Modeling of Water Absorption of Chickpea During Soaking

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Abstract— Chickpea are known as an important source of protein, grown as specialty crop in Iran and is exported around the world. Soaking of grains is usually used before hulling and cooking. Understanding water absorption of different seeds during soaking was considered by researchers. Materials under different conditions of soaking have different water absorption rate and capacity. Relationship between moisture content of materials versus time during soaking has been expressed by different models. In this study the different standard models were used to predict the moisture ratio of three varieties of chickpeas in Iran (Desi, small Kabuli and large Kabuli). The experiments were carried by using distilled water at three temperatures (5, 25 and 45°C) and three replicate. 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. Fourteen standard models of moisture absorption were fitted to the experimental data by using Matlab software. To evaluate the models, three parameters; coefficient of determination (R^2), chi-square (x^2) and root mean square error (RMSE) were used. Based on maximum value of coefficient of determination and minimum value of chi-square and root mean square error, the best model was chosen. The result showed that the Binomial model is the most appropriate for each of the three varieties in each experimental temperature to predict ratio moisture changes by the time in soaking. So, moisture ratio versus time was plotted for each case, by using Binomial equation. The plotted curves for each variety of chickpea indicated that moisture ratio is decreasing with increasing temperature.

Keywords: Immersion, moisture ratio, Binomial model, Matlab software, statistical index.

INTRODUCTION

Legumes are source of protein, including 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.

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

Since soaking the grains is usually used before dehulling and cooking, understanding the water absorption of different seeds during soaking was considered by researchers. Materials in different conditions of soaking have different water absorption rate and water absorption capacity [10]. Relationship between moisture content of materials versus time during soaking has been expressed by different models. Also these models were used for dehydration of agricultural material. Binomial model used to describe the water absorption of soychickpea and white chickpea. Peleg model was used for studying water absorption of leaves of dasheen [6].

The objectives of the present study were to determine the best appropriate model for water absorption of three varieties of chickpea (Desi, small Kabuli (Chico) and large Kabuli (Kabuli)) during soaking to predict moisture ratio changes by passing the time during soaking.

MATERIAL AND METHODS

Each type of chickpea Were prepared from Legumes seed collection center, agricultural organizations Khomeini, Arak, Iran. The initial moisture content of samples was determined by following AACC 44-15A [1]. 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 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. The loss of soluble solids from soaked seeds was calculated by measuring distilled water and drained water in each experiments [7]. 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 Peleg points were intentionally chosen from recorded data, as that extremely small weight gains at the beginning of soaking were not included [8]. 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 the soluble and distilled water density.

In the majority research water absorption and drying model are achieved based on the moisture ratio (MR), due to reduce data dispersion and optimize data [2].

$$MR = \frac{M_c - M_e}{M_o - M_e} \quad (1)$$

Where MR is moisture ratio at time t (%), M_o is initial moisture content (%), M_e is saturated moisture (%) and M_c is moisture content at time t (%). The most common water absorption models for seeds, which were driven by researchers, are shown in Table 1[9, 5]. The parameters of these models for each sample in water absorption during soaking were extracted via using Matlab software. To evaluate of models three parameters; coefficient of determination (R^2), chi-square ($\boldsymbol{x^2}$) and root mean square error (RMSE) were determined [3, 4].

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

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{n}(M_{pre,i} - M_{exp,i})\right]^2 \quad (3)$$

where $M_{exp,i}$ is experimental moisture ratio of chickpea at measured i (%), $M_{pre,i}$ is predicted moisture ratio model at measured i (%), N, is number of data and n, is number of constant coefficient of model. Averages of regression index of each sample at different temperature were calculated and reported. Based on maximum value of coefficient of determination and minimum value of chi-square and root mean square error, the best model was chosen.

RESULTS AND DISCUSSION

Values of initial moisture content of chickpeas were 9.85, 10.25 and 10.27% dry basis for Desi, small Kabuli and large Kabuli respectively. According to the R^2, x^2 and *RMSE* corresponding models, which described moisture change during soaking, are listed (Table 2, 3 and 4).

Table 1. Regression models used in modeling of water absorption.

Model	**Equations**
Nyton	$MR=exp(-kt)$
Page	$MR=exp(-kt^n)$
Modified Page	$MR=exp[-(kt)^n]$
Henderson and Pabis	$MR=aexp(-kt)$
Modified Henderson and Pabis	$MR=aexp(-kt)+bexp(-gt)+cexp(-ht)$
Logarithmic	$MR=aexp(-kt)+c$
Binomial	$MR=aexp(-k_0t)+bexp(-k_1t)$
Modified Binomial	$MR=aexp(-kt)+bexp(-gt)+c$
Binomial exponential	$MR=aexp(-kt)+exp(-mt)$
Wang and Sang	$MR=1+at+bt^2$
Diffusion	$MR=aexp(-kt)+(1-a)exp(-kbt)$
Midili and others	$MR=aexp(-kt^n)+bt$
Werma and others	$MR=aexp(-kt)+(1-a)exp(-gt)$
Weibull	$MR=exp(-(t/\beta)^\alpha)$

Table 2. Average statistical index of fitted models during soaking at different water temperatures for Desi variety.

Model	R^2	x^2	RMSE
Nyton	0.976467	0.000473633	0.037667
Page	0.9923	0.000262647	0.026333
Modified Page	0.9923	0.000262647	0.026333
Henderson and Pabis	0.995067	0.00021133	0.022015
Modified Henderson and Pabis	0.995933	0.000179366	0.022306
Logarithmic	0.996267	0.000158907	0.019965
Binomial	0.9964	0.000152123	0.020148
Modified Binomial	0.996267	0.000163437	0.021042
Binomial exponential	0.996367	0.00015384	0.01977
Wang and Sang	0.976467	0.009045	0.095733
Diffusion	0.994	0.00029269	0.025419
Midili and others	0.9964	0.00015985	0.019642
Werma and others	0.977667	0.0004277	0.03727
Weibull	0.9923	0.000262747	0.026333

Table 3. Average statistical index of fitted models during soaking at different water temperatures for Chico variety.

Model	R^2	x^2	RMSE
Nyton	0.952733	0.001032953	0.049733
Page	0.992733	0.00012448	0.0191
Modified Page	0.9808	0.00020838	0.025323
Henderson and Pabis	0.990133	0.000402183	0.023419
Modified Henderson and Pabis	0.989667	0.000138632	0.022057
Logarithmic	0.994667	0.00011791	0.017703
Binomial	0.995933	0.00008803	0.015663
Modified Binomial	0.996033	0.000087357	0.015699
Binomial exponential	0.948967	0.00106954	0.054257
Wang and Sang	0.962467	0.009045	0.095733
Diffusion	0.987767	0.0002025	0.025563
Midili and others	0.994867	0.000094933	0.0172
Werma and others	0.987767	0.0002025	0.025563
Weibull	0.992733	0.00012448	0.0191

Table 4. Average statistical index of fitted models during soaking at different water temperatures for Kabuli variety.

Model	R^2	x^2	RMSE
Nyton	0.886033	0.001593567	0.06964
Page	0.984933	0.000205167	0.02547
Modified Page	0.984933	0.000205167	0.02547
Henderson and Pabis	0.9918	0.000343417	0.020677
Modified Henderson and Pabis	0.992333	0.000128868	0.021443
Logarithmic	0.992167	0.000136847	0.020473
Binomial	0.9942	0.000085859	0.01681
Modified Binomial	0.9943	0.000084999	0.017107
Binomial exponential	0.945267	0.001289874	0.056707
Wang and Sang	0.964533	0.011443	0.0769
Diffusion	0.993833	9.34367E-05	0.017197
Midili and others	0.9939	0.000105219	0.0182
Werma and others	0.993833	9.34367E-05	0.017197
Weibull	0.984933	0.0002052	0.02547

According to result, Binomial model is the most appropriate for each of the three varieties in each experimental temperature to predict moisture ratio changes by the passing time in soaking. The coefficients of Binomial model for each variety at different temperatures in this test are shown in Table 5. The moisture ratio versus time was plotted for each variety, by using Binomial model (Fig. 1, 2 and 3).

Table 5. The coefficient of Binomial model for each chickpea variety.

Variety	Temperature (°C)	a	b	$K_0(h^{-1})$	$K_1(h^{-1})$
Desi					
	5	0.754	0.000036	0.2126	0.2564
	25	0.1164	0.9525	0.0750	0.4223
	45	0.4878	0.5686	0.5897	0.5971
Chico					
	5	0.541	0.1762	1.602	0.2088
	25	0.3098	0.5331	0.1803	0.8882
	45	0.0890	0.7493	0.1738	1.19
Kabuli					
	5	0.754	0.5621	4.408	0.214
	25	0.2093	0.7002	4.343	0.3483
	45	0.7194	0.1459	0.6527	5.353

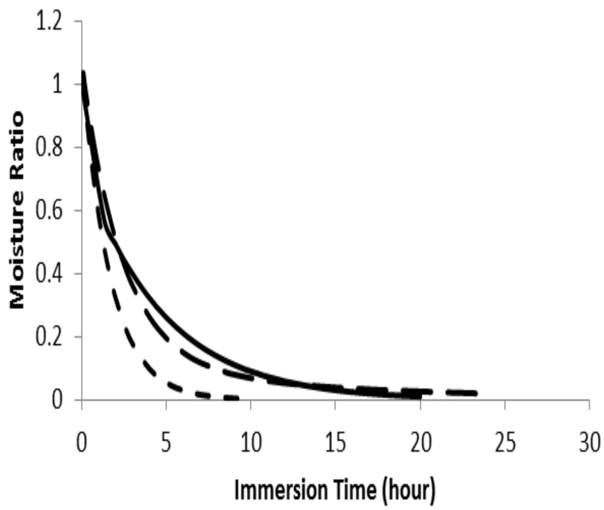

Fig. 1. Moisture Ratio characteristics of Desi, during immersion, 5°——, 25°— — , 45°---,

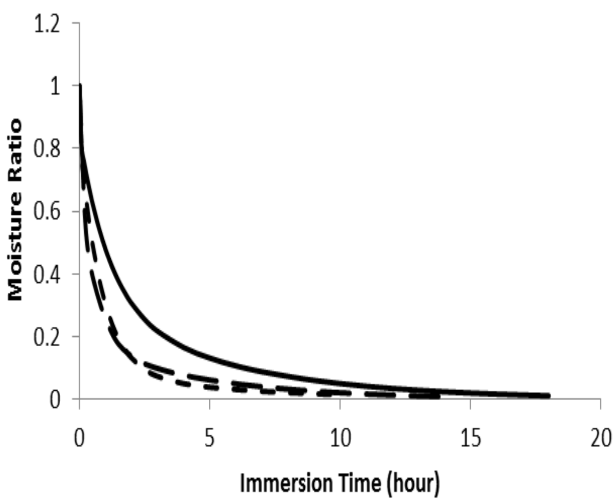

Fig. 2. Moisture Ratio characteristics of Chico, during immersion, 5°—— , 25°— — , 45°---,

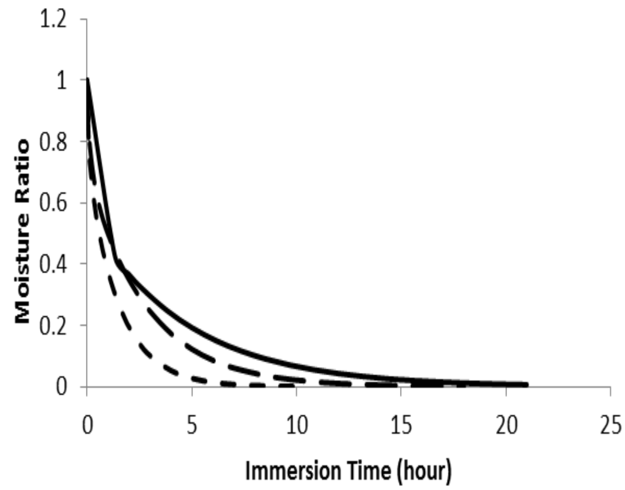

Fig. 3. Moisture Ratio characteristics of Kabuli, during immersion, 5°—— , 25°— — , 45°---,

CONCLUSIONS

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

All recommended models by researchers were fitted to data appropriately. The Binomial model was proper for predicting moisture content of different types of chickpea during soaking.

The corresponding plotted curves for each variety of chickpeas indicated that moisture ratio decreasing with increased temperature.

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