Journal of the Saudi Society of Agricultural Sciences (2016) xxx, xxx–xxx

King Saud University

Journal of the Saudi Society of Agricultural Sciences

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FULL LENGTH ARTICLE

Modeling the effect of temperature on the hydration kinetic whole moong grain

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Received 14 March 2016; revised 12 May 2016; accepted 12 May 2016

KEYWORDS

Water absorption;
Peleg's model;
Fick's law;
Activation energy;
Diffusion

Abstract Water hydration characteristics of moong at temperatures of 25, 35, 45 and 55 °C were determined and three major dimensions (length, width and thickness) and moisture content were determined at time interval varying from 0 to 500 min. Peleg's model and Fick's second law of diffusion were used to simulate water absorption and effective diffusivity with varying temperature. Peleg's equation was adequately capable of predicting the experimental condition and the rate constants k_1 and k_2 were decreased with increased soaking water temperature from 0.5132 to 0.1081 and 0.0165 to 0.151, respectively. Effective diffusivity of water increases from 1.12×10^{-11} to 1.98×10^{-11} m^2/s over the temperature range. Reduction of activation energy with temperature and temperature dependency of diffusivity coefficient was also described by Arrhenius equation.

1. Introduction

The moong bean, alternatively known as the mung bean, green gram, is a plant species in the legume family. Legumes are good sources of protein, calorie, vitamins and minerals. They reduce the rate of cancer, cardiovascular diseases, obesity and diabetes (Bhathena and Velasquez, 2002). Although legume seeds contain a moderately high nutrition, their use in food and feed is still limited by the presence of several anti-nutritional factors such as tannins (Reddy and pierson, 1985), phytic acid (Urbano et al., 2000), trypsin inhibitors

☆ ***Practical application:*** Hydration kinetics in food technology produces a significant impact on physicochemical properties. The knowledge of moisture content and moisturizing kinetics is vitally important to determine the chemical and physical properties of food products and their shelf life. Hydration time and temperate will affect the characteristic of food grain as well as in line processing unit operation. Optimum hydration time and temperature will be important for better quality final food and shorter processing time. Changes in the physical properties are also important to design and development of processing, transportation and storage system. This study provides information on the effect of water temperature and time on water absorption kinetics of moong grain for optimization of processing and handling parameter.

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Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jssas.2016.05.005

and flatulence causing oligosaccharides (Singh, 1988; Udensi et al., 2007). Various food processing and preparation techniques, such as decortications, soaking, cooking, germination and fermentation, are the major efforts to reduce the phytate in foods (Elmaki et al., 2007; Sangronis and Machado, 2007; Liang et al., 2008; Khattab and Arntfield, 2009; Wang et al., 2010; Kumar et al., 2010).

Soaking of grains, legumes, seeds, nuts and beans is a traditional practice that can positively impact the nutritional qualities of these foods (Elmaki et al., 2007). Overnight soaking seems to be an traditional and effective method of enhancing the nutrient profile of these foods, and it is one method consistently used among peoples who adhered to time-honored, traditional methods of preparing native, unprocessed foods. It was also used to improve the processing performance before some unit operations such as dehulling and cooking. It was observed that grains in different soaking conditions show different water absorption rates and capacities (Turhan et al., 2002; Shafaei and Masoumi, 2013; Shittu et al., 2012; Bello et al., 2010; Kashiri et al., 2012; Montanuci et al., 2013). It mainly depends on soaking water temperature and time. Throughout the hydration process, water spreads slowly into the seeds and eventually reaches a constant level of moisture content (Ranjbari et al., 2013). Using warm water is a typical method to diminish the soaking time because higher temperatures increase moisture diffusivity leading to a higher hydration rate (Kashaninejad et al., 2009; Khazaei and Mohammadi, 2009). Different studies have been done on water absorption characteristic of different grains such as rice (Kashaninejad et al., 2007; Oli et al., 2016), adzuki beans (Oliveira et al., 2013; Miano and Augusto, 2015), Chestnuts (Moreira et al. (2008)), chickpea seeds (Shafaei and Masoumi, 2014; Ranjbari et al., 2013); cereal grains and legumes (Abu-Ghannam and McKenna, 1997; Turhan et al., 2002), barley (Montanuci et al., 2013), corn kernel (Botelho et al., 2013) and Andean lupin grain (Miano et al., 2015). As per the knowledge of the author limited studies were available on the water hydration characteristics of moong. The objective of this study was to determine the water absorption character of moong over the range of temperature, and modeling of water absorption kinetics of moong bean.

2. Material and method

2.1. Materials

Experimental material moong grain was obtained from a local market in Kundli, Sonipat, Haryana. They were cleaned manually for the removal of foreign matter, such as stones, dirt and broken seeds. Initial moisture content of moong grain were determined using halogen bulb moisture meter and the average moisture content was found to be 15.59% (d.b.). Known weights of grains were soaked in water at different temperatures (25, 35, 45 and 55 °C) for different time intervals 0–500 min. Temperature range of soaking water was selected based on normal room temperature and gelatinization temperature of starch (i.e. 60 °C). Water bath was used to maintain different temperature to check the hydration kinetic. Time of study (500 min) was based on the preliminary study i.e. after 500 min., rate of water absorption is independent of temperature (near to equilibrium).

2.2. Physical properties of moong grain

Physical properties length (L_1), width (L_2), and thickness (L_3) were measured using a digital micrometer (least count 0.01 mm) and Other physical properties geometrical mean diameter (D_g), sphericity (Φ), surface area (S) and volume (V) of grains were also calculated in 0, 100, 200, 300, 400 and 500 min time during water hydration using the following equations:

$$D_g = \frac{L_1 + L_2 + L_3}{3} \tag{1}$$

$$\Phi = \frac{(L_1 \times L_2 \times L_3)^{1/3}}{L_1} \tag{2}$$

$$S = \pi D_g^2 \tag{3}$$

$$V = \frac{\pi}{6} D_g^3 \tag{4}$$

2.3. Water hydration tests

Water hydration behavior of moong grain was determined by soaking samples (W_o), with an initial moisture content of 15.59% (d.b.) in different time and temperature. Four different Water baths were used to maintain the different soaking temperature 25, 35, 45 and 55 °C and samples were packed in muslin cloth and placed in the water bath. The experiment was conducted in three replicates. Sample was taken out after 100, 200, 300, 400 and 500 min time interval and dried using filter paper to eliminate the surface water. Grains were then weighed (W_s) to determine the moisture uptake. Water absorption capacity (WAC) of moong grain was determined using the following equation:

$$\text{WAC} = \frac{W_s - W_o}{W_o} \times 100 \tag{5}$$

2.4. Mathematical modeling

Hydration process is known to be important for the design and optimization of food processing operations. Generally, the hydration process is time taking and results in loss of water-soluble nutrients that can be checked by soaking time. The relationship between moisture content during hydration and time required is usually expressed by different models. Many theoretical and empirical approaches have been employed and occasionally empirical models were preferred because of their relative ease of use (Shafaei and Masoumi, 2014; Ghafoor et al., 2014). Two-parameter sorption empirical equation was proposed by Peleg in 1988. It is most popular and suitable empirical model which has been used to model the hydration process of various biological products (Paquet-Durand et al., 2015; Garcia-Pascual et al., 2006; Turhan et al., 2002). Mathematical modeling of water hydration of moong grain during different soaking temperatures 25, 35, 45 and 55 °C was performed using the Peleg model. Model parameters were estimated and performance of model was evaluated according to coefficient of determination (R^2).