Equilibrium Relative Humidity-Equilibrium Moisture Content Isotherms of Oil Palm Kernels

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ABSTRAK

Lengkung sesuhu kelembapan nisbi keseimbangan-kandungan lembapan keseimbangan (ERH-EMC) atau lengkung sesuhu lembapan pepejal penting dalam pengeringan, pencampuran pepejal, pembungkuşan dan storan bahan tersebut. Lengkung sesuhu ERH-EMC kernel kelapa sawit ditentukan dengan menggunakan sebuah kebuk sekitaran malar untuk beberapa gabungan kelembapan nisbi (30%-90%) dan suhu udara (30° – 70°C). Lengkung sesuhu ini dapati memadani persamaan-persamaan Hasley dan Henderson.

ABSTRACT

Equilibrium relative humidity-equilibrium moisture content (ERH-EMC) or moisture isotherms of solids is important in the drying, solid mixing, packaging and storage of such material. ERH-EMC isotherms of oil palm kernels are determined by using a constant environmental chamber for several combinations of air relative humidity (30-90%) and temperature (30-70°C). The isotherms are found to fit the Hasley and Henderson equations well.

INTRODUCTION

Equilibrium moisture content and equilibrium relative humidity relationship or sorption and desorption isotherms are used in post-harvest processes and the food industry for a number of purposes, with drying, mixing, packaging and storage being the main fields of application (Gal 1983). In drying operations desorption isotherms determine the lowest possible moisture content attainable at the process temperature. Determination of

the ERH-EMC isotherms has become a very common practice in food laboratories due to an increased awareness of its importance for characterizing the state of water in foods, namely its availability for biological, physical, and chemical changes (van den Berg and Bruin 1978; Rockland and Nishi 1980).

Brooker *et al*. (1974) observed that moisture sorption and desorption characteristics of a material are influenced by many factors such as the origin, composition, and history of the material and the methodology of measurement. Speiss and Wolf (1983) concluded that ERH-EMC isotherms of the same material from different sources usually differ widely and are comparable only with qualification. Different objectives in measuring the isotherms complicate the issue further, and have resulted in a great variety of measurement methods. Gravimetric, manometric and hygrometric procedures for obtaining the isotherms have been well described in detail by various workers such as Taylor (1961), Toledo (1973), Labuza (1974), Gal (1975, 1983), Troller and Christian (1978), and Neuber (1981).

Attempts to define a microcrystalline cellulose (MCC) as a reference material, a reference method and thus a reference isotherm as reported by Speiss and Wolf (1983) have been of limited success because of the need to use standard equipment. Gal (1983) argued that isotherms of other workers should not be used unless all relevant data are duly quoted and there is a close correspondence between the substance for which the isotherm had been determined and that to which it is applied. This condition is hardly ever fulfilled and application oriented sorption/desorption isotherm measurement by laboratories involved in the application of such data has become more important.

Equilibrium between the ambient and the sample is achieved either by the static method where the sample is allowed to come to equilibrium in still moist air or by the dynamic method where the air is mechanically moved. The static method has been used extensively in the past, but its main drawback is the relatively long equilibration time of up to several weeks. Furthermore at high relative humidity and temperature, samples of biological material, especially agricultural products, may become mouldy before equilibrium is attained. The dynamic method is faster and is thus to be preferred.

The desorption data are fitted to the Hasley's and Henderson's equations. Hasley's equation (Hasley 1948; Iglesias *et al*. 1975) is given by

$$y_e = \exp\left[-A_2 \Big/ X_e^{A_1}\right] \qquad (1)$$

where y_e is the ERH, X_e is the EMC and A_1 and A_2 are constants.

Henderson's equation (Henderson 1952) is given by

$$1 - y_e = \exp\left[-B_2 X_e^{B_1}\right] \tag{2}$$

where B_1 and B_2 are constants. The choice of the use of these two equations instead of much more recent ones is determined by the ease in which the constants can be determined. The constants are estimated by using a least square fitting algorithm. The aptitude of each equation is evaluated by using the mean relative percentage modulus, E, which is defined by

$$E = \frac{100}{N} \sum_{i=1}^{N} \frac{y_{e(meas)} - y_{e(val)}}{y_{e(meas)}} \tag{3}$$

where $y_{e(meas)}$ and $y_{e(cal)}$ are respectively the experimental and the predicted values of the equilibrium relative humidity and N is the number of experimental data.

MATERIALS AND METHODS

Equilibrium between the air and the sample was achieved by using an environmental chamber (ISUZU model μ-2501); air at approximately 1 m/s was forced around the sample for about 24 h at fixed relative air humidity and temperature. The working range for air relative humidity and temperature was 20-90% and 30-70°C respectively. The size of oil palm kernels used was of the range 11.2-12.5 mm. After the completion of the equilibrating period, the equilibrium moisture content of the sample was determined according to the ASAE S352.2; approximately 10 g of the sample in five replicates were dried in an electric oven at 103°C for 72 h.

RESULTS AND DISCUSSION

It is observed that equilibrium in the constant environmental chamber is approached after about 16 h. All desorption experiments are carried over a time interval of 16 h to ensure equilibrium is reached before measurements are made. *Fig. 1 and 2* show the desorption isotherms of oil palm kernels at 30-70°C fitted with Hasley's and Henderson's models respectively. Both graphs depict the typical sigmoid shape which indicates multi-layers adsorption of water in a macroporous material.

Both Hasley's and Henderson's models show better fit at temperatures of 40 and 30°C compared to higher temperatures. This trend can be seen in Table 1 where the relative deviations are tabulated against all the temperatures. This phenomenon could be accounted for by kernel oil losses at higher temperatures because oil can be seen exuding from the sample at these temperatures.
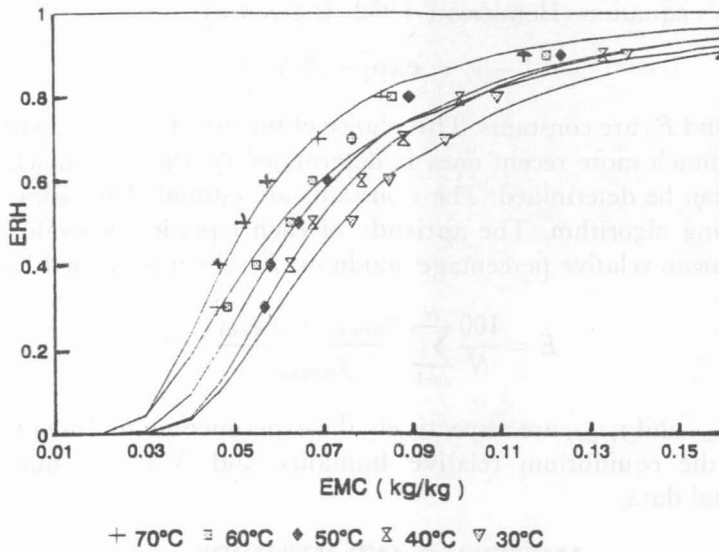
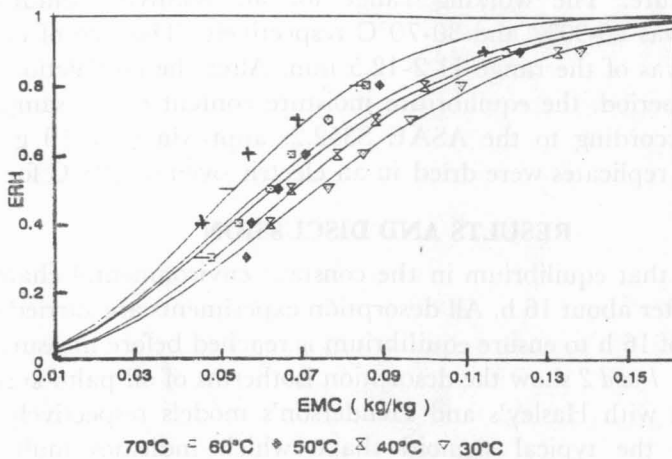*Fig. 1. Moisture desorption isotherms for oil palm kernels using Hasley's model*

+ 70°C ᵌ 60°C ◆ 50°C ⅄ 40°C ▽ 30°C

70°C = 60°C ◆ 50°C ⅄ 40°C ▽ 30°C

Fig. 2. Moisture desorption isotherms for oil palm kernels using Henderson's model

CONCLUSION

Experimental desorption data were generated for oil palm kernels and typical sigmoidal desorption isotherms were established. The relative deviation increases with respect to temperature. This is most probably due to the oil losses observed at temperatures of 50°C and higher. Both Hasley's and Henderson's models seem to be suitable to represent the

TABLE 1

Model parameters and relative deviations

Model	Temperature (°C)	A_1	A_2	E (%)
	70	2.6461	0.000292	6.10
	60	2.1587	0.001623	6.62
Hasley	50	2.6000	0.000552	7.11
	40	2.8379	0.000351	1.90
	30	2.5448	0.000938	2.97
	Temperature (°C)	B_1	B_2	E (%)
	70	1.9306	194.7500	8.16
	60	1.8420	118.7059	8.10
Henderson	50	1.8245	105.4636	6.92
	40	2.0218	155.9306	3.42
	30	1.9943	124.4463	2.08

desorption isotherms of oil palm kernels especially at a temperature of 40°C or lower. This work represents the preliminary stage of a study of the ERH-EMC relations of oil palm kernels which is very significant in the study of its drying kinetics.

ACKNOWLEDGEMENTS

REFERENCES

ASAE 1991. *Standards*. American Society of Agricultural Engineers.

BROOKER, D.B., F.W. BAKKER-ARKEMA and C.W. HALL. 1974. *Drying Cereal Grains*. Westport, Connecticut: Avi Publishing.

GAL, S. 1975. Recent advances in techniques for the determination of sorption isotherms. In *Water Relations of Foods*, ed. R.B. Duckworth, p. 139. New York: Academic Press.

GAL, S. 1983. The need for practical applications of sorption data. In *Physical Properties of Foods*, ed. R. Jowitt *et al*. London: Applied Science Publishers.

HASLEY, G. 1948. Physical adsorption in non-uniform surfaces. *J. Chem. Phys.* **16**: 931.

HENDERSON, S.M. 1952. A basic concept of equilibrium moisture. *Agric Eng.* **33**: 29.

IGLESIAS, H.A., J. CHIRIFE and J.L. LOMBRARDI. 1975. An equation for correlating

equilibrium moisture content in foods. *J. Food Technol.* **10**: 289.

LABUZA, T.P. 1974. *Theory, Determination and Control of Physical Properties of Food Materials.* Dordrecht: D. Riedel.

NEUBER, E.E. 1981. Evaluation of critical parameters for developing moisture sorption isotherms of cereal grains. In *Water Activity: Influence on Food Quality* ed. L.B. Rockland and G.F. Stewarts, p. 199-222. New York: Academic Press.

ROCKLAND, L.B. and S.K. NISHI. 1980. Influence of water activity on food product stability. *Food Technol.* **34**: 42.

SPEISS, W.E.L. and W. WOLF. 1983. Critical evaluation of methods to determine moisture sorption isotherms. In *Water Activity: Theory and Applications to Food* ed. L.B. Rockland and L.R. Beuchart. New York: Marcel Dekker.

TAYLOR, A.A. 1961. Determination of moisture equilibrium in dehydrated foods. *Food Technol.* **15**: 566.

TOLEDO, R.T. 1973. Determination of water activity in foods, *Proc Meat Ind. Res Conf AMIF.*

TROLLER, J. and J.H.B. CHRISTIAN. 1978. *Water Activity and Food.* New York: Academic Press.

VAN DEN BERG, C. and S. BRUIN. 1978. Water activity and its estimation in food system: theoretical aspects. In *2nd Int. Symp. Properties of Water in Relation to Food Quality and Stability* (Isopow-11), September 10-16, Osaka, Japan.