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Influence of dehulling and roasting process on the thermodynamics of moisture adsorption in sesame seed

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Abstract

Sesame seed can be stored and processed within main three forms; whole sesame seed, dehulled sesame seed, and dehulled-roasted sesame seed. In this study, the effects of dehulling and roasting process on the moisture adsorption isotherms and thermodynamic properties of sesame seed were investigated. The moisture adsorption isotherms of sesame seed were determined using gravimetric static method at 15, 25, and 35 °C. The isotherms exhibited Type II behavior. Though the trend of sorption isotherms of the samples were similar, equilibrium moisture content was decreased with dehulling and roasting process at a certain water activity. The Guggenheim–Anderson–de Boer (GAB) and Halsey models were found to adequately describe the sorption characteristics. Thermodynamic properties (net isosteric heat, differential entropy, spreading pressure, net integral enthalpy and net integral entropy) were calculated to determine the properties of water and energy requirements associated with the adsorption data. The net isosteric heat of adsorption and differential entropy decreased with increasing moisture content. The values of the net isosteric heat of adsorption and differential entropy decreased with application of dehulling and roasting process. The changes in the net isosteric heat of adsorption and differential entropy with moisture content were sufficiently described by power-law model. The net integral enthalpy increased with moisture content to a maximum and then decreased, while the integral entropy decreased to a minimum and then increased with increasing moisture content. The order in the magnitude of integral enthalpy was found as whole sesame (WS) > dehulled-roasted sesame (DRS) > dehulled sesame (DS).

Keywords: Sesame seed; Thermodynamics; Roasting; Dehulling; Adsorption isotherm

1. Introduction

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 (MSI). Several empirical and semi-empirical equations have been proposed to correlate equilibrium moisture content, temperature and a_w (Chirife & Iglesias, 1978). The Guggenheim–Anderson–de Boer (GAB) and Halsey models were mostly applied to describe the sorption isotherms of foods (McMinn & Magee, 2003).

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. The net isosteric heat of adsorption (q_{st}), differential entropy (S_d), spreading pressure (Φ), net integral enthalpy (Q_{in}) and net integral entropy (S_{in}) are used as thermodynamic functions for analysis of sorption isotherms (Aviara & Ajibola,

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Nomenclature

a, r, C, k	sorption isotherm constants	m_0	monolayer moisture content, % dry basis
A_m	surface area of a water molecule in m^2 (1.06×10^{-19} m^2)	n	number of experimental data
a_w	water activity	Q_{in}	net integral enthalpy (kJ kg^{-1})
a_w^*	geometric mean water activity	Q_{st}	isosteric heat of adsorption (kJ kg^{-1})
E	mean deviation modulus (%)	q_{st}	net isosteric heat of adsorption (kJ kg^{-1})
G	Gibbs free energy (kJ kg^{-1})	R	universal gas constant (0.462 J g^{-1} K^{-1})
i	number of terms	R^2	determination of coefficient
K	Boltzman's constant (1.380×10^{-23} J K^{-1})	S_d	differential entropy (J g^{-1} K^{-1})
M_i	moisture content (experimental value), % dry basis	S_{in}	net integral entropy (J g^{-1} K^{-1})
M_{pi}	moisture content (predicted value), % dry basis	T	temperature (K)
m	moisture content of samples, % dry basis	Φ	spreading pressure (J m^{-2})
		λ	latent heat of vaporization of pure water (2447.62 kJ kg^{-1})

2002; Aviara, Ajibola, & Oni, 2004; Kaya & Kahyaoglu, 2005; McMinn & Magee, 2003; Rizvi & Benado, 1984). The changes in integral enthalpy may provide a measure of the energy changes occurring upon mixing of water molecules with sorbent during sorption processes (Telis, Gabas, Menegalli, & Telis-Romero, 2000). The differential entropy (S_d) of a material may be related to the number of available sorption sites at a specific energy level (Madamba, Driscoll, & Buckle, 1996). The changes in entropy could be used in energy balance giving valuable information about energy utilization in food processing (Rotstein, 1983). Also, the order/disorder concept, useful for the interpretation of processes that take place during moisture sorption such as dissolution, crystallization and swelling, is related with entropy variation (Aviara, Ajibola, & Dairo, 2002). The spreading pressure (Φ), or surface potential, represents the surface free energy of adsorption and can be regarded as the difference in the surface tension between bare sorption sites in the solid and sorbed molecules (Al-Muhtaseb, McMinn, & Magee, 2004).

Sesame (*Sesamum indicum* L., Pedaliaceae) is a unique food. Its seed, both whole and ground, and its oil, have been consumed since ancient times (Namiki, 1995). It is a very old cultivated crop and thought to have originated in Africa (Ram, Catlin, Romero, & Cowley, 1990). Whole sesame seeds are generally used for oil production and some types of bakery foods. Dehulled seeds also have been consumed in baked goods such as breads, hamburger buns, cakes, cookies, confections and snack foods. In many countries (Middle-East, Mediterranean and Oriental) dehulled roasted sesame seeds are used for producing sesame paste (called tahin, tehina, tahina or matahina) (El-Adawy & Mansour, 2000; Lokumcu & Ak, 2005). The effective design of roasting, drying and storage systems for both three forms of sesame seeds (whole, dehulled and dehulled-roasted) needs knowledge of their energy requirements and the state and mode of the moisture sorption with them (Aviara & Ajibola, 2002).

The objectives of this study were to obtain MSI data of the WS, DS, and DRS samples, to evaluate the best MSI equation to fit the experimental data, and to determine the effect of dehulling and roasting on the thermodynamic parameters of sesame seed (net isosteric heat of adsorption, differential entropy, spreading pressure, net integral enthalpy, and net integral entropy) in relation to moisture adsorption.

2. Materials and methods

2.1. Preparation of the sesame seed samples

Turkish cultivars brown sesame seeds (Gaziantep region, season 2003), containing 57.96% crude fat, 20.23% crude protein, 13.54% carbohydrate 4.87% ash and 3.40% moisture, were used in this study. Mechanically dehulled sesame seeds are generally used in the production of sesame paste, therefore sesame seeds were dehulled as follows; firstly seeds were sieved and then soaked in water ($T = 18 \pm 2$ °C) for 12 h. The soaked seed were strained off and passed through a mechanical peeler for removing of hulls from seed. The hulls and other foreign materials were separated from seed by using salt solutions. The seeds were taken from surface of solution batches and then washed with water many times to remove the salt. The cleaned sesame seeds were centrifuged to reduce the water content from the surface of seeds (wet dehulled sesame seeds). The wet dehulled sesame seeds (25 kg) were roasted using a temperature-controlled rotary roasting machine (Gürmaksan Co., Turkey) at roasting temperature of 150 °C for 100 min. The final characteristics of roasted sesame seed were