available at www.sciencedirect.com

ScienceDirect

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

Equilibrium distribution coefficients during osmotic dehydration of apricot

İnci Türk Toğrul[a,*], *Ayşe İspir*[b]

[a] *Afyon Kocatepe University, Engineering Faculty, Chemical Engineering Department, 03200 Afyonkarahisar, Turkey*
[b] *Firat University, Engineering Faculty, Chemical Engineering Department, 23279 Elaziğ, Turkey*

ARTICLE INFO

Article history:
Received 18 October 2007
Accepted 7 March 2008

Keywords:
Apricot
Equilibrium distribution coefficient
Osmotic dehydration
Mass transfer

ABSTRACT

The effect of initial osmotic solution concentration (40–70%, w/w), solution temperature (25–45 °C), pretreatment before osmotic dehydration (by using chemicals such as $K_2S_2O_5$, $Na_2S_2O_5$, ethyl oleat + $K_2S_2O_5$, ethyl oleat + $Na_2S_2O_5$ and ethyl oleat + K_2CO_3) and the ratio of the sample to solution (1/4–1/25) on equilibrium distribution coefficients of apricot were investigated during osmotic dehydration. The various osmotic agents such as sucrose, fructose, glucose, maltodextrin and sorbitol were used in osmotic dehydration of apricot. The distribution coefficients of water ranged from 1.893 to 0.822 $g\,g^{-1}$ for various concentrations, 1.302–0.651 $g\,g^{-1}$ for different temperatures, 2.013–0.560 $g\,g^{-1}$ for application of pretreatment and 1.126–0.822 $g\,g^{-1}$ for the ratio of the sample to solution, respectively, while the distribution coefficient for solid varied from 1.473 to 0.719 $g\,g^{-1}$ for various concentrations, 0.933–0.719 $g\,g^{-1}$ for various temperatures, 1.427–0.453 $g\,g^{-1}$ for application of pretreatment and 0.916–0.718 $g\,g^{-1}$ for sample to solution ratio, respectively. The distribution coefficient for water decreased with increasing temperature and decreasing sample to solution ratio, and with the increase in syrup concentration it increased or decreased with respect to osmotic agent type. The distribution coefficient for the solid was increased with both an increase in temperature and a decrease in the sample to solution ratio, though it decreases with an increase in syrup concentration. A nonlinear regression of experimental data was carried out to correlate the cumulative relationship between distribution coefficient and syrup concentration. In addition to modeling of the effect of the sample to solution ratio on distribution coefficients of apricots, whole developed models have been tested by using statistical analyses such as χ^2, mean bias error (MBE) and root mean square error (RMSE).

1. Introduction

In simple terms, osmosis is a process in which solvents flow from a diluted solution to a concentrated one through a semipermeable membrane to equalize the chemical potential of solute (Aguilera and Stanley, 1999). In foods, osmotic dehydration involves partial dehydration of water-containing cellular solids, which are immersed in hypertonic aqueous solution of various edible solutes (syrup or brine). The driving force for water removal is the chemical potential between the solution and the intercellular fluid. If the membrane is perfectly semipermeable (i.e., water-permeable, solute-repellant) solute is unable to diffuse through the membrane into the cells. However, due to absence of semipermeable membrane in food, there is always some solute diffusion into the food and leak of the food's own solute. Thus, mass transport in osmotic dehydration is actually a combination of simultaneous water and solute transfer processes (Panagiotou et al., 1998; Rahman and Perera, 1999; Rault-Wack, 1994).

The osmotic dehydration process can be characterized by equilibrium and dynamic periods (Rahman, 1992). In the dynamic period, the mass transfer rates are increased or decreased until equilibrium is reached. Equilibrium is the end of osmotic process, i.e., the net rate of mass transport

* *Corresponding author*. Tel.: +90 272 228 12 13/287; fax: +90 272 228 14 17.
E-mail addresses: itogrul@aku.edu.tr, itogrul44@hotmail.com (İ.T. Toğrul).
0960-3085/$ – see front matter
doi:10.1016/j.fbp.2008.03.001

Nomenclature

C	osmotic solution concentration (%, w/w)
D	relative percentage deviation
MBE	mean bias error
R	correlation coefficient
RMSE	root mean square error
T	osmotic medium temperature (°C)
X_{se}	equilibrium salt content
X_{so}	initial solid concentration
X_{we}	equilibrium water content
X_{wo}	initial water concentration
X_s^e	the mass fractions (wet basis) of the water in food product at equilibrium
X_w^e	the mass fractions (wet basis) of the water in food product at equilibrium
Y_s^o	the mass fractions (wet basis) of the solid in the initial osmotic syrup
Y_w^o	the mass fractions (wet basis) of the water in the initial osmotic syrup
WL_∞	equilibrium water loss
SG_∞	equilibrium solid gain

Greek letters

λ_w^e	the distribution coefficient for water
λ_s^e	the distribution coefficient for overall solids
χ^2	reduced chi-square

is zero. The study of the equilibrium state is necessary for the modeling of the osmotic process as unit operation and also important for a good understanding of the mass transfer mechanisms involved in this system (Barat et al., 1998). Kinetics of osmotic dehydration of potato (Lenart and Flink, 1984; Biswal and Bozprgmehr, 1991), fish tilapia (Medina-Vivanen et al., 1998), apples (Mosalve-Gonzalez et al., 1993; Ertekin and Sultanoğlu, 2000), peas (Ertekin and Çakaloz, 1996a, 1996b), banana and kiwi fruit (Panagiotou et al., 1998) were studied, but there are a little of study on apricot (Forni et al., 1997; Khoyi and Hesari, 2007; Riva et al., 2005). However, the equilibrium distribution coefficients in these studies were not calculated.

Distribution coefficient for salt is defined as the ratio of salt concentration in fish muscle and brine at equilibrium (Del Valle and Nickerson, 1967; Favetto et al., 1981). Since this approach needs the value of salt concentration in brine at equilibrium, Rahman (1992) used initial syrup concentration instead of the equilibrium concentration of the syrup. This assumption is valid when value of ratio *R* (ratio of mass of solution to the mass of the product) is very high. For the other cases the distribution coefficient is a function ratio *R*, in addition to other process parameters. This approach becomes practical when equilibrium concentration is difficult to predict. The equilibrium distribution coefficients for the *i*th component can be defined as (Rahman, 1992);

$$\lambda_i^e = \frac{X_i^e}{Y_i^o} \tag{1}$$

where λ_i^e is the distribution coefficient, and both Y_i^o and X_i^e are the mass fractions (wet basis) of the *i*th component in the initial osmotic syrup and food product at equilibrium, respectively. The distribution coefficient for water can be defined as:

$$\lambda_w^e = \frac{X_w^e}{Y_w^o} \tag{2}$$

Similarly, the distribution coefficient for overall solids can be defined as:

$$\lambda_s^e = \frac{X_s^e}{Y_s^o} \tag{3}$$

Making use of overall solids to evaluate equilibrium values turns the system food product to a binary system (i.e., water and overall solids), and similarly the solution of sugar (or salt) is also a binary system. Consequently, there is an explicit relationship between λ_w^e and λ_s^e. Once λ_w^e is known λ_s^e can be calculated using the following relationship:

$$\lambda_s^e = \frac{1-\lambda_w^e Y_w^o}{1-Y_w^o} \tag{4}$$

Parjoko et al. (1996) proposed the following equations to estimate the equilibrium water content (X_{we}) and equilibrium salt content (X_{se}):

$$X_w^e = \frac{X_{wo} - WL_\infty}{1-(WL_\infty + SG_\infty)} \tag{5}$$

$$X_s^e = \frac{X_{so} + SG_\infty}{1-(WL_\infty + SG_\infty)} \tag{6}$$

where X_{wo} and X_{so} are initial water and solid concentration respectively, WL_∞ is the equilibrium water loss and SG_∞ is the equilibrium solid gain.

The osmotic dehydration process can be characterized by equilibrium and dynamic periods (Rahman, 1992). In the dynamic period, the mass transfer rates are increased or decreased until equilibrium is reached. Equilibrium is the end of osmotic process, i.e. the net rate of mass transport is zero. The study of the equilibrium state is necessary for the modeling of osmotic process as a unit operation and also important for a good understanding of the mass transfer mechanisms involved in this system (Barat et al., 1998).

The distribution coefficients for water and solids were determined for osmotic drying of pineapple in sucrose (Parjoko et al., 1996) and palm sugar (Silveira et al., 1996), and potato (Rahman et al., 2001) in sucrose. They also developed models to predict the distribution coefficients as a function of process temperature and syrup concentration. In the literature there is little information available about the distribution coefficients of water and solids for wide number of food products. In addition, there were negligible studies, which had been carried out to find the effect of pretreatment application and sample to solution ratios. The objectives of this study were to measure and model the equilibrium distribution coefficients of water and solids for osmotically dehydrated apricot, and to investigate the effect of both the pretreatment application prior to osmotic dehydration and the sample to solution ratio on the equilibrium distribution coefficient of water.

2. Marerials and methods

2.1. Materials

There are various kinds of apricots in nature. The Hacıhalil type of apricot, which has greater importance than the others