Sjournals
Scientific Journals
Agricultural Advances (2014) 3(1) 1-8
ISSN 2251-7820
doi: 10.14196/aa.v3i1.1101

Contents lists available at Sjournals

Agricultural Advances

Journal homepage: www.Sjournals.com

Original article

Evaluation of khazaei model in predicting of water absorption of chickpea during soaking

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A R T I C L E I N F O

Article history:
Received 25 December 2013
Accepted 19 January 2014
Available online 29 January 2014

Keywords:
Immersion
Moisture content
Peleg model
Water uptake

A B S T R A C T

In this study the Khazaei model, which has good ability to analyze water absorption in the second phase for crops was used to predict the water absorption of chickpea during soaking. The water rate absorption of initial and second phases are high and low, respectively. The main problem of all existing mathematical models for water absorption such as Peleg model is none of them do not assessment present for the second phase. The model was carried out to predict moisture content of three varieties of chickpea (Desi, small Kabuli and large Kabuli). The experiments were carried out at three distilled water temperatures (5, 25 and 45°C) in triplications. Amount of water absorption by varies seeds were determined 5, 10, 15, 30 minutes and one hour after immersion. The tests were followed at intervals of one hour toward gelatinized seeds. Khazaei and Peleg model of moisture absorption were fitted to experimental data. To compare the Khazaei model versus Peleg model, three parameters, coefficient of determination (R2), chi-square (x2) and root mean square error (RMSE) were used. The results showed that Khazaei model has enough accurate to predict the moisture content of chickpea during soaking and not significant difference between two models ($P<0.05$). Also, water uptake of seed increasing with increasing water temperature during soaking.

1. Introduction

Chickpea (Cicer arietinum L.) is an important protein source in several developing countries. It is the third most commonly consumed legume in the world (Singh, 1990). Chickpeas are a summer crop that needs warm climate to grow. It maturity is typically 55-60 days from planting to harvest. Toap shelf life, ease of transportation, and the cost are attractive for farmers. There are two main varieties of chickpea namely Desi and Kabuli. The Kabuli type has thin, white seed coat and Desi type has a thick, colored seed coat and has smaller seed than Kabuli type (Salunkhe et al., 1985).

Since soaking the grains is usually used before dehulling and cooking, understanding water absorption of different seeds during soaking was considered by researchers. Grains in different conditions of soaking have different water absorption rate and water absorption capacity (Sopade et al., 1994). Understanding water absorption in legumes during soaking is of practical importance since it affects following processing operations and the quality of the final product (Turhan et al., 2002). The water absorption of seed during soaking mainly depends on soaking time and water temperature. Warm water is a common method to decrease the soaking time, duo to higher temperature increases moisture diffusivity leading to higher hydration rate (Kashaninejad et al., 2009). Relationship between moisture content of seeds in soaking versus time has been 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 (Nussinovitch and Peleg, 1990; Singh and Kulshrestha, 1987).

Water absorption process in agricultural products includes an initial phase and second phase that have faster and lower water absorption rate, respectively. The main problem of all existing mathematical models for water absorption such as Peleg model is that, none of them not presenting assessment for the second phase. In fact, the coefficient of k1 of Peleg model is criterion of water absorption in the first phase only, while k2 is criterion of water absorption in second phase.

Water absorption behavior, such as viscoelastic properties of food products, is a time dependent behavior (Figure 1). Therefore, it is possible to model these two different properties of agricultural materials with the same model. According to Figure 1, the water absorption behavior of the agricultural products can be defined as equation (1) (Khazaei and Daneshmandi, 2007; Khazaei and Mohammadi, 2009):

$$M_t = M_o + M_{ret}(1 - \exp(-t / T_{ret})) + K_{rel}t \qquad (1)$$

Where Mret (retardation moisture content) is the rate of absorption in the first phase during of soaking (d. b. %). Tret (time of retardation) is the required time to approach approximately, 63% of the retarded moisture content (hr). Krel is the rate of water absorption in the relaxation phase (% hr-1). The highest amount of Tret shows the high rate of absorbance in the first phase absorption. In addition, Krel shows the rate of absorption in the relaxation phase and is calculated by determining the slope of the tangent line on the last part of sorption curve (Figure 1).The advantage of Khazaei model is ability to drive all the parameters from the absorption curve directly. As well as, this model has ability to depict the second phase of moisture absorption (Khazaei and Daneshmandi, 2007; Khazaei and Mohammadi, 2009). Some researchers used Khazaei model to describe, water absorption of three wood varieties and found the model was more accurate for describing the water absorption characteristics of wood samples (Khazaei, 2008). Also, the model can use for drying progress which is lead to result negative value of constant coefficient. Khazaei and Daneshmand (2007), used Khazaei model for drying of sesame seed.

Using short time experimental data for predicting equilibrium moisture content of foods and grains is the major advantage of the Peleg model, it is commonly used to describe absorption characteristic of various materials during soaking (Sopade and Kaimur, 1999; Sopade and Obekpa, 1990). The Peleg model is shown as equation (2):

$$M_t = M_o \pm \frac{t}{K_1 + K_2 t} \qquad (2)$$

Where Mt is moisture content at time t (d. b. %), Mo is initial moisture content (%), t is time (h), k1 and K2 are the Peleg rate (hr%-1) and Peleg capacity constant (%-1) respectively. In equation (2), ‘‘±’’ becomes ‘‘+’’ if the process is absorption or adsorption and ‘‘-’’ if the process is drying or desorption (Maharaj and Sankat, 2000).

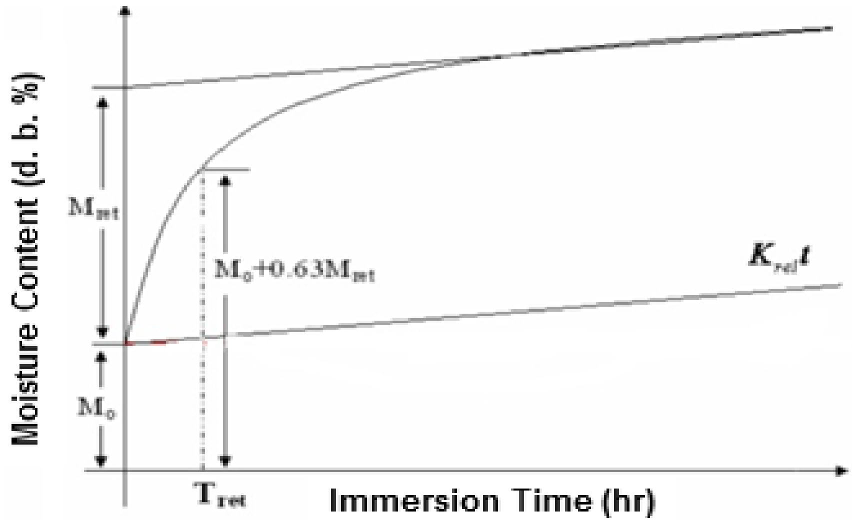

Fig. 1. Khazaei model of agriculture material (Mohsenin, 1986).

The Peleg model has been used to describe sorption processes in various foods. Some researchers studied simultaneous water desorption and sucrose absorption of papaya using the model (Palou et al., 1994). Sopade and Kaimur (1999) used it for describing water desorption of sago starch. Maharaj and Sankat (2000) applied the model for studying water absorption of dasheen leaves. The Peleg model was also exploited to model water absorption of many starchy and oily kernels (Abu-Ghannam and McKenna, 1997; Hung et al., 1993; Lopez et al., 1995; Sopade et al., 1992; Sopade et al., 1994; Sopade and Obekpa, 1990). In these reports mostly the fit of the model was found out below the gelatinization temperature (conditioning step) rather than above the gelatinization temperature (cooking step) of the starchy grains. Other investigators studied simultaneous water desorption and sucrose absorption of papaya using the model (Palou et al., 1994). Therefore, the objectives of present study are:

1- Fitted the soaking data of three chickpea varieties (Desi, small Kabuli (Chico) and large Kabuli (Kabuli)) to both Khazaei and Peleg models to predict moisture content during soaking.

2- Evaluating of accuracy of Khazaei model in soaking of Chickpea varieties.

2. Materials and methods

2.1. Sample preparation

Each type of chickpea was prepared from Legumes seed collection center, agricultural organizations Khomeini, Arak, Iran. Before testing, the broken seeds and external materials removed. Seeds of chickpea partitioned as three groups by size of large dimension. In order to eliminate the effect of seed size on the soaking trials, medium-size grains were used. The initial moisture content at samples was determined by following AACC 44-15A method (AACC, 1999).

2.2. Soaking tests

Experiments were conducted in distilled water at 5, 25 and 45oC for each sample at different duration. Before each experiment, containers and distilled water were kept in desired temperature for a few hours to reach the same temperature.

For each duration included in the timetable, ten seeds of each type were randomly chosen and weighed, then placed in glass beakers containing 200 ml distilled water. Amount of water absorption by varies seeds were determined 5, 10, 15, 30 minutes and one hour after immersion. The tests followed at intervals of one hour toward gelatinized seeds. After reaching at each predetermined sampling time, the samples were drained on a paper and the excess water eliminated with adsorbent paper, and the soaked sample were weighed. A digital chronometer and an electronic weighing balance (AND, Model GF400, Japan) reading to 0.001 gram were used to control soaking duration and measure weight of sample before and after soaking. Tests were done in three replicates. The water absorption capacity was determined by follow equation (McWatters et al., 2002):

$$Wa = \frac{W - W}{W} \times 100 \quad (3)$$

Where, Wa is water absorption (d. b. %), Wf is weight of seeds after immersion (g) and Wi is weight of seed before immersion (g).

According to Peleg (1988), points were intentionally chosen from recorded data, as that extremely small weight gains at the beginning of soaking were not included. Also, data with increasing losses of soluble solids of more than 1% of the initial samples mass were not included. Therefore, at each stage, amount of solid material dissolved in water was controlled by measuring density of distilled water and drained water in each experiment.

2.3. Analysis of soaking models

Seeds absorbed just a little amount of water before two hours. So, recorded data before this time were not used in fitting to the Peleg model. Also the soluble solids losses more than 1% of the initial mass of the samples are not desired, recorded data after this time were not used to determine the Peleg constants (Masumi and Tabil, 2003). Some researchers used a soaking time of 11 and seven hours for chickpea at 20oC and 40oC respectively. Another researchers predicted this time about seven hours for chickpea at 20oC (Sayar et al., 2001; Turhan et al., 2002).

Khazaei and Peleg models for determination of moisture content during water absorption were driven based on the time (independent variable) using MATLAB software. To evaluation of Khazaei and Peleg models prediction, data of prediction against test data were plotted for each variety at three temperatures and determined the coefficient of determination (R2), by following equation (4). Also, chi-square (x2) and root mean square error (RMSE) were determined base on equation (5) and (6), respectively.

$$\mathbf{R^2} = \frac{\sum_{i=1}^{N}(M_{exp,i} - M_{exp\,ave})^2 - \sum_{i=1}^{N}(M_{exp,i} - M_{pre,i})^2}{\sum_{i=1}^{N}(M_{exp,i} - M_{exp\,ave})^2} \quad (4)$$

$$\mathbf{x^2} = \frac{\sum_{i=1}^{N}(M_{exp,i} - M_{pre,i})^2}{N - n} \quad (5)$$

$$\mathbf{RMSE} = \left[\frac{1}{N}\sum_{I=1}^{N}(M_{pre,i} - M_{exp,i})^2\right]^{1/2} \quad (6)$$

where, Mexp,i is the ith experimentally observed moisture content (d. b. %), Mpre,i the ith predicted moisture content (d. b. %), Mexp ave is average moisture content observed (d. b. %), N, is number of data and n, is number of constant coefficient of model. Regression index in each temperature were calculated and compared together. The coefficients of two models for any variety at different temperatures test were determined using MATLAB software.

3. Results and discussion

3.1. Water uptake curve

Values of initial moisture content of chickpea were 8.74, 7.79 and 8.86% dry basis for Desi, Chico and Kabuli, respectively in which did not significantly difference (P<0.05). The increasing moisture content of samples on soaking time is shown in Figure 2. Absorption curves show the rate of water absorption increased with increasing temperature. In higher water temperature, time need to reach saturated moisture was shorter for samples. The reason of these phenomena is increasing of propagation velocity of water in seeds. Higher temperatures result to the grain gelatinization and will lead to the expansion and softening of grain. Therefore, more pores and cracks opened and finally transmission of water through the seed were increased (Ranjbari et al., 2011). Thus, high temperatures can cause the seeds to soften and expand. The moisture absorption rate will be higher, if the soaking temperature is closer to gelatinization temperature of seed. Therefore, use of higher temperatures on short time has affected to reach equilibrium moisture in shorter time during soaking. In general, the water absorption rate is fast in the beginning of soaking and slowed in the end of soaking progress. More extracting solid matter from seeds in the end of soaking time is negative factor to water absorption. Similar results have been reported for various legumes such as chickpea, cow chickpea, soybean, and chick peanuts (Sopade and Kaimur, 1999; Sopade and Obekpa, 1990; Turhan et al., 2002; Pan and Tangratanavalee, 2003).

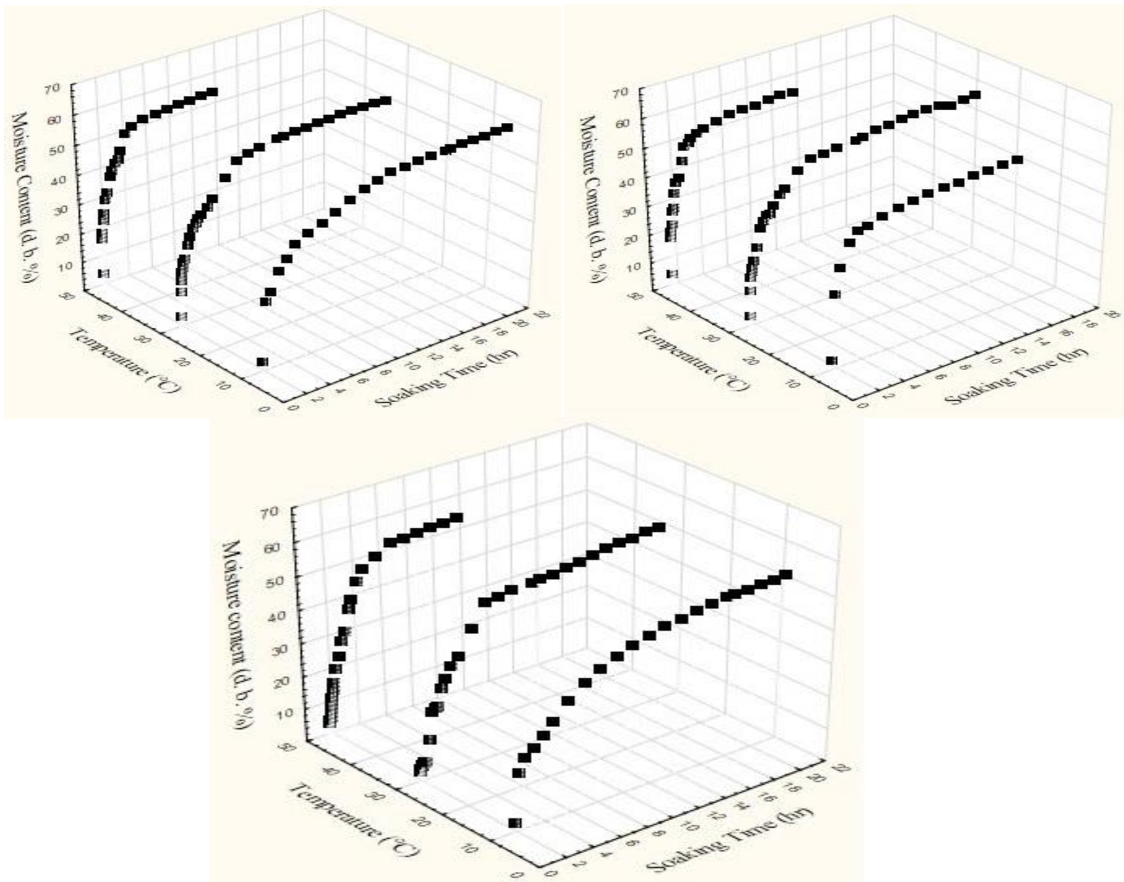

Fig. 2. Water uptake characteristics of chickpea during soaking, (a) Kabuli, (b) Chico, (c) Desi variety.

Result of compare for each variety of chickpea indicate that, water absorption value were not significant different ($P<0.05$). It is due to same condition of cultivation and partial different on morphology and physiologic properties of this variety of chickpea in Iran.

3.2. Evaluation of khazaei model

Constants of models were obtained at three different temperatures for samples and shows in Table (1) and (2), respectively. Results show that, the coefficient of Peleg model k1, decreased with increasing temperature from 5 to 45°C and the coefficient of Peleg model k2, not affected by temperature. The coefficients of Khazaei model are criterion of detection first and second phase of water absorption and they had not changed regularly with temperature. Prediction value base on Khazaei model against test value were plotted for Desi variety of chickpea at 25°C on Figure (3). For other variety, at each temperature, prediction values against test values extracted same as this. Coefficient of determination (R2), chi-square (x2) and root mean square error (RMSE) are shown in Tables (1) and (2). In case of Khazaei model, the minimum value of coefficient of determination was 0.951, maximum of chi-square and root mean square error are 3.223 and 3.227 respectively, which demonstrate the suitability of the model to modeling the experimental absorption characteristics of chickpea samples. Thus, Khazaei model has enough accurate to predict the moisture content of the chickpeas during soaking and not significant difference with Peleg model ($P<0.05$), according to the compare value of static index of both models. Also, Khazaei and Daneshmand (2007) found that, Khazaei model for drying of sesame seed had an acceptable accuracy in predicting the drying kinetics of sesame seed. Figure (4) shows fitting both Peleg and Khazaei models of Desi chickpea during soaking in different temperature. The same curves were driven for other varieties, in this study.

Table 1
The coefficients of Peleg model and R2, x2, RMSE for moisture content of chickpea during soaking in various temperature of water.

Type	Temperature (°C)	K1×10-2 (hr×%-1)	K2×10-2 (%-1)	R2	x2	RMSE
Desi						
	5	4.40	1.9	0.959	0.141	0.674
	25	2.90	1.9	0.981	2.363	2.725
	45	2.60	1.7	0.987	2.138	2.619
Chico						
	5	2.50	2.0	0.986	0.134	0.666
	25	1.60	1.9	0.997	0.944	1.724
	45	0.80	1.9	0.996	0.867	1.667
Kabuli						
	5	3.50	2.0	0.986	0.442	1.193
	25	2.40	1.9	0.967	1.658	2.284
	45	2.19	1.9	0.996	1.220	1.978

Table 2
The coefficients of Khazaei model and R2, x2, RMSE for moisture content of chickpea during soaking in various temperature of water.

Type	Temperature (°C)	Mret (d. b. %)	Tret (hr)	Kret (% hr-1)	R2	x2	RMSE
Desi							
	5	36.34	2.178	0.539	0.984	0.363	1.106
	25	47.79	2.881	0.057	0.989	1.253	2.009
	45	50.09	1.861	0.055	0.993	0.756	1.545
Chico							
	5	40.20	0.393	0.519	0.961	0.614	1.466
	25	40.76	0.853	0.670	0.967	2.151	2.636
	45	43.13	0.543	0.769	0.973	1.481	2.222
Kabuli							
	5	39.63	1.328	0.808	0.945	0.807	1.645
	25	38.92	0.914	0.125	0.951	3.223	3.227
	45	39.28	0.556	0.422	0.957	2.445	2.855

4. Conclusion

The summarize of results that obtained in the present experiment are:

The Khazaei model is acceptable for predicting moisture content of different types of chickpea during soaking.

Khazaei model showed water absorption increased with increasing of temperature during soaking.

In the soaking progress, moisture content increased rapidly in the first time of immersion. After that, the rate of water absorption was slow and quiet until the moisture content reached a saturated point.

The coefficients of Khazaei model had not changed regularly with temperature.

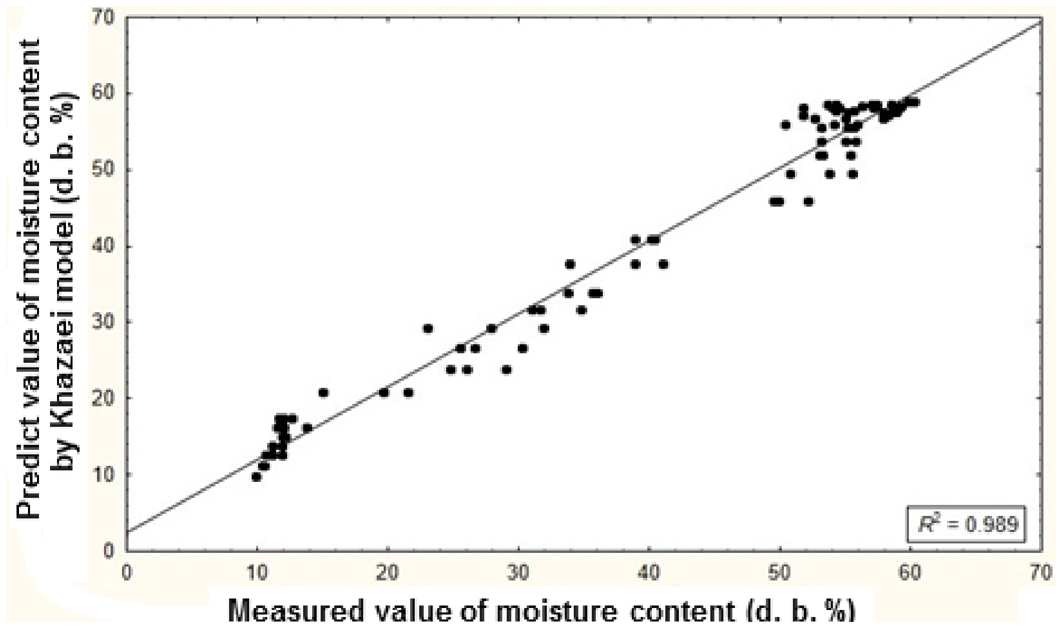

Fig. 3. Prediction values against test values for Desi variety at 25°C.

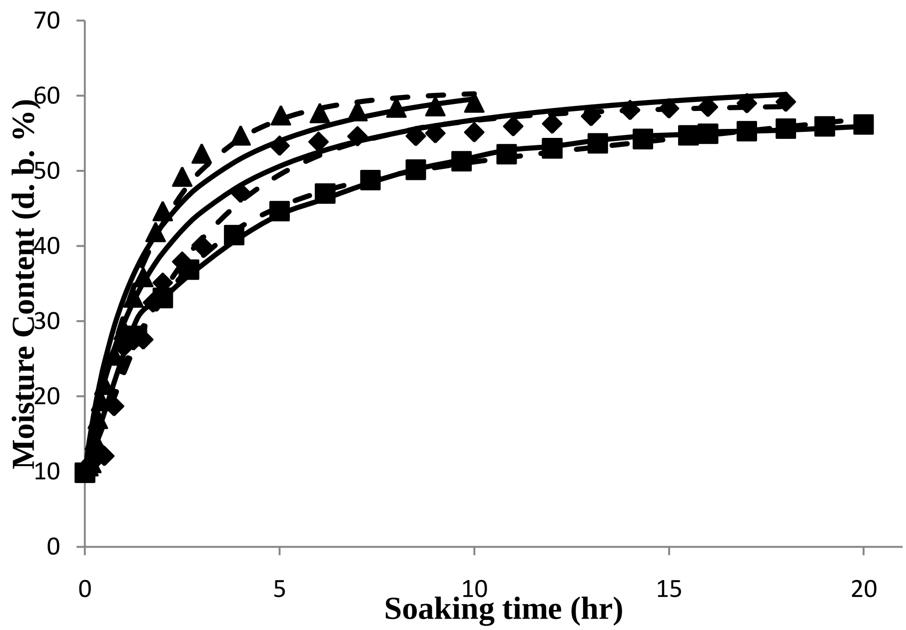

Fig. 4. Fitting models of Desi variety during soaking, 5˚■, 25˚♦, 45˚▲. Peleg model, - - - - Khazaei model.

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