Journal of Food Engineering 118 (2013) 417–420

Contents lists available at SciVerse ScienceDirect

Journal of Food Engineering

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

Research note

Modelling the effect of temperature on the hydration kinetic of adzuki beans (*Vigna angularis*)

Amanda Leal Oliveira, Beatriz Gouveia Colnaghi, Emily Zucatti da Silva, Isabela Romão Gouvêa, Raquel Lopes Vieira, Pedro Esteves Duarte Augusto *

Technical School of Campinas (COTUCA), University of Campinas (UNICAMP), Campinas, SP, Brazil

ARTICLE INFO

Article history:
Received 15 November 2012
Received in revised form 17 April 2013
Accepted 22 April 2013
Available online 10 May 2013

Keywords:
Food properties
Grains
Hydration
Physical properties
Rehydration

ABSTRACT

The Aw reduction is a widely used technique to preserve grains, which hydration kinetics needs to be studied in order to obtain optimized processes. This work evaluated the hydration kinetic of Adzuki beans, a widely consumed grain by the oriental culture, modelling its behaviour as function of temperature. The grains were soaked in water and the moisture over the time was evaluated at temperatures of 25–70 °C. The grain behaviour during water uptake showed an initial lag phase, with a low water absorption rate. Therefore, the hydration kinetic was evaluated using a sigmoidal model ($R^2 > 0.99$). When soaking temperature was increased the hydration rate increased and both the lag phase and the moisture at the equilibrium decreased. These behaviour were, then, modelled as function of the soaking temperature ($R^2 > 0.99$). The obtained results are potentially useful for future studies on product development, food properties and process design.

1. Introduction

The activity of water (Aw) reduction due to drying process is a widely used technique to preserve grains and other foods, although, in general, the products are rehydrated before processing and consumption. The hydration process is, thus, an important unit operation in dried foods, as it describes and defines its properties and using during cooking, extraction, fermenting, germinating and eating. Therefore, it is important to understand the hydration kinetics of different food products, as well as the influence of process conditions (as temperature) on its rate.

In fact, there are many works relating the hydration kinetics of different grains, as some kidney beans (Piergiovanni, 2011; Sobukola and Abayomi, 2011; Kaptso et al., 2008; Abu-Ghannam, 1998; Sopade and Obeka, 1990), chickpea (Gowen et al., 2007; Ibarz et al., 2004), rice (Fonseca et al., 2011; Cheevitsopon and Noomhorm, 2011; Botelho et al., 2010), corn (Fernández-Muñoz et al., 2011; Sobukola and Abayomi, 2011), soybean (Coutinho et al., 2010a; Coutinho et al., 2010b; Sopade and Obeka, 1990), bambara (Jideani and Mpotokwana, 2009; Kaptso et al., 2008), lentils (Joshi et al., 2010), asha (Tunde-Akintunde, 2010), lupin (Solomon, 2009), basil (Demirhan and Özbek, 2010), peanuts (Sopade and Obeka, 1990), seasame (Khazaei and Mohammadi, 2009) and *Cicer arietinum* (Prasad et al., 2010) seeds. Most of these works just evaluated the grain hydration using simple kinetic models, neglecting the initial lag phase.

The Peleg's Equation (Peleg, 1988; Eq. (1)), is the most used model to describe the food products hydration phenomenon. It consists in a two-parameter model (k_1 and k_2), which function describes a continuous change from a first-order (at $t \to 0$) to a zero-order (at $t \to \infty$) kinetic. The Peleg's equation is described on Eq. (1).

However, although being the most used model, and although suiting well some products hydration data, the Peleg's equation cannot describe an initial lag phase, which is observed during the hydration of some dried grains. Therefore, other models must be evaluated, as that previous proposed by Kaptso et al. (2008). It describes a sigmoidal behaviour with an initial lag phase followed by a high absorption rate phase and, finally, by a stationary phase, using three parameters: τ(that describes the function inflexion point, and relates the lag phase); k (the kinetic parameter) and M_{eq} (the moisture at the equilibrium, that relates the maximum water absorption). The sigmoidal model is described on Eq. (2):

$$M(t) = M_0 + \frac{t}{k_1 + k_2 \cdot t} \tag{1}$$

$$M(t) = \frac{M_{eq}}{1 + \exp[-k \cdot (t - \tau)]} \tag{2}$$

The Adzuki beans are small red seeds, widely consumed in Asia, directly cooked or prepared as many sweet and salty typical dishes (Mendes et al., 2011; Yousif et al., 2002). Therefore, its hydration is

* Correspondening author. Address: COTUCA/UNICAMP – Rua Culto à Ciência, 177, Botafogo, CEP 13020-060, Campinas, SP, Brazil. Tel.: +55 19 3521 9950; fax: +55 19 3521 9998.

E-mail address: pedro@cotuca.unicamp.br (P.E.D. Augusto).

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http://dx.doi.org/10.1016/j.jfoodeng.2013.04.034

necessary during industrial processing, and its study is important in order to optimize those processes. However, there is not any work in the literature studying the hydration kinetics of Adzuki beans (*Vigna angularis*).

The objective of the present work was to evaluate the hydration kinetic of Adzuki beans (*Vigna angularis*) and modelling its behaviour as function of temperature.

2. Materials and methods

Adzuki beans (*Vigna angularis*) with initial moisture of 13.04 ± 0.27 g water/100 g of dry basis were purchase in a local market. Prior to use, the samples were cleaned and selected, in order that only the intact grains were designated to be used. These grains were then sealed in plastic bags and storage in a dry place before using.

The hydration procedure was carried out in the same way as described in previous works (Cheevitsopon and Noomhorm, 2011; Fonseca et al., 2011; Piergiovanni, 2011; Sobukola and Abayomi, 2011; Botelho et al., 2010; Joshi et al., 2010; Prasad et al., 2010; Tunde-Akintunde, 2010; Jideani and Mpotokwana, 2009; Khazaei and Mohammadi, 2009; Solomon, 2009; Kaptso et al., 2008 and Ibarz et al., 2004).

A sample of 30 g, randomly selected, was used in each one of the four replicates. The samples were soaked in 200 mL of distilled water at the studied temperatures using a 600 mL beaker immersed in a water-bath with a temperature control system which guarantees a fluctuation between ±0.5 °C. (Quimis Q215u2, PID controlled, Brazil). The studied temperatures were 25.0, 32.5, 40.0, 55.0, and 70.0 °C. At specific interval times (15 min until the first hour; 20 min until the second hour; 30 min until the third our an 40 min until stabilization), the grains were removed from the water, drained, superficially blotted with absorbent paper, weighed and returned to the water. The moisture content at each time step ($M(t)$) was, then, calculated by mass balance, considering the initial sample mass (m_0), the moisture (M_0), and the obtained mass at each time step. The sample soluble solids leakage to the hydration water was neglected, as its concentration was always less than 2°Brix.

The Adzuki bean hydration kinetic was, then, evaluated for each temperature using two mathematical models: the Peleg's equation (Eq. (1)) and the sigmoidal model (Eq. (2)). For the models that suitable described the experimental data, their parameters were, then, modelled as a function of the process temperature.

The parameters for each model were obtained by linear or non-linear regression using the CurveExpert Professional software (v.1.5, http://www.curveexpert.net/, USA) with a significant probability level of 95%. The regressions were carried out for each replicate. Thus, each model parameter could be evaluated by its mean value and standard deviation.

3. Results and discussion

Fig. 1 A shows the effect of temperature (25–70 °C) on the Adzuki beans hydration during time.

The grain behaviour during water uptake clearly showed an initial lag phase, i.e., a period with a low water absorption rate, in the evaluated temperatures range (25–70 °C). This behaviour is similar to those observed for some cowpeas (Kaptso et al., 2008) and common beans (Piergiovanni, 2011), but being different to those described by the Peleg's equation. The observed behaviour is related to a hard seed coat in the grain (Kaptso et al., 2008), which

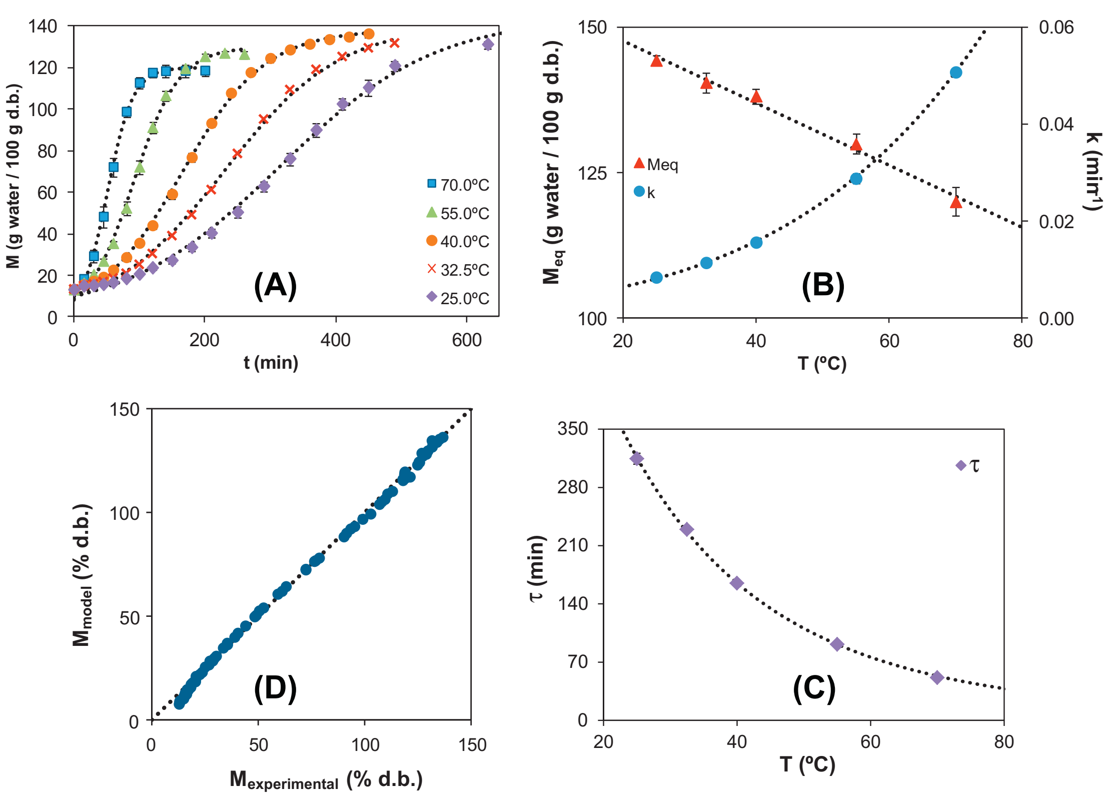

Fig. 1. Adzuki beans hydration as function of temperature. Mean of four replicates; vertical bars represent the standard deviation for each experimental mark. (A): water uptake for temperatures between 25 °C and 70 °C; the curves are the sigmoidal hydration model on Eq. (2). (B) and (C): effect of temperature on the hydration kinetic parameters; the curves are the modes of Eqs. (3, 5, and 6). (D) Experimental values versus those obtained by the sigmoidal model with parameters as a function of the temperature (Eq. (7)); the dashed line represents a regression with $\alpha = 1$, $\beta = 0$ and $R^2 = 1$ (Eq. (8)).