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Application of seed equilibrium moisture curves in agro physics

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ABSTRACT

The water relations play a fundamental role in seed comprehension of biology. In order to describe the process of drying and the effect on water activity, which controls biological change in storage, a sound knowledge of the relationship between equilibrium moisture content (EMC) and water activity/equilibrium relative humidity (ERH) is essential. The relationship between the total moisture content and water activity of the food, over a range of values, at a constant temperature and under equilibrium conditions, yields a moisture sorption isotherm when expressed graphically. This isotherm curve can be obtained in one of two ways; adsorption or desorption. The establishment and the mathematical description of the moisture sorption isotherms could help the food engineers to design these processing equipments. Here there are many researches on seeds of plant and some foods. In all researches seeds or foods has one or more mathematical models for describing of the moisture sorption isotherms. However, in all seeds or foods the equilibrium moisture contents increased with an increase in the water activity at any particular temperature and decreased with increase in temperature at constant water activity. The researches have suggested that the water potential of the seed or seed structures provides a better indicator of the seed water status than water content.

Key words: Agro physic, Isotherm and seed

INTRODUCTION

For give to highest seed yield in agriculture addition to both nitrogen and phosphate fertilizer (Azimi et al, 2013) seed vigor is very important factor. Many studies has been performed on seeds for seed protein changes (Shaban, 2013) seed vigor, seed germination and seed storage. Agrophysic is one of the must important aspects of research in agriculture. For example, in order to establish humidity bounds to inhibit microbial growth and mycotoxin production during storage, the knowledge of water sorption isotherms of grains and seeds is essential. The control of moisture content of foods during processing and storage is very important as water has many roles in food reactions and food quality. In this respect, the moisture sorption isotherm is an extremely important tool in food science because it can be used to predict changes in food stability and to select appropriate packaging materials and ingredients. There are very many

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works on moisture sorption isotherms of foods over the last two decades. Some of these works are related to the determination of moisture sorption isotherms and some are related to the mathematical formulations to represent the moisture sorption isotherms (Ayranci, 1995; Debnath, Hemavathy, & Bhat, 2002; Maskan & Gogus, 1997; Menkov, 2000). It is well known that, among other factors, sorption behavior depends on the variety under consideration. In recent papers (Larumbe et al., 1994; Boente, Gonz_alez, Mart_õnez, Pollio, & Resnik, 1994, 1996; Boente et al., 1995; Bianco, Pollio, Resnik, Boente, & Larumbe, 1997), the authors proposed a statistical methodology to establish di€erences or similarities between varieties of wheat, sorghum, maize hybrids and rice, at 25°C, in the range of microbial growth (aw 0.6±0.9) which is the most important to avoid molds, the predominant spoilage flora of stored grains and seeds. By far, the most common procedure used to preserve quality in stored grains and seeds is reducing the water activity to a level low enough to inhibit microbial growth. Because the control parameter used is the moisture content, in order to establish humidity limits to inhibit microbial growth and mycotoxins production during storage, knowledge of water sorption isotherms of grains and seeds is essential to prevent the damage during storage and to diminish economical losses (Boente, Gonz_alez, Mart_ınez, Pollio, & Resnik, 1994, 1996). In addition, it is useful to establish differences or similarities in water sorption characteristics of the black bean varieties harvested in Argentina in order to optimize their storage. Moisture sorption behaviour is an important property of foodstuff. It is useful for modelling the drying process and is important in the design and optimization of drying equipment, aeration and storage. Also, this information is used to calculate moisture change, which may occur during storage and for predicting shelf life stability, which in turn determine the quality criteria of a food product.

Water activity

The application of thermodynamic principles to sorption isotherm data has been used to obtain more information about the dehydration process energy requirement, the properties of water, food microstructure, and physical phenomena on the food surfaces, and sorption kinetic parameters.Water activity has long been considered as one of the most important quality factors in food systems especially for long-term storage, drying and roasting operations. The determination of water activity and moisture content relation is described by moisture sorption isotherms.

Isotherm curve

Seed hygroscopic properties are determined by the binding formed by biological macromolecules in the seed-atmosphere systemand the available water vapor molecules (Probert et al., 2003; Vertucci and Leopold 1987a,b). The sorption isotherm curve represents the capacity of the seed tissue and the bound water to adhere more water molecules due to external relative vapor pressure. When the Gibbs free energy difference 'G' of the seed and the atmosphere are equal, water exchange ceases and the system arrives at the equilibrium state represented by a sigmoid shaped isotherm curve (Alsadon 2001; Vega et al., 2005). The isothermal sorption is represented by the AC segment. When the system changes from state A to state B the pressure value inconstant, therefore this route is called isobaric, while the BC segment relates to a state change where values of equilibrium moisture content are constant.

Methodology

The methods used for the determination of equilibrium moisture sorption isotherms of agricultural products can be classified into: (1) those in which the material is brought into equilibrium with air of fixed temperature and relative humidity and the moisture content of the material is measured (equilibrium moisture content (EMC) or gravimetric method) and (2) those in which air is brought to equilibrium with material at a fixed temperature and moisture content and the relative humidity of the air determined (ERH method). Rao and Pfost (1978) determined the equilibrium moisture sorption isotherms for some 20 agricultural products and concluded that the ERH methods are simpler and faster. The most commonly used ERH methods are the dew point method and the vapor pressure man metric (VPM) method. The dew point method has been used to obtain equilibrium moisture sorption isotherms of rapeseed (Sokhansanj, Zhijie, Jayas, & Kameoka, 1986) and wheat flour (Henderson & Pixton, 1982). The VPM method has been used to obtain equilibrium isotherms of apples (Singh & Lund, 1984), dry milk (Sood & Heldman, 1974) and sesame seed (Ajibola & Dairo, 1998). Labuza, Accott, Tatini, and Lee (1976) observed that the VPM method is one of the best methods of determining the sorption isotherm of agricultural material as it measures directly the vapour pressure exerted by the moisture in the grain kernels contained in previously evacuated jar. The devices and procedures involved in this method have been described by Labuza (1976).

Mathematical models

Van den Berg and Bruin (1981) stated more than 200 equations have been developed theoretically, semi-theoretically and empirically to model the sorption isotherms of different biological materials. Labuza (1975) noted that no sorption isotherm model could fit data over the entire range of relative humidity because water is associated with the food matrix by different mechanisms in different activity regions. The establishment and the mathematical description of the moisture sorption isotherms could help the agricultural engineer to design these processing equipment.The equilibrium isotherms have been represented by more than 23 mathematical models for seed or other materials, like maize and soybean flour (Eslava, 1999, 2000; Hay et al., 2003; Jimenes et al., 1995; Ospina and Cruz 1989; Resende et al., 2006; Socorro et al., 2007). Some of them take into account the effect of temperature, these are modified Chung–Pfost (Chung & Pfost, 1967), modified Henderson (Henderson, 1952), modified Halsay (Halsey, 1948; Iglesias & Chirife, 1976), modified Oswin (Chen & Morey, 1989; Oswin, 1946), and Guggenheim, Anderson and de Boer (GAB) (Maroulis, Tsami, Morinos-Kouris, & Saravacos, 1988; Van den Berg, 1984). Veltchev and Menkov (2000) applied successfully a new four-parameter, Fraction-linear (FL) model, for describing the S-shape desorption isotherms of apples. For example, The Guggenheim–Anderson–de Boer (GAB) and Halsey models were mostly applied to describe the sorption isotherms of foods (McMinn & Magee, 2003). All this models include only one parameter. While incorporation of water activity and temperature data into a single model can be achieved when artificial neural networks (ANN) are used. ANN is an alternative for this application because modeling is carried out by using data recorded during normal productions. ANN is general non-linear model inspired on a simplified model of human brain function. More than other modeling strategies, they have the capability to internally self-adapt and relate complex non-linear relationships between input and output variables, without the need for rigid a priori models (Thibault & Grandjean, 1992). This makes them particularly useful when a phenomenological model of the process is not available or would be far too complex to derive. ANN concepts have been used in many food and agricultural applications such as psychrometry (Sreekanth, Ramaswamy, & Sablani, 1998), drying (Huang &Mujumdar, 1993), thermal processing (Sablani, Ramaswamy, & Prasher, 1995) rheology (Ruan, Almaer, & Zhang, 1995) and sensory science (Park, Chen, Whittaker, Miller, & Hale, 1994).

Monolayer moisture content

The monolayer moisture content (MMC) which is of significant importance to the physical and chemical stability of dehydrated materials with regard to lipid oxidation, enzyme activity, non-enzymatic browning, flavour components preservation, and structural characteristics (Labuza, Tannenbaum & Karel, 1970; Karel & Yong, 1981), can be determined from the equilibrium sorption isotherms by means of the two-parameter BET (Brunauer-Emmett-Teller) equation (Brunauer, Emmett & Teller, 1938).The monolayer moisture content shows the amount of water that adsorbed by a single layer to binding sites in the material. The water binding properties of active points in roasted seeds were probably reduced; hence, some water sorption active points disappeared (Martinez & Chiralt, 1996).

Different study in plant seeds

Bori nuggets seeds

The wet ground aerated pulse batter with moisture content about 67% is used for making these nuggets as wet droplets on a smooth oil smeared surface followed by drying and storage. The quality of the product on storage is largely depended on the water activity of the product (McMinn & Magee, 1999; Singh & Singh, 1996; Wang & Brennan, 1991) which in turn depends on the moisture content and temperature of storage. Moisture sorption behaviour of this product could be a valuable information on its drying behaviour and storage quality. However, there is very little information available on sorption behaviour of pulse based products in general and on nuggets for black gram pulse in particular. In Bori nuggets samples, the adsorption and desorption isotherms demonstrate a concurrent increase in equilibrium moisture content with increasing equilibrium relative humidity (Shrikant et al, 2005). However, . GAB model was found to be suitable for describing the sorption behaviour of bori nuggets (Shrikant et al, 2005).

Black bean seeds

In black bean, at high water activity levels some samples showed visually fungal contamination Between the equations considered, the Oswin and the White and Eiring equations provided the best adjustments. Generally the best adjustment was provided by the White and Eiring equation.

Pea seeds

pea seeds revealed a hysteresis and that treatment temperature affected the sorption isotherms. The Modified-Henderson equation was an adequate model for the sorption data of three treatments used in study. No universal or best sorption model was found for the isotherms of pea seeds from published data. The GAB model was not a good model when applied to the sorption properties of pea seeds (Chen, 2003). Also, Mazza and Jayas (1991) described equilibrium moisture content (EMC) data of Lathyrus pea seeds at four temperatures and proposed the Chung–Pfost equation as the best model among the four models. Pixton and Henderson (1979) tested the equilibrium relative humidity (ERH) data of dried pea seeds by the dewpoin t method over the range 30– 90% RH at three temperatures. Shepherd and Bhardwaj (1986) determined the isotherms of pigeon pea type-17 between 10% and 80% relative humidity (RH) at four temperatures. In cowpea seeds the goodness of fit was evaluated on the basis of criteria such as the mean relative deviation modulus, coefficient of determination and standard errors of models. It was found that the GAB model was the most satisfactory model for representation of the sorption data (Ayranci and Duman, 2005). Chen (2003) reported the moisture sorption isotherms of pea seeds with different treatments and adopted some of the mathematical models to the isotherm data. In that, work the modified Henderson equation was found to be an adequate model.

Sesame seeds

In sesame, the equilibrium moisture contents increased with an increase in the water activity at any particular temperature and decreased with increase in temperature at constant water activity. (Kaya and Kahyaoglu, 2006). The increased temperature activated the water molecules to a higher energy levels and this allows them break away from their sorption sites, thus decreasing the equilibrium moisture content (Arslan & Togˇrul, 2005). However, it is possible to state Halsey and GAB models gave acceptable fit for Sesame seeds and The GAB model gave the important information (monolayer moisture content) for the sesame seed samples (Kaya and Kahyaoglu, 2006). Both models gave an acceptable fit of the experimental data. The Halsey equation was used for predicting the water activity of samples for thermodynamic calculations (Kaya and Kahyaoglu, 2006). Aviara et al. (2002) studied the moisture sorption isotherms of sesame seeds and concluded that the modified Halsey model was the best to explain experimental sorption data.

Amaranth seeds

In amaranth seeds The three-parameter GAB isotherm was the best and gave a good correlation, and random residuals-plots) for the general data-fit in the range of aw from 0.1 to 0.9, of interest in seed storage and processing. The Modified Halsey equation was rejected because it gave poor statistic parameters of agreement and patterned residual plots (Pagano and Mascheroni, 2005). For desorption, the Modified Chung–Pfost model gave the lowest mean relative deviation; the Modified Henderson equation was the second best in describing the EMC–ERH data, followed by the Modified Oswin and GAB models. For adsorption, the GAB equation presented the lesser MRD, followed by the Modified Chung–Pfost, Henderson and Oswin models. When mean sorption data were analyzed, the Modified Chung–Pfost equation was the best. However, when the GAB isotherm was adjusted at each temperature, a higher quality of agreement was obtained compared with the other isotherms, demonstrating the adequacy of GAB model to describe the experimental data of EMC–ERH for amaranth(Pagano and Mascheroni, 2005).

Ckickpea seeds

The equilibrium moisture contents of chickpea seeds were determined using the gravimetric static method at 5°C, 20°C, 40°C and 60°C over a range of water activities from 0.110 to 0.877. The sorption capacity of seeds decreased with the increase in temperature at constant water activity. The FL model was found to be the most suitable for describing the sorption data. For practical considerations a single monolayer value (in water activity range 0.16-0.18) can be assumed (Nikolay and Menkov, 2000). The knowledge of the equilibrium moisture content of chickpea seeds at various temperatures would allow to specify the storage conditions for the seeds.

Mungbean seeds

In research on mungbean seeds, The modified Chung–Pfost and modified Oswin equations have the ability to describe well the EMC/ERH relationship selected range of the relative humidity and temperature. The modified Chung–Pfost equation is the most suitable in M= f(rh,T) form while the modified Oswin equation is the most suitable in rh= f(M,T) form (Chowdhury et al, 2006).

Lupine seeds

In this research, the behavior of lupine seeds was, as expected, the following: equilibrium moisture content decreases while the temperature increases at constant water activity. The sorption isotherms was successfully modeled using the GAB model with five parameters yielding a value of the monolayer moisture content. No hysteresis cycles was detected in the range of temperatures assayed.

Medicinal plant seeds

The experimental results in that experiment showed that the sorption isotherms of some medicinal plant seeds (sage, verbena and mint) follow the general trend given by Multon (1980) and that Henderson's equation gives a better fit for aromatic herbs. In a previous work, Kouhila et al. (1999) determined and modeled the sorption isotherms of three varieties of mint and came to the same conclusion. A knowledge of the equilibrium moisture content of medicinal plants are useful for the numerical modelling of heat and mass transfers during the drying process (Belghit, Belahmidi, Bennis, Boutaleb, & Benet, 1997). These data are also necessary for the study of drying kinetics of the products. The equilibrium moisture content increases with decreasing temperature at constant water activity. Henderson's equation is suitable for representing the relationship between water activity and equilibrium moisture content of the three plants in the range of water activity 5-91% (Kouhila et al, 2001).

Some foods

Potato starch

Potato starch, highly amylopectin and highly amylase powders present Type II isotherms. Temperature affects the sorption behaviour; the equilibrium moisture content decreases with increasing temperature, at constant water activity. Hysteresis is evident over the entire range of water activity for all materials.The empirical Peleg model followed by the kinetic GAB and the semi empirical Ferro-Fontan models were found to best represent the experimental data in the water activity range 0.05–0.95. In the range of water activity 0.35–0.95 the Smith model was shown to give the closest fit to the experimental data (Al-Muhtaseb et al. 2007).

Corn starch

A new sorption model of corn starch powder on BP neural network is established. The BP neural network model not only accommodated temperature and water activity parameter, but also is more accurate than other mathematical models. The GAB model is considered to be the most versatile sorption model available in the literature, however the average relative error of GAB model is 6.10% and 6.60% at 45 C. So within the temperature range investigated, BP network model can be used to describe sorption isotherms of corn starch powder (Peng et al, 2007).

Macaroni

In macaroni the Peleg equation was best for characterizing the sorption behavior for the whole range of temperatures and relative humidities studied. The surface area of monolayer and the water activities corresponding to the monolayer values were determined (Arslan and Hasan, 2004).

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