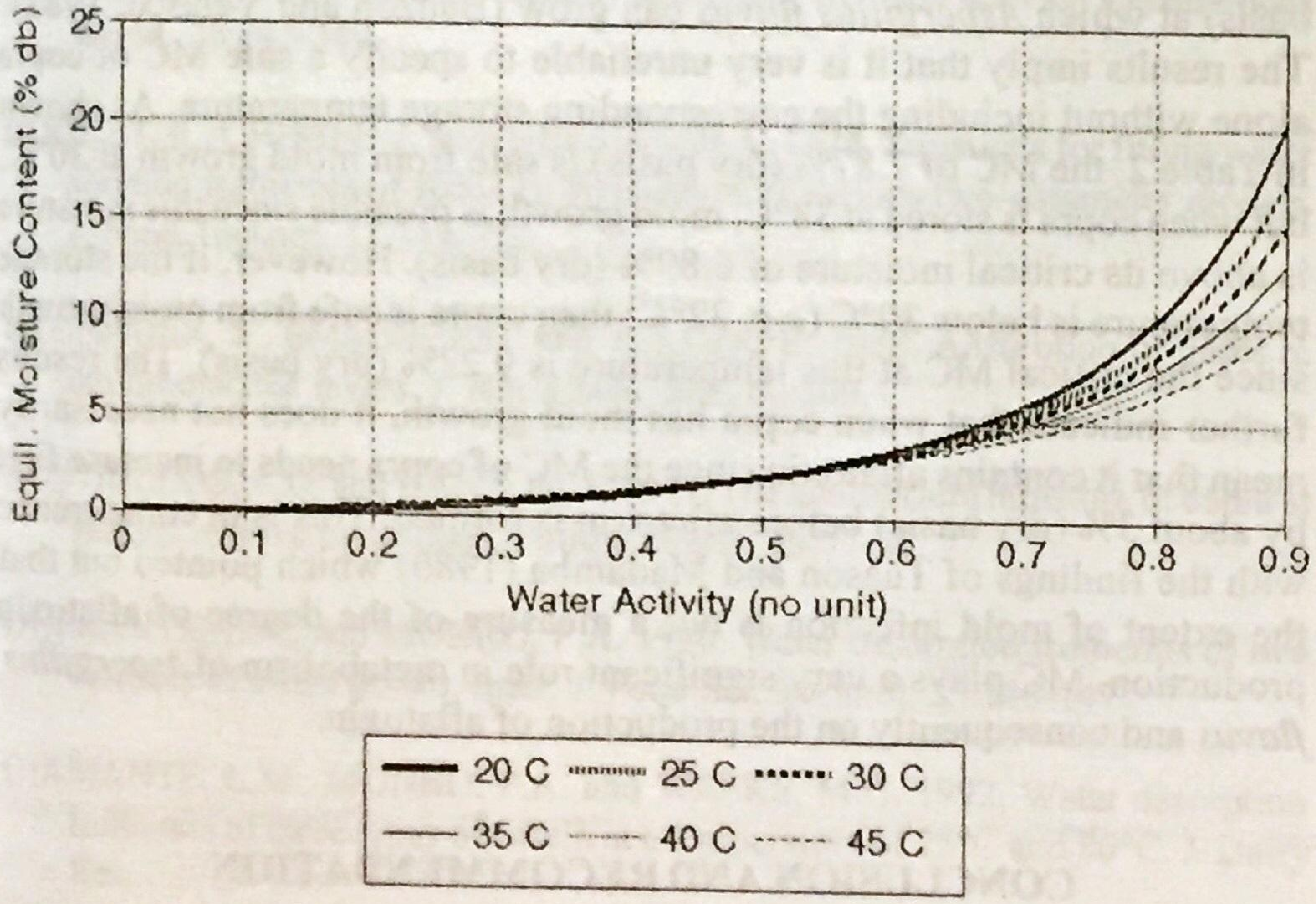

Figure 3. Adsorption isotherms of tapahan-dried copra at different temperatures as derived from the modified Henderson equation.

Table 4. Critical moisture contents for mold *(Aspergillus flavus)* growth and aflatoxin production of copra at different temperatures.

Isotherm Temperature	Critical Moisture Contents (% dry basis)	
	Mold Growth	Aflatoxin Production
22°C	9.22	13.26
30°C	7.87	10.68
38°C	6.89	9.22

Critical moisture content determination for copra

From the data of Beuchat (1981), the minimal A_w range for the growth of *Aspergillus flavus* is 0.78-0.80 and 0.83-0.79 for aflatoxin production. Using the mean A_w of 0.79 and 0.85, the critical MCs for mold growth and aflatoxin production were calculated using the Henderson equation for the three temperature levels (Table 4). Critical MC of copra decreases as temperature increases. Aflatoxin production required higher critical MC than mold growth only. The calculated critical MC for copra at 30°C of 7.87% (dry basis) is almost the same as the low level MC of 7%, wet basis (7.53%, dry basis) at which *Aspergillus flavus* can grow (Banzon and Velasco, 1982). The results imply that it is very unreliable to specify a safe MC of copra alone without including the corresponding storage temperature. As shown in Table 2, the MC of 7.87% (dry basis) is safe from mold growth at 30°C, but when copra is stored at 38°C, mold growth is possible since this moisture is above its critical moisture of 6.89% (dry basis). However, if the storage temperature is below 30°C (*e.g.* 22°C) then copra is safe from mold growth since the critical MC at this temperature is 9.22% (dry basis). The results further indicate that when copra has mold growth, it does not necessarily mean that it contains aflatoxin since the MC of copra needs to increase first by about 3% (dry basis) before aflatoxin is formed. This is in concurrence with the findings of Tuason and Madamba (1980) which pointed out that the extent of mold infection is not a measure of the degree of aflatoxin production. MC plays a very significant role in metabolism of*Aspergillus flavus* and consequently on the production of aflatoxin.

CONCLUSION AND RECOMMENDATION

The adsorption isotherms of*tapahan* dried copra at different temperatures were of type III according to the BET classification. The equilibrium moisture content of copra at a given A_w increased as the temperature decreased. The Henderson equation gave better fit of the adsorption isotherms of copra at each given temperature followed by Oswin and Caurie equations, respectively. A modified Henderson equation can describe the effect of temperature on the isotherms of copra.

The critical moisture content of copra with respect to mold growth and aflatoxin production decreases as temperature increases. Aflatoxin production had higher critical moisture content than mold growth. It is recommended that confirmatory storage studies for copra packaged at different A_w and different temperatures be carried out in order to confirm the predicted mold growth and aflatoxin production found in this study.

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