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Article · January 2014

DOI: 10.14196/aa.v3i1.1101

A.A. Masoumi
Isfahan University of Technology

Evaluation of Khazaei Model in Predicting of Water Absorption of Chickpea during Soaking

S. M. Shafaei* and A. A. Masoumi

Department of Agricultural Machinery Engineering, Faculty of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran.
*Corresponding author's E-mail: *smshafaei@shirazu.ac.ir*

Abstract

Water absorption progress of agricultural productions includes two parts. Water absorption rate of initial and second phase are high and low, respectively. The main problem of all existing mathematical models of water absorption such as Peleg model is none of them do not assessment present for the second phase. Khazaei model which, has good ability to analyze water absorption of agricultural productions in the second phase was used to predict water absorption of three varieties of chickpea (Desi, small Kabuli and large Kabuli) during soaking, in this study. 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 mailed saturated moisture content of seeds. Khazaei and Peleg model of water absorption were fitted to experimental data. To compare the accuracy of Khazaei model versus Peleg model, three parameters, coefficient of determination (R^2), chi-square (x^2) and root mean square error (*RMSE*) were used. The results demonstrated that Khazaei model has enough accurate to predict the moisture content of three varieties of chickpea in the second phase during soaking and not significant difference between two models ($P<0.05$). Also, water absorption curves indicated that water uptake of seeds increasing with increasing water temperature during soaking.

Keywords: Immersion, Moisture content, Peleg model, Temperature effect, Water uptake.

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 need warm climate to grow. It maturity is typically 55-60 days from planting to harvest. Top 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 (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 capacity (Sopade *et al*., 1994). Understanding water absorption in legumes during soaking is practical importance since it affects following processing operations and the quality of the final product (Turhan *et al*., 2002). The water absorption of seeds during soaking mainly depends on soaking time and water temperature. Warm water is a common method to diminish 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 mathematical models (Shafaei and Masoumi, 2013b and 2013c). 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). Against mathematical models, using intelligent models to predict hydration of agricultural products have been reported by many researchers (Kashaninejad *et al.*, 2009; Shafaei and Masoumi, 2013d).

Water absorption process in agricultural products includes an initial and second phase that have faster and lower water absorption rate, respectively. The main problem of all existing mathematical models of water absorption such as Peleg model is none of them do not present assessment for the 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):

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

Where M_t is moisture content at time t (d. b. %), M_o is initial moisture content (d. b. %), M_{ret} (retardation moisture content) is the rate of water absorption in the first phase of soaking (d. b. %). T_{ret} (time of retardation) is the required time to approach approximately, 63% of the retarded moisture content (hr). K_{rel} is the rate of water absorption in the relaxation phase (hr^{-1}%). The highest amount of T_{ret} shows the high rate of absorbance in the first phase of water absorption. In addition, K_{rel} shows the rate of water absorption in the relaxation phase and it is calculated by determining the slope of the tangent line on the last part of water absorption 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 water 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). Other researchers applied the model to describe water absorption of bean during immersion and they found the model has enough ability to predict moisture content of seeds during soaking (Shafaei and Masoumi, 2013a). Also, the model can use for drying progress which is lead to result negative values of constant coefficient. Khazaei and Daneshmandi (2007), used Khazaei model for drying of sesame seed.

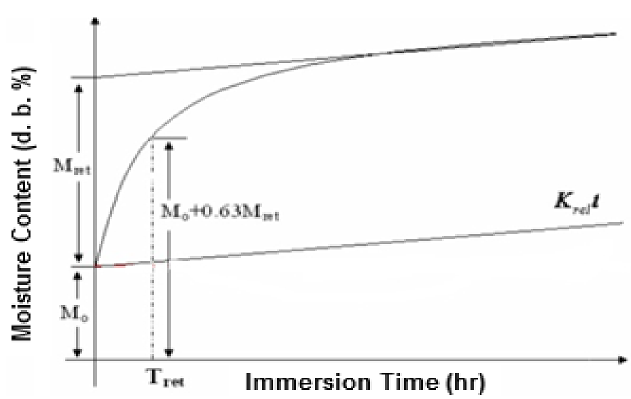


Figure 1. Khazaei model of agricultural products (Khazaei, 2008).

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):

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

Where M_t is moisture content at time t (d. b. %), M_o is initial moisture content (d. b. %), t is time (h), K_1 and K_2 are the Peleg rate (hr%$^{-1}$) and Peleg capacity constant (%$^{-1}$), respectively. In fact, the coefficient of K_1 of Peleg model is criterion of water absorption in the first phase only, while K_2 is criterion of water absorption in second phase. In equation (2), ‘‘±’’ becomes ‘‘+’’ if the process is absorption or adsorption and ‘‘-’’ if the process is drying or desorption (Maharaj and Sankat, 2000).

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 rather than above the gelatinization temperature 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 studying behavior of chickpea varieties in water absorption progress and evaluating of Khazaei model accuracy in the soaking.

2. Material and methods

2.1. Sample preparation

Each type of chickpea was prepared from Legumes seed collection center, agricultural organization Khomein, 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 seeds 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

Duo to possibility of gelatinization grains in higher temperatures, Experiments were conducted in distilled water at 5, 25 and 45°C 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 equilibrium moisture content. 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 samples 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):

$$W_a = \frac{W_f - W_i}{W_i} \times 100 \quad (3)$$

Where, W_a is water absorption (d. b. %), W_f is weight of seeds after immersion (g) and W_i is weight of seeds 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, to determined equilibrium moisture content of seeds, when observed losses of soluble solids increased more than 1% of the initial samples mass during soaking, tests was stopped. 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, thus recorded data after this time were not used to determine the Peleg constants. Some researchers used a soaking time of eleven and seven hours for chickpea at 20 and 40°C respectively. Another researchers predicted this time about seven hours for chickpea at 20°C (Sayar *et al*., 2001; Turhan *et al*., 2002).

Khazaei and Peleg model for determination of moisture content during water absorption were driven based on the time (independent variable) using Matlab software. To evaluation of Khazaei versus Peleg model prediction, data of prediction against test data were plotted for each variety at three temperatures and determined the coefficient of determination (R^2), by following equation (4). Also, chi-square ($\boldsymbol{x}^2$) and root mean square error (*RMSE*) were determined based on equation (5) and (6), respectively.

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

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

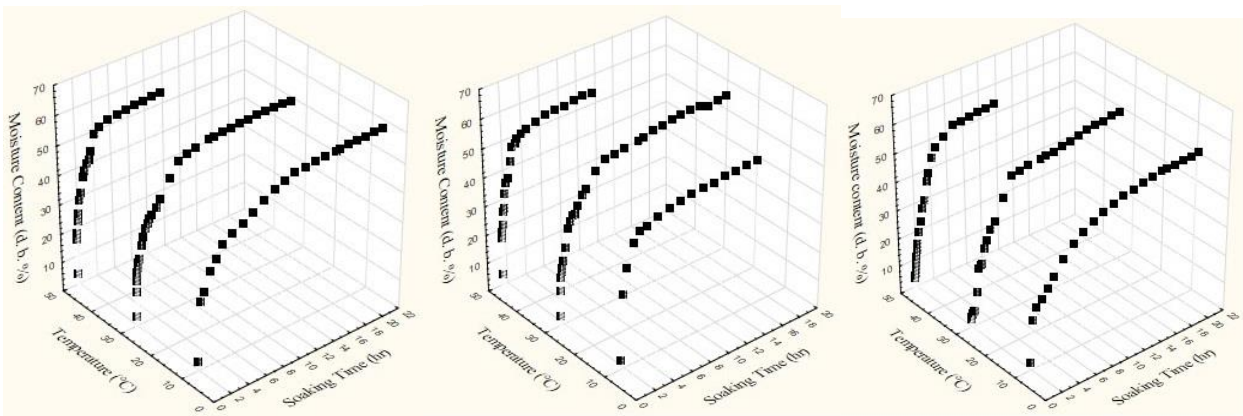
$$RMSE = \left[\frac{1}{N}\sum_{I=1}^{N}(M_{pre,i}-M_{exp,i})^2\right]^{1/2} \tag{6}$$

where, $M_{exp,i}$ is the i^{th} experimentally observed moisture content (d. b. %), $M_{pre,i}$ the i^{th} predicted moisture content (d. b. %), $M_{exp\ ave}$ 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 curves

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 content 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 water absorption rate will be higher, if the soaking temperature is closer to gelatinization temperature of seeds. Therefore, use of higher temperatures on short time has affected to reach equilibrium moisture in shorter time during soaking. In general, in the beginning time of soaking, the water absorption rate is fast 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).



(a) (b) (c)

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

Result of compare for three varieties of chickpea indicate that, water absorption values were not significant different in each variety ($P<0.05$). It is due to same condition of cultivation and partial different on morphology and physiologic properties of the varieties of chickpea in Iran. Also three varieties of chickpea have same behavior in water absorption progress; that indicated variety not affected in values of water absorption of seeds during soaking, in this study ($P<0.05$).

3.2. Evaluation of Khazaei model

Constants of models were obtained at three different temperatures for samples are shows in Table (1) and (2). Results show that, the coefficient of Peleg model K_1, decreased with increasing temperature from 5 to 45°C and the coefficient of Peleg model K_2, not affected by temperature. The coefficients of Khazaei model are criterion of detection first and second phase of water absorption and they not changed regularly with temperature. Figure (3) shows fitting both Peleg and Khazaei model of Desi chickpea during soaking in three different temperature. Also, prediction values based on Khazaei model against test values were plotted for Desi variety of chickpea at 25°C on Figure (3). The same curves were driven for other varieties, in this study.

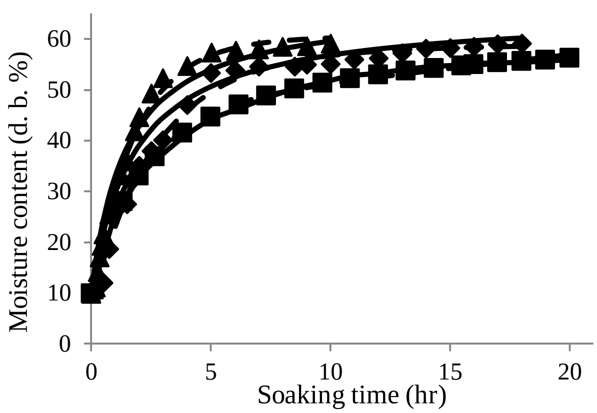
Table 1. The coefficients of Khazaei model and R^2, x^2, *RMSE* of fitted model during soaking in various water temperature

Type	**Temperature (°C)**	**M_{ret} (d. b. %)**	**T_{ret} (hr)**	**K_{rel} (hr^{-1}%)**	***R^2***	***x^2***	***RMSE***
Desi							
	5	36.34	2.178	0.539	0.984	0.113	0.506
	25	47.79	2.881	0.057	0.989	0.353	0.609
	45	50.09	1.861	0.055	0.993	0.126	0.545
Chico							
	5	40.20	0.393	0.519	0.991	0.121	0.556
	25	40.76	0.853	0.670	0.997	0.851	0.636
	45	43.13	0.543	0.769	0.993	0.681	0.522
Kabuli							
	5	39.63	1.328	0.808	0.995	0.407	0.145

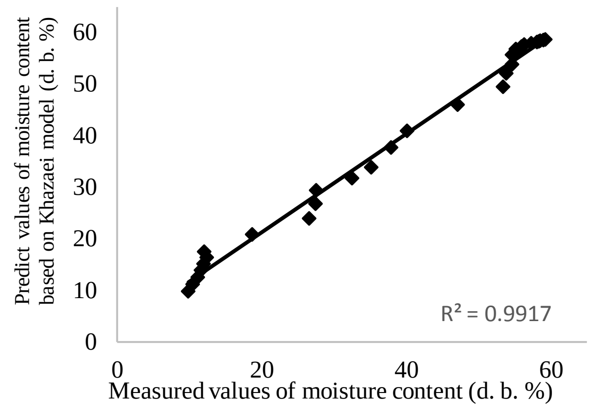
Type	Temperature (˚C)	M_{ret} (d. b. %)	T_{ret} (hr)	K_{rel} (hr^{-1}%)	R^2	x^2	*RMSE*
	25	38.92	0.914	0.125	0.971	0.223	0.227
	45	39.28	0.556	0.422	0.998	1.045	0.955

Table 2. The coefficients of Peleg model and R^2, x^2, *RMSE* of fitted model during soaking in various water temperature

Type	Temperature (˚C)	$K_1 \times 10^{-2}$ (hr×$\%^{-1}$)	$K_2 \times 10^{-2}$ ($\%^{-1}$)	R^2	x^2	*RMSE*
Desi						
	5	4.40	1.9	0.959	0.141	0.674
	25	2.90	1.9	0.981	0.363	0.725
	45	2.60	1.7	0.987	0.138	0.619
Chico						
	5	2.50	2.0	0.986	0.134	0.666
	25	1.60	1.9	0.997	0.944	0.724
	45	0.80	1.9	0.991	0.867	0.667
Kabuli						
	5	3.50	2.0	0.986	0.442	0.193
	25	2.40	1.9	0.967	0.658	0.284
	45	2.19	1.9	0.996	1.120	0.978



(a)



(b)

Figure 3. (a) Fitting models of Desi variety during soaking, 5˚■, 25˚♦, 45˚▲, - - - - Peleg model, —— Khazaei model, (b) Prediction values against test values of Desi variety at 25°C

Coefficient of determination (R^2), chi-square (x^2) 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 0.971, maximum value of chi-square and root mean square error are 0.851 and 0.955 respectively, which demonstrate the suitability of the model to modeling the experimental water absorption characteristics of chickpea samples. In order to compare two models static indexes of both models were studied. Result of comparison of them showed that, not only Khazaei model has not significant difference with Peleg model ($P<0.05$) but also, the adjusting of Khazaei model to experimental data of water absorption of seeds better than Peleg model, according to the lower values of chi-square (x^2) and root mean square error (*RMSE*) and upper values of coefficient of determination (R^2) of Khazaei model against Peleg model. It is due to the three constant coefficient of Khazaei model that lead to better describe water absorption rate of seeds during soaking in the first and second phase of immersion. On figure (4) comparison of static indexes of Desi variety at 25°C was showed. For other variety same curves was depicted.

Thus, Khazaei model has enough accurate to predict the moisture content of the chickpeas during. Other investigator applied the model on drying progress. Khazaei and Daneshmandi (2007) found that Khazaei model for drying of sesame seed had an acceptable accuracy in predicting the drying kinetics of sesame seed.

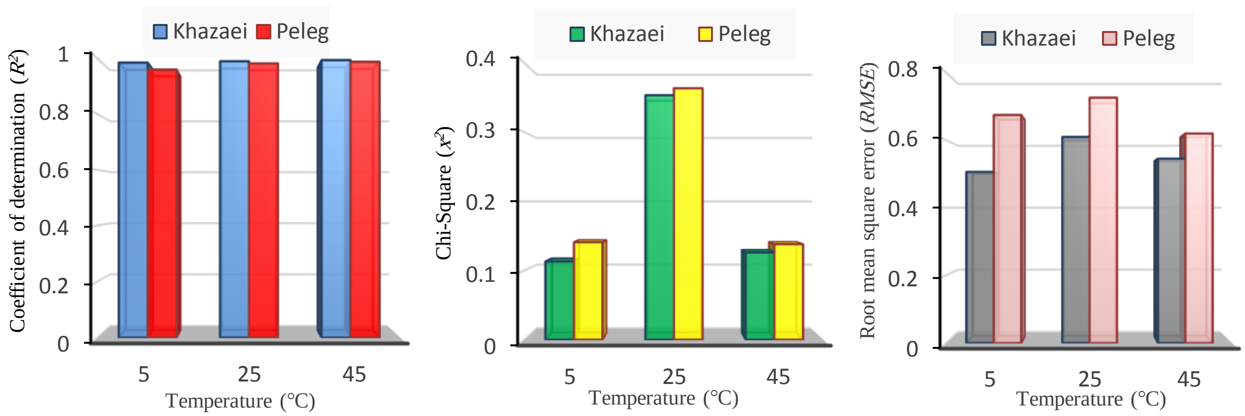


Figure 4. Comparison of static indexes of fitted models of Desi variety at 25°C

4. Conclusions

The summarize of results that obtained in the present experiment demonstrated that The Khazaei model is acceptable model to predict moisture content of different types of chickpea during soaking. In spite of Peleg model, the coefficients of Khazaei model not changed regularly versus temperature. Although, water uptake curves showed water absorption increased with increasing water temperature during soaking in each variety, but the variety did not effect on water absorption rate. In general, moisture content increased rapidly in the first phase of immersion and in the second phase, the rate of water absorption was slow and quiet until the moisture content reached a saturated point.

References

AACC. Methods 44-15A, Moisture – air – oven. 1999. Approved Methods of the American Association of Cereal Chemists, The Association, St. Paul.

Abu-Ghannam, N., McKenna, B., 1997. Hydration Kinetics of Kidney Beans (Phaseolus vulgaris L). Journal of Food Science, 62, 520–523.

Hung, T.V., Liu, L.H., Black, R.G., Trewhella, M.A., 1993. Water Absorption in Chickpea (C. arietinum) and Field Pea (P. sativum) Cultivars Using Peleg Model. Journal of Food Science, 58, 848–852.

Kashaninejad, M., Dehghani, A.M., Khashiri, M., 2009. Modeling of Wheat Soaking Using Two Artificial Neural Networks (MLP and RBF). Journal of Food Engineering, 91(4), 602–607.

Khazaei, J., 2008. Water Absorption Characteristic of Three Wood Varieties. Cercetări Agronomice în Moldova, 134(2), 1-12.

Khazaei, J., Daneshmandi, S., 2007. Modeling of Thin-Layer Drying Kinetics of Sesame Seeds: mathematical and neural networks modeling. International AgroPhysics, 21(4), 335-348.

Khazaei, J., Mohammadi, N., 2009. Effect of Temperature on Hydration Kinetics of Sesame Seeds (sesamum indicum L.). Journal of Food Engineering, 91(4), 542-552.

Lopez, A., Pique, M.T., Clop, M., Tasias, J., Romero, A., Boatella, J., Garcia, J., 1995. The Hygroscopic Behaviour of the Hazelnut. Journal of Food Engineering, 25, 197–208.

Maharaj, V., Sankat, C.K., 2000. Rehydration Characteristics and Quality of Dehydrated Dasheen Leaves. Canadian Agricultural Engineering, 42, 81–85.

McWatters, K.H., Chinnan, M.S., Phillips, R.D., Beuchat, L.R., Reid, L.B., Mensa-Wilmot, R.M., 2002. Functional, Nutritional, Mycological and Akara-Making Properties of Stored Cowpea Meal. Journal of Food Science, 67(6), 2229–2234.

Nussinovitch, A., Peleg, M., 1990. An Empirical Model for Describing Weight Changes in Swelling and Shrinking Gels. Food Hydrocolloids, 4, 69–76.

Palou, E., Lopez-Malo, A., Argaiz, A., Welti, J., 1994. Use of Peleg's Equation to Osmotic Concentration of Papaya. Drying Technology, 12, 965–978.

Pan, Z., Tangratanavalee, W., 2003. Characteristics of Soybeans as Affected by Soaking Conditions. Lebensm.-Wiss. U.-Technol, 36, 143–151.

Peleg, M., 1998. An empirical model for the description of moisture sorption curves. Journal of Food science, 53, 1216-1219.

Ranjbari, A., Kashaninejad, M., Alami, M., Khomeiri, M., 2011. Effect of Ultrasound Pretreatment on Water Absorption Characteristic of Chickpea during Steeping Process (in Farsi). Electronic Journal of Food Processing and Preservation, 2(1), 91-105.

Salunkhe, D.K., Kadam, S.S., Chavan, J.K., 1985. Postharvest Biotechnology of Food Legumes. Boca Raton, FL: CRC Press.

Sayar, S., Turhan, M., Gunasekaran, S., 2001. Analysis of Chickpea Soaking by Simultaneous Water Transfer and Water-Starch Reaction. Journal of Food science, 50, 91-98.

Shafaei, S.M., Masoumi, A.A., 2013a. Application of Viscoelastic Model in the Bean Soaking. International Conference on Agricultural Engineering: New Technologies for Sustainable Agricultural Production and Food Security, February 24- 26, Muscat (Oman).

Shafaei, S.M., Masoumi, A.A., 2013b. Modeling of Water Absorption of Bean during Soaking. International Conference on Agricultural Engineering: New Technologies for Sustainable Agricultural Production and Food Security, February 24- 26, Muscat (Oman).

Shafaei, S.M., Masoumi, A.A., 2013c. Modeling of Water Absorption of Chickpea during Soaking. 1st International e-Conference on novel Food Processing, February 26- 27, Mashhad (Iran).

Shafaei, S.M., Masoumi, A.A., 2013d. Using Artificial Neural Network to Predict Moisture Content of Three Varieties of Chickpea in Soaking (In Farsi). 21Th National Congress of Food Science and Technology, October 29- 31, Shiraz (Iran).

Singh, B.P.N., Kulshrestha, S.P., 1987. Kinetics of Water Sorption by Soybean and Pigeon Pea Grains. Journal of Food Science, 52, 1538–1544.

Singh, R.P., 1990. Status of Chickpea in the World. International Chickpea Newsletter, 22, 10–16.

Sopade, P.A., Ajisegiri, E.S., Badau, M.H., 1992. The Use of Peleg's Equation to Model Water Absorption in Some Cereal Grains during Soaking. Journal of Food Engineering, 15, 269–283.

Sopade, P.A., Ajisegiri, E.S., Okonmah, G.N., 1994. Modelling Water Absorption Characteristics of Some Nigerian Varieties of Cowpea during Soaking. Tropical Science, 34, 297–305.

Sopade, P.A., Kaimur, K., 1999. Application of Peleg's Equation in Desorption Studies of Food Systems: a Case Study with Sago (Metroxylon Sagu rottb.) starch. Drying Technology, 17, 975–989.

Sopade, P.A., Obekpa, J.A., 1990. Modeling Water Absorption in Soybean, Cowpea and Peanuts at Three Temperatures Using Peleg's Equation. Journal of Food Science, 55, 1084–1087.

Turhan, M., Sayar, S., Gunasekaran, S., 2002. Application of Peleg Model to Study Water Absorption in Chickpea during Soaking. Journal of Food science, 53, 153-159.