Food Bioscience 7 (2014) 88–94

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/fbio

Moisture sorption isotherms and isosteric heat of sorption of dry persimmon leaves

R. Martínez-Las Heras, A. Heredia, M.L. Castelló, A. Andrés*

Institute of Food Engineering for Development, Universitat Politècnica de València, Camino de Vera s/n, P.O. Box 46022, Valencia, Spain

ARTICLE INFO

Article history:
Received 4 March 2014
Received in revised form
29 May 2014
Accepted 23 June 2014

Keywords:
Persimmon leaves
Equilibrium moisture content
Isosteric heat of sorption
Modeling
Sorption isotherms

ABSTRACT

Moisture sorption isotherms of persimmon leaves were determined at 20, 30 and 40 °C using the standard gravimetric static method over a range of relative humidity from 0.06 to 0.9. The experimental sorption curves were fitted by seven equations: Henderson, Halsey, Smith, Oswin, BET, GAB and Caurie. The Halsey, Smith, GAB and BET models were found to be the most suitable for describing the sorption curves. The isosteric heat of sorption of water was determined from the equilibrium data at different temperatures. It decreased as moisture content increased and was found to be a polynomial function of moisture content.

1. Introduction

Persimmon crops in Spain have grown exponentially over the last decade to double their cultivated area as a result of the profitability of farming and the process of conversion of citrus and other fruit trees (Llácer & Badenes, 2002). Persimmon fruit demand has increased significantly in Germany, the United Kingdom, France, Italy and Russia, as well as in new emerging markets (the United States, Canada and Brazil). In addition, persimmon trees are deciduous; therefore, making use of their leaves could be a good way to increase the economic value of this crop. Persimmon leaves, which are well-known in Japan, are infused with hot water and are used traditionally due to their healing properties (treatment of paralysis, frostbite, burns and to stop bleeding) (Matsuo & Ito, 1978). Their principal compounds are flavonoid oligomers, tannins, phenols, organic acids, chlorophyll, vitamin C and caffeine (Jo, Son, Shin, & Byun, 2003; Matsuo & Ito, 1978). Once collected, the leaves need to be stabilized, usually by drying, before their commercialization and use. To preserve the quality of any dried product during storage, it is necessary to know its water sorption properties.

The properties and quality of persimmon leaves preserved by drying depends to a great extent on their physical, chemical and microbiological stability. This stability is determined by the relationship between the EMC of the leaves and its corresponding water activity at a given temperature (Myhara, Sablani, Al-Alawi, & Taylor, 1998; Temple & van Boxtel, 1999), which is called sorption isotherm. Among the factors that influence the shape and characteristic of water sorption isotherms are the composition, physical state of the components and temperature (Leung, 1986). The physical state (crystalline, amorphous) in which the material components are found significantly affects water retention and

*Corresponding author. Tel.: +34 963877365.
E-mail address: aandres@tal.upv.es (A. Andrés).

http://dx.doi.org/10.1016/j.fbio.2014.06.002
2212-4292/

Nomenclature

A, *B* and *C*	model coefficients
a_w	water activity (dimensionless)
d.b.	dry basis
d_f	number of degrees of freedom
EMC	equilibrium moisture content
K	constant
M	equilibrium moisture content (% d.b.)
$M_{i,exp}$	ith experimental moisture content (% d.b.)
$M_{i,pre}$	ith predicted moisture content (% d.b.)
MRE	mean relative error (%)
N	number of data points
Qst	net isosteric heat of sorption (kJ/mol)
R	universal gas constant (8.314 J/mol K)
r	coefficient correlation
T	temperature (°C, K)

depends largely on the previous technological treatments the products have been subjected to. Due to the exothermic character of the phenomenon of adsorption, an increase in temperature results in a loss of product moisture in equilibrium at a given relative humidity. In general, the effect of temperature is most significant for intermediate and low values of water activity.

There is no reported research on the moisture sorption characteristics of persimmon leaves even though they are commonly commercialized and consumed in China and Japan in infusions. Moisture sorption isotherms are important for predicting stability during storage and selecting an appropriate packaging material. Once the sorption isotherms at different temperatures have been measured, it is possible to evaluate heat sorption, which determines the interaction between the adsorbent and the adsorbate. Water activity which participates in the degradation reactions in biosystems depends both on water content and the properties of the diffusion surface (Al-Muhtaseb, McMinn, & Magee, 2004).

Equilibrium moisture content data can be determined using two different techniques: (a) manometric or hygrometric techniques based on direct determination of the vapor pressure or the relative humidity of the interface of a solid with a known moisture content and (b) techniques based on the determination of moisture content of the sample after it has reached equilibrium in a gas environment with a known relative moisture content. This last procedure can be carried out by static or dynamic means. The static gravimetric method is the most commonly used in food engineering, and a large amount of experimental EMC data reported for many plants with medicinal and therapeutic properties was mainly found by employing the gravimetric method. Literature reported experimental EMC for bitter orange leaves (Mohamed, Kouhila, Jamali, Lahsasni, & Mahrouz, 2004), chenopodium ambrosioides (Jamali et al., 2004), citrus reticulate leaves (Jamali, Kouhila, Mohamed, Idlimam, & Lamharrar, 2005), garden mint leaves (Park, Vohnikova, & Reis Brod, 2001), green tea in powder and granules (Arslan & Togrul, 2005; Sinija & Mishra, 2007), leaves and stems of lemon balm (Argyropoulos, Alex, Kohler, & Müller, 2012), mate leaves (Zanoelo, 2005), olive leaves and Tunisian olive leaves (Bahloul, Boudhrioua, & Kechaou, 2008; Nourhène, Neila, Mohammed, & Nabil, 2008) and orange peel and leaves (*Citrus sinensis*) (Kammoun Bejar, Boudhrioua Mihoubi, & Kechaou, 2011). The numerous studies carried out evidence the importance of the characterization of EMC for predicting the stability and shelf-life of agricultural products. There are four common specific areas of practical application of isotherms related to food processing: drying (in order to save energy and establish the optimal processing conditions), mixing (to determine the water activity of the mixture from the isotherms of each component), packaging (to determine the permeability of the packing) and storage (to lengthen the shelf-life of foods) (Gal, 1983; Labuza, 1984).

The objectives of this study were to determine the effect of temperature on the moisture sorption isotherms of persimmon leaves. Experimental data will be analyzed by using seven sorption isotherm equations available in the related literature in order to find the most suitable model describing the isotherms of persimmon leaves and the net isosteric heat of sorption of water will be estimated.

2. Materials and methods

2.1. *Samples preparation*

Persimmon leaves (*Diospyros kaki*, *Rojo Brillante* var.) were picked from trees in an orchard in Valencia (Spain), blanched at 100 °C for 5 min and then dried at 100 °C for 30 min in a convective drier. The selection of the drying conditions was based on the results obtained in a previous work (Martínez-LasHeras, Heredia, Castelló, & Andrés, 2014) were it was demonstrated that this drying method allowed a good preservation of the antioxidant properties of persimmon leaves.

2.2. *Chemicals*

Potassium Chloride, Magnesium Chloride 6-hydrate, Potassium Hydroxide, Sodium Chloride, Magnesium Nitrate 6-hydrate, Potassium Carbonate, Lithium Chloride, and Thymol were obtained from Panreac. Ammonium nitrate was obtained from VWR and dehydrated Barium chloride from Scharlab.

2.3. *Determination of sorption isotherms*

The sorption method used was the static gravimetric technique, which involves the use of saturated salt solutions to maintain a fixed relative humidity when equilibrium is reached. The mass transfer between the product and the ambient atmosphere is assured by natural diffusion of the water vapor and the water activity of the product equals the relative humidity of the atmosphere at equilibrium conditions. Nine saturated salt solutions (KOH, LiCl, $MgCl_2$, K_2CO_3, $Mg(NO_3)_2$, NH_4NO_3, NaCl, KCl and $BaCl_2$) corresponding to a