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Moisture sorption isotherms of sorghum malt at 40 and 50 °C

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Abstract

The desorption and adsorption equilibrium moisture isotherms of sorghum malt at the temperatures of 40 and 50 °C, over the water activity range of 0.1–0.9, were determined using the static gravimetric method. A non-linear regression programme was used to fit five moisture sorption isotherm models [Modified Henderson, Modified Chung-Pfost, Modified Guggenheim–Anderson–de Boer (GAB), Modified Halsey and Modified Oswin] to the experimental data. The models were compared using the standard error of estimate, mean relative percentage deviation, fraction explained variation and residual plots.

The Modified Chung-Pfost model was found to be the best for predicting the desorption equilibrium moisture content, while the adsorption equilibrium moisture content was best predicted by the Modified Oswin model. The desorption and adsorption water activities were found to be best fitted by the Modified Oswin model.

The moisture sorption isotherms were sigmoidal in shape and showed a marked effect of temperature. The span of the moisture sorption hysteresis loop formed, decreased with increase in temperature, while the size increased with increase in temperature.

Keywords: Adsorption; Desorption; Equilibrium moisture content; Modified Chung-Pfost model; Modified Oswin model; Water activity

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1. Introduction

Sorghum belongs the Gramineae family of crops and the Andropogoneae tribe. The species *Sorghum bicolor* (L.) Moench is cultivated throughout the inter-tropical zone of Africa (Chantereau and Nicou, 1994). In Nigeria, it is mainly grown in the region lying between the middle belt and semi-arid zones. Sorghum grain is an energy-providing food and according to Oyenuga (1978), sorghum has a carbohydrate and protein content of 76.18% and 15.03% respectively.

The production of sorghum malt from the grain involves processes such as cleaning, grading, steeping, germination and kilning. Graded sorghum grains are soaked in water for 2 days. The water is changed every 6 h to maintain the supply of oxygen. At the end of the steeping process, the grains are allowed to germinate for three days, then the germination is terminated and the grains are dried (kilned) either in an oven at the temperature of about $48 \pm 2\,^{\circ}C$ or in the sun for 24 h. The kilned malt is either stored in sacks or used in the production of local alcoholic drinks and as a substitute for rice, maize and barley in the brewing of beer and other malted drinks. It is also used as a flavouring agent in the making of bread, biscuits and instant food.

The efficient processing and storage of sorghum malt and proper modelling and optimization of the drying process require the knowledge of its moisture sorption isotherms at different temperatures. The moisture sorption isotherm of food graphically relates its equilibrium moisture content in either desorption or adsorption, to the water activity at a definite temperature.

The methods of determining moisture sorption isotherms have been thoroughly reviewed by Gal (1975,1981,1983). In all, three basic techniques were pointed out, namely the manometric, the gravimetric and the special methods. The static gravimetric technique, which involves the use of saturated salt solutions to maintain constant relative humidity (r.h.) in enclosed still moist air at a certain temperature, has been considered preferable for obtaining the complete sorption isotherms (Gal, 1981), and has been recommended as the standard method (Speiss and Wolf, 1987).

Several equations have been used by investigators to describe the moisture isotherms of food and agricultural materials (Van den Berg and Bruin, 1981). However the five commonly used equations have been noted (Yu et al., 1999; Aviara et al., 2004) to be the Modified Henderson model (Thompson, 1972), Modified Chung-Pfost model (Pfost et al., 1976), Modified Halsey model (Iglesias and Chirife, 1976), Modified Oswin model (Chen and Morey, 1989), and the Guggenheim–Anderson–de Boer (GAB) model (Van den Berg, 1984) as modified by Jayas and Mazza (1993). The expression of these equations for both the equilibrium moisture content and water activity are presented in Table 1.

The desorption process has been noted to yield a higher equilibrium moisture content than the adsorption process at the same water activity and temperature. As a result, the desorption isotherm usually lies above the adsorption counterpart and this gives rise to moisture sorption hysteresis. Several explanations have been proposed for the occurrence of this phenomenon. These include the ink bottle theory, the molecular shrinkage theory (Chung and Pfost, 1967) and the capillary condensation and swelling fatigue theory of Ngoddy and Bakker-Arkema (1975). Ngoddy and Bakker-Arkema (1975) also developed a method for calculating the desorption isotherms of biological products from the corresponding adsorption isotherms, if the bulk moduli of the product as a function of moisture content is known. Chinachotti and Steinberg (1986), however, noted that moisture sorption hysteresis is due to the presence of amorphous sugar.