Application of Peleg Model to Study Water Absorption in Bean and Chickpea During Soaking

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Abstract— Legumes are economic sources of protein, energy, vitamins and minerals. Despite their good nutritional qualities, legume consumption is declining worldwide. Legumes cook in many different ways throughout the world. However, they need prolonged preparation and may cause some gastrointestinal distress after eating. Seed soaking in order to absorb moisture and soften the crust and the core is usual. Moisture absorption rate during emersion in water is different. Moisture absorption has affected by size of seed, and water temperature. The model presented by Peleg matches with the experimental results of moisture absorption material in the immersion in the short-term period to reach saturated moisture. Therefore, in present study, use the model for determining the instance moisture content of three varieties of beans (Talash, Sadri and Mahali Khomein) and three varieties of chickpea (Desi, small Kabuli and large Kabuli) during soaking. To eliminate the effect of grain size on the rate of water absorption, samples of grains with an average size were selected. The experiments were carried at three temperatures (5, 25 and 45°C) and three replicate by using distilled water. For each variety, the moisture content versus time curves were plotted at different temperatures. The corresponding plotted curves for each variety of bean and chickpea indicated that moisture absorption increasing with increased temperature. The Peleg model constants (k_1 and k_2) for each sample at each temperature settle by data fitting by using Matlab software. The obtained constants were investigated regard temperature. For bean, the results showed that after two hours the coefficient of k_1 and k_2 decrease linearly. Also for chickpea, the coefficient of k_1 decrease linearly and the effect of temperature on the coefficient of k_2 was partial and decreasing.

Keywords: Immersion, coefficients of Peleg model, moisture content, legumes.

INTRODUCTION

Legumes are source of protein, including plant proteins, carbohydrates and minerals like iron, calcium, potassium, magnesium and vitamins, especially the B vitamin. Legumes contain relatively low quantities of the essential amino acid methionine, as compared to whole eggs, dairy products or meat. This means that a smaller proportion of the plant proteins, compared to proteins from eggs or meat, may be used for the synthesis of protein in humans.

Unlike the closely related chickpea, beans are a summer crop that needs warm climate to grow. Maturity is typically 55-60 days from planting to harvest.

In Iran, the bean is widely grown as product legumes for a long time. Top shelf life, ease of transportation, and the cost are attractive to farmers.

There are two main varieties of chickpeas 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 [8].

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 [12]. Relationship between moisture content of seeds in soaking versus time has been expressed by different models. 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 [10, 11].

The Peleg model is shown as:

$$M_t = M_o \pm \frac{t}{K_1 + K_2 t} \quad (1)$$

Where M_t is moisture content at time t (%), M_o is initial moisture content (%), t is time (h), K_1 and K_2 are the Peleg rate ($h\%^{-1}$) and Peleg capacity constant ($\%^{-1}$) respectively. In equation (1), ‘‘±’’ becomes ‘‘+’’ if the process is absorption or adsorption and ‘‘-’’ if the process is drying or desorption [5].

The rate of sorption (R) can be gotten from first derivative of the Peleg equation

$$R = \frac{dM}{dt} = \pm \frac{K_1}{(K_1 + K_2 t)^2} \quad (2)$$

The Peleg rate constant K_1 relates to sorption rate at the beginning (R_0), R at $t = t_0$

$$R = \frac{dM}{dt}\Big|t = 0 = \pm \frac{1}{K_1} \quad (3)$$

The Peleg coefficient constant K_2 relates to maximum (or minimum) possible moisture content. As $t=\infty$, equation1 gives the relation between equilibrium moisture content (M_e) and K_2

$$M\big|_{t=\infty} = M_e = M_0 \pm \frac{1}{K_2} \quad (4)$$

Peleg model was used for describing sorption of various foods. Maharaj and Sankat (2000) used the model for studying water absorption of leaves of dasheen [5]. Sopade and Kaimur (1999) used it for defining of sago starch water desorption [10]. Palou, Lopez- Malo, Argaiz, and Welti

(1994) studied simultaneous water desorption and sucrose absorption of papaya by using the model [6].

The objective of this study was to determine the Peleg constants (K_1 and K_2) of various types of chickpea (large Kabuli(Kabuli), small Kabuli(Chico) and Desi) and three varieties of beans (Talash, Sadri and Mahali Khomein) at three temperatures (5, 25 and 45°C).

MATERIAL AND METHODS

Each type of bean and chickpea were prepared from Legumes seed collection center, agricultural organizations Khomeini, Arak, Iran. The initial moisture content at samples was determined by following AACC 44-15A method [1] for chickpea and ASAE S352.2 DEC97 [2] for bean. In order to eliminate the effect of seed size on the soaking trials, medium-size grains were used.

Experiments were conducted in distilled water at 5°C, 25°C and 45°C for each type of chickpea and bean 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. A digital chronometer and an electronic weighing balance (AND, Model GF400, Japan) reading to 0.0001 g were used to control soaking duration and measure weight of sample before and after soaking. Tests were done in three replicates.

According to Pelege (1988), points were intentionally chosen from recorded data, as that extremely small weight gains at the beginning of soaking were not included [7]. 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. Peleg's model was fitted to experimental data by using of toolbox of Matlab software. After, determining the coefficients of Peleg model in each temperature for every variety of bean and chickpea, the relationship between them and temperature test were examined.

RESULTS AND DISCUSSION

Values of initial moisture content of beans were 7.16, 7.41 and 7.36% dry basis for Talash, Sadri and Mahali Khomein and 9.85, 10.25 and 10.27% dry basis for Desi, small Kabuli and large Kabuli, respectively in which did not significantly differ ($p<0.05$).

The increasing moisture content of samples on soaking time is shown in Fig 1 to 6. Absorption curves show the rate of water absorption increased with increasing temperature. Similar results have been reported for various legume grains such as chickpea, cow chickpea, soybean, and chick peanuts [10, 11, 13, 15].

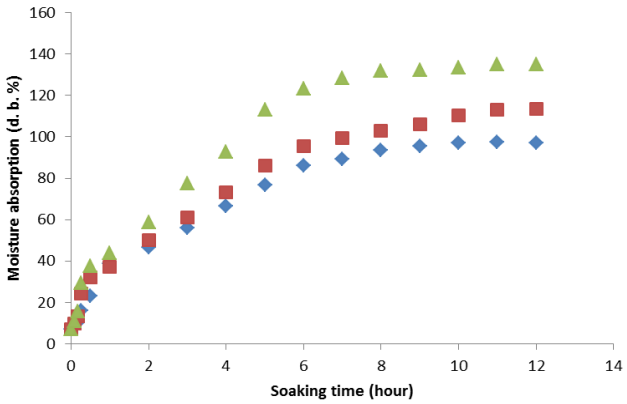

Figure 1. Moisture absorption characteristics of bean (Talash) during immersion, 5°♦, 25°■, 45°▲.

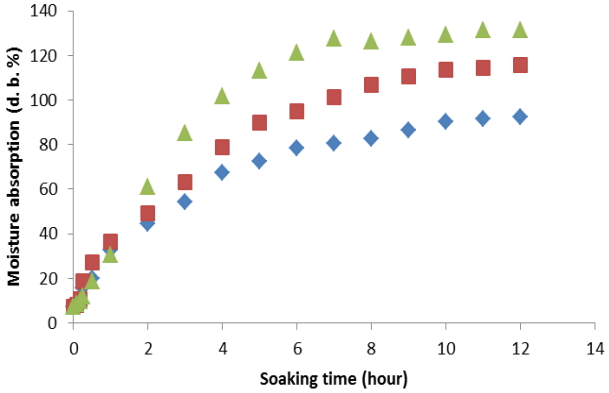

Figure 2. Moisture absorption characteristics of bean (Sadri) during immersion, 5°♦, 25°■, 45°▲.

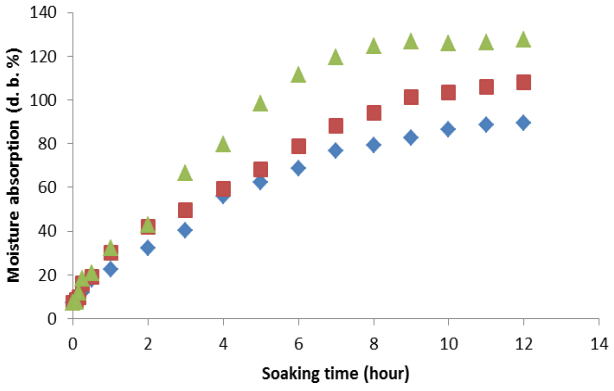

Figure 3. Moisture absorption characteristics of bean (Mahali Khomein) during immersion, 5°▲, 25°■, 45°♦.

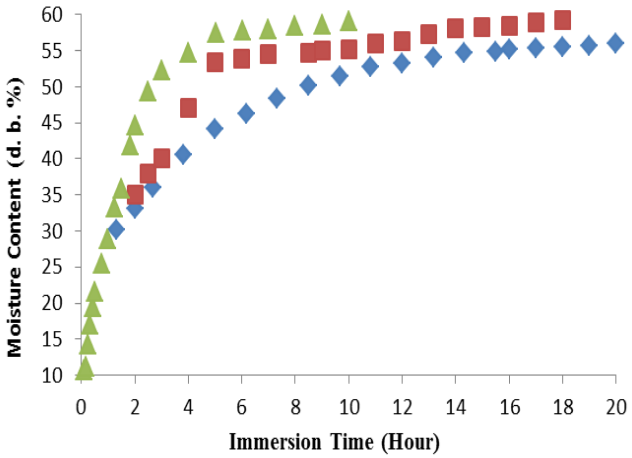

Figure 4. Moisture absorption characteristics of chickpea (Desi) during immersion, 5°♦, 25°■, 45°▲.

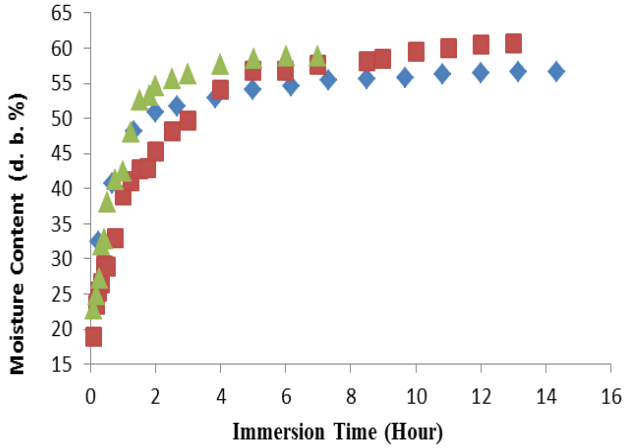

Figure 5. Moisture absorption characteristics of chickpea (Chico) during immersion, 5°♦, 25°■, 45°▲.

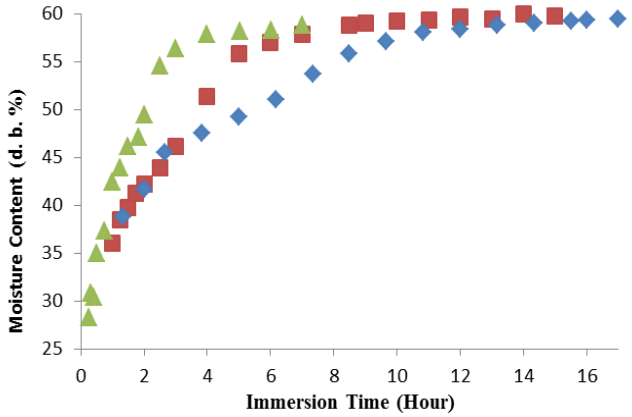

Figure 6. Moisture absorption characteristics of chickpea (Kabuli) during immersion, 5°♦, 25°■, 45°▲.

In order to choose the initial data, equation 1 rearranged as linear regression (Eq.5).

$$\frac{t}{M_t - M_0} = K_1 + K_2 t \qquad (5)$$

Fig. 7 shows regression line for Sadri type of bean at 45°C. It shows that the Sadri cultivar absorbed just a little amount of water before 2h, so recorded data before this time were not used in fitting to the Peleg model. Since the soluble solids losses after 12h of soaking of Sadri cultivar at 45°C was more than 1% of the initial mass of the samples, recorded data after this time were not used to determine the Peleg constants. The same procedure was done for data from the other cultivars of bean and chickpea.

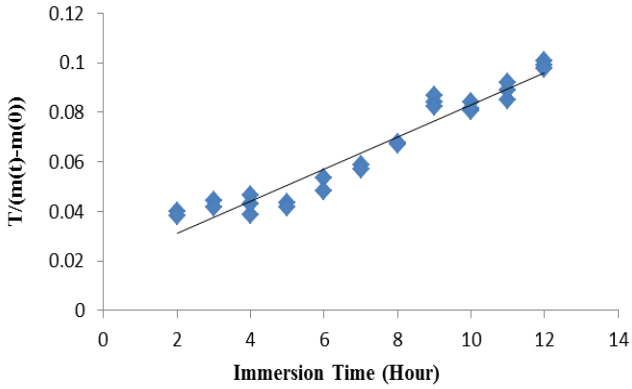

Figure 7. Linear curve Peleg model of Moisture absorption by bean (Sadri) at a temperature, 45° C during immersion conditions.

Some researchers such as Sayar and the others, (2001), used a soaking time of 11 and 7 hours for chickpea at 20°C and 40°C respectively, and Turhan and others, (2002), predicted this time about 7 hours for chickpea at 20°C [9, 13] .

TABLE 1 and 2 shows the constants k_1 and k_2 at three different temperatures for bean and chickpea samples, respectively. To evaluate the fitted model on the data collected, the predicted values of moisture content by the model were plotted against the corresponding measured values in the test. Coefficient of determination (R^2) of them is shown in Tables 1 and 2, which are more than 0.9. Results show that Peleg rate constants (k_1 and k_2) for bean (Fig. 8 and 9) with temperature, decrease linearly. While, k_1 for chickpea is very partial and decreasing, but constant k_2 was not affected by temperature for chickpea. The same results were reported by some researchers [13, 15].

TABLE1. The coefficients of Peleg model and Coefficient of determination (R^2) for moisture content of bean during immersion in various temperature.

Type	Temperature (°C)	K_1(hour*%$^{-1}$)	K_2(%$^{-1}$)	R^2
Talash				
	5	0.03403	0.00774	0.975
	25	0.02319	0.00638	0.987
	45	0.01304	0.00547	0.977
Sadri				
	5	0.03439	0.00875	0.990
	25	0.02683	0.00629	0.987
	45	0.01920	0.00411	0.967
Mahali Khomein				
	5	0.05845	0.00686	0.983
	25	0.05215	0.00529	0.989
	45	0.04207	0.00409	0.988

TABLE1. The coefficients of Peleg model and Coefficient of determination (R^2) for moisture content of chickpea during immersion in various temperature.

Type	Temperature (°C)	K_1(hour×%$^{-1}$)	K_2(%$^{-1}$)	R^2
Large Kabuli				
	5	3.5×10^{-2}	2×10^{-2}	0.986
	25	2.4×10^{-2}	1.9×10^{-2}	0.997
	45	2.19×10^{-2}	1.9×10^{-2}	0.996
Chico				
	5	2.5×10^{-2}	2×10^{-2}	0.986
	25	1.6×10^{-2}	1.9×10^{-2}	0.997
	45	0.8×10^{-2}	1.9×10^{-2}	0.996
Desi				
	5	4.4×10^{-2}	1.9×10^{-2}	0.959
	25	2.9×10^{-2}	1.9×10^{-2}	0.981
	45	2.6×10^{-2}	1.7×10^{-2}	0.987

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

1- The Peleg model is acceptable for predicting moisture content of different types of bean and chickpea during soaking.
2- The Peleg rate constant k_1 decreased with temperature for each type of bean and chickpea.
3- k_2 constant coefficient for beans tested, decreased with temperature for each sample type.
4- The Peleg capacity constant k_2 was not affected by temperature for chickpea.

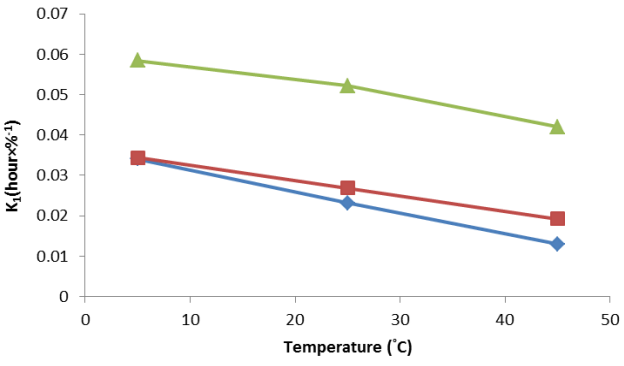

Figure 8. Effect of immersion temperature on Peleg rate constant k_1 for bean, ▲Mahali Khomein, ■Sadri, ♦Talash.

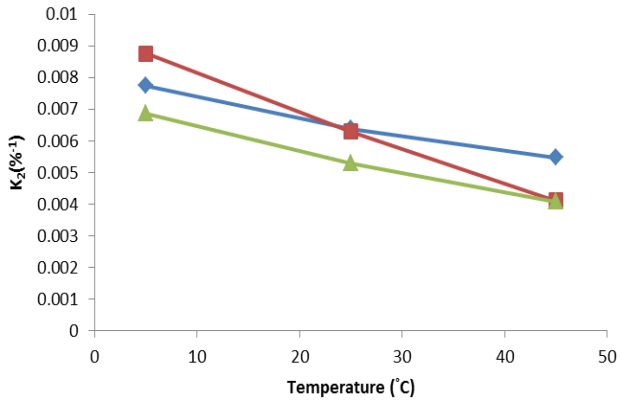

Figure 9. Effect of immersion temperature on Peleg rate constant k_2 for bean, ▲Mahali Khomein, ■Sadri, ♦Talash.

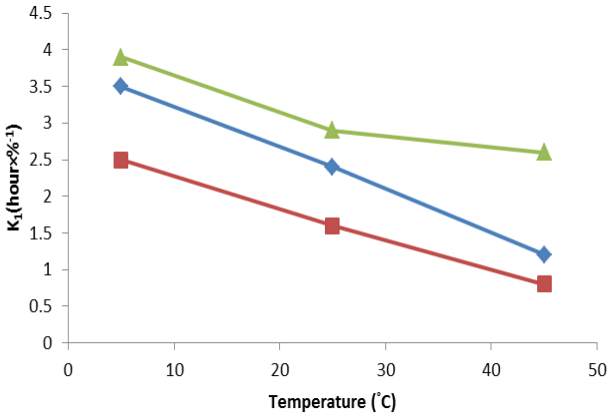

Figure 10. Effect of immersion temperature on Peleg rate constant k_1 for chickpea, ♦Kabuli, ■Chico, ▲ Desi.

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