LWT 38 (2005) 303–310

LWT

www.elsevier.com/locate/lwt

Effect of temperature on moisture desorption isotherms of *kheer*

A. Jayendra Kumar, R.R.B. Singh*, G.R. Patil, A.A. Patel

Division of Dairy Technology, National Dairy Research Institute, Karnal 132 001, India

Received 5 July 2003; received in revised form 21 October 2003; accepted 24 October 2003

Abstract

Desorption isotherms of *kheer*, a rice based partially heat concentrated and sweetened Indian milk dessert, were obtained in the temperature range of 10–40°C. The desorption curves exhibited sigmoid shape corresponding to type II, typical of many foods. There was generally a negative temperature effect on EMC at low a_w, but curves at 25°C and 40°C showed inversion above water activity of 0.60 implying a higher equilibrium moisture content at higher temperature. Of the five sorption models tested, the GAB model gave the best fit at all the three temperatures. Besides monolayer moisture, properties of sorbed water viz. number of adsorbed monolayers, bound or nonfreezable water, density of sorbed water and surface area of sorption were also obtained. Isosteric heat of sorption obtained by applying Clausius–Clapeyron equation decreased exponentially with the increasing moisture content.

Keywords: Indian dairy product; Water activity; Desorption isotherms; Heat of desorption; Sorption models; Properties of sorbed water

1. Introduction

Kheer also known as *Payas* or *Payasam* in many parts of India, is an extremely popular rice based heat concentrated and sweetened dairy dessert. Conventionally, *kheer* is manufactured by concentration of milk while cooking of rice added to it in an open pan over low fire. Sugar and in many cases assorted dry fruits are also added at the completion of cooking and condensing process (Chaudhary, 1989). As it contains nutrients from milk and rice, it is considered a very nutritious food. Its characteristic sweet, nutty and pleasant taste makes it a premier milk delicacy savoured by the entire Indian population. Despite such wide popularity of the product, the scope for large-scale manufacture and organised marketing of the product is limited by lack of mechanised production and by its short shelf-life, which ranges from few hours at room temperature to a few days (usually, 3–4) at refrigerated conditions. One of the reasons for the short shelf-life is the products' high water content viz., about 60 g/100 g product.

Moisture sorption isotherms exhibit the equilibrium relationship between the moisture content of food and the water activity at a given temperature and pressure. Knowledge of sorption isotherms of a food product is essential for product and process development, besides food engineering applications (Delgado & Sun, 2002b). The deteriorative mechanisms in food systems are dependent on water activity and, therefore, water activity modifications are often suggested for enhanced storage stability of the product (Asbi & Bainu, 1986). In addition to this, an understanding of moisture sorption isotherms would help in designing and optimization of unit operations such as preservation, drying, storage, packaging and mixing (Roman, Rotsein, & Urbicain, 1979).

Several empirical, semi-empirical and theoretical models have been used for mathematically describing moisture sorption isotherms of foods. Boquet, Chirife, and Iglesias (1978) reported that the models proposed by Halsey (1948) and Oswin (1946) are the most versatile two-parameter equations for describing sorption isotherms. Caurie (1981) proposed a model which could help in analysing different properties of sorbed water. The COST 90 study (Wolf, Spiess, & Jung, 1985) revealed that the three-parameter GAB equation (Bizot,

*Corresponding author. Tel.: +91-1842259202; fax: +91-1842250042.
E-mail address: rrb@ndri.hry.nic.in (R.R.B. Singh).

0023-6438/$30.00
doi:10.1016/j.lwt.2003.10.009

Nomenclature

W	equilibrium moisture content, g/100 g solids
W_0	moisture content equivalent to the monolayer
a_w	water activity
a, b, c	constants
C	density of sorbed water
G	guggenheim constant
K	correction factor for properties of multilayer molecules with respect to the bulk liquid
Q_{st}	net isosteric heat of sorption or excess heat of sorption
W_{exp}	experimental moisture content
W_{cal}	calculated moisture content
N	number of observations
u_e	experimental value
u_p	predicted value
R	gas constant (8.314 J deg^{-1} mol^{-1})
T	Absolute temperature (K)
S	Caurie's slope
N	no. of adsorbed monolayers

Abbreviations

RMS%	root mean square percent
R^*	residual
ERH	equilibrium relative humidity

1983) could be used to describe most food isotherms over a wide water activity range. Modified Mizrahi equation (Mizrahi & Karel, 1977) is another three-parameter model, which has yielded a good fit for water sorption isotherms of some foods. Furthermore, the knowledge of temperature dependence of sorption phenomenon is important for modeling the thermodynamics of the system. The excess heat of sorption (the difference between enthalpy of a mole of adsorbed water at equilibrium pressure and the enthalpy of a mole of water in the ideal gas state) obtained from the sorption data provides useful information on the energetics of water sorption processes in food (Rizvi, 1995; Delgado & Sun, 2002b). The excess heat of sorption (Q_{st}) is greater than the latent heat of vaporisation of pure water at a particular temperature and can be considered as indicative of intermolecular attraction forces between sorptive sites and water. The change in Q_{st} with the change in moisture content of the sample indicates the availability of polar sites to water vapor as the desorption/adsorption proceeds (Chung & Pfost, 1967).

The objective of the present study was therefore to obtain experimental data on moisture desorption isotherms of *kheer* at different temperatures so as to analyse them with different recommended models and generate information on moisture sorption parameters which could help in developing a process for the manufacture of shelf stable *kheer*.

2. Material and methods

2.1. Preparation of kheer

Fresh, clean buffalo milk (10 l) was collected from the Institute's Experimental Dairy and standardised to 5 g fat/100 g milk, then transferred to a steam-jacketed kettle and brought to boil. Good quality, broken Basmati rice (5 g/100 g of milk), pre-cleaned, washed twice with tap water and soaked in water at 30 °C for 30 min, was added to the milk. The mixture was gently simmered at 90 °C for 40 min with continuous stirring and scraping. Refined sugar (10 g/100 g of milk) was added towards the end of the process. The mixture was then transferred to a stainless steel pail and cooled to 30 °C.

2.2. Preparation of sample

Potassium sorbate dissolved in small quantity of water was added to *kheer* (0.5 g/100 g of *kheer*) to check mold growth during the sorption studies. *Kheer* was passed through Fryma grinder ML150 (Fryma Maschinen AG, Switzerland) so that rice grains were disintegrated and dispersed uniformly in the milk concentrate to obtain a homogeneous consistency of a thin paste.

2.3. Chemical analysis

Chemical composition of *kheer* was determined in terms of moisture, fat, crude protein, total ash and starch using standard methods (ISI, 1981; AOAC, 1996) whereas lactose and sucrose were estimated as per method recommended by Perry and Doan (1950). The proximate chemical composition of *kheer* is presented in Table 1.

Table 1
Proximate composition of *kheer*

Constituent	(g/100 g *kheer*)
Moisture	56.79
Ash	1.16
Fat	6.40
Protein	4.20
Sucrose	14.08
Starch	7.01
Lactose	8.28