Advance Journal of Food Science and Technology 13(2): 68-71, 2017
DOI:10.19026/ajfst.13.3767
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: April 2, 2016 Accepted: June 18, 2016 Published: February 25, 2017

Research Article

Effect of Temperature on Rehydration of Freeze-Dried Dumpling and the Peleg Rehydration Model

Xuewei Cui, Wanren Chen, Hua Li, Xiang Gui, Yinghua Qiao and Xingli Jiao
School of Chemical and Energy Engineering, Zhengzhou University, Zhengzhou, Henan, 450001, China

Abstract: In order to study the effect of temperature on rehydration of freeze-dried dumpling, the rehydration kinetic of freeze-dried dumpling was investigated at water temperature of 308K, 343K and 368K. Peleg model is used to describe the rehydration process. Result shows that: rehydration rate increased with time during initial phase and decreased in the final phase until equilibrium, Peleg model shows good agreement with experimental data and the correlation coefficients are above 0.99.

Keywords: Dumplings, peleg model, rehydration, vacuum freeze drying

INTRODUCTION

Dumplings are one of the most widely loved traditional foods in China. With the improvement of people's living standard and the acceleration of fast-paced life, the instant dumplings have attracted more attention from people. The freeze-drying technology was able to ensure original protein, vitamins and other nutrients and can inhibit the harmful effects of bacteria (Deng and Gu, 2004; Zhao *et al*., 1995). Therefore, it becomes the most advanced food drying technology. But it needs rehydration when people eat freeze-dried dumplings, so it has important significance to study the rehydration regularities and properties of freeze-dried dumplings for people's daily life and the industrialization of freeze-dried dumplings.

Rehydration process essentially belongs to the mass transfer process and conforms to the Fick's second law. While this law is more complex and difficult to calculate, it also needs a lot of assumption, so it's hard to apply to practical system. While due to Peleg equation's simplicity and flexibility in the estimation of two parameters, it is extensively applied in food industry (Corzo *et al*., 2012; Turhan *et al*., 2002; Yu *et al*., 2009; Xu *et al*., 2011), therefore, in this study, Peleg equation was used to describe the rehydration of freeze-dried dumplings.

The objective of this work is to study the effect of water temperature on rehydration process of freeze-dried dumplings by Peleg model.

MATERIALS AND METHODS

Experimental materials and Equipment: fresh pork, Chinese chives, eggs, wheat flour, salt and cooking oil were purchased in a local supermarket. LGJ-12S vacuum freeze-dried machine (Beijing Huaxing Technology Development Co., Ltd. Songyuan), JY-electronic balance (Mettler-Toledo Group), H.H.S-electric constant temperature water bath (Shanghai Medical Instruments Factory).

Experimental method: Take about 10 g dumplings into 300 mL distilled water with the constant temperature water bath at a certain temperature, the temperature is 308 K, 343 K and 368 K. In the rehydration process, every 20 sec, remove the water on the surface of dumplings by filter paper, when the deviation of mass for two times is less than 0.01 g, water content reached a balance and the rehydration process is finished.

Peleg equation: The expression of Peleg equation is as follow (Peleg, 1988):

$$M_t = M_0 + \frac{t}{k_1 + k_2 t} \tag{1}$$

where M_0 is the initial moisture content (g), M_t is the moisture content at time t (g H_2O/g dry material); k_1(s % $^{-1}$) and k_2(% $^{-1}$) are the Peleg's first and second constants. k_1 is a kinetic rate constant, k_2 is a characteristic constant.

The rate of absorption (R) can be obtained from the first derivative of the Peleg equation, as the formula (2) shows:

$$R = \frac{dM}{dt} = \frac{k_1}{(k_1 + k_2 t)^2} \tag{2}$$

Corresponding Author: Hua Li, School of Chemical and Energy Engineering, Zhengzhou University, No.100 Science Road, Zhengzhou, Henan 450001, China, Fax: 0086-371-63886154

When t take 0, formula (2) is converted to (3), from (3) known, k_1 is related to initial absorption rate (R_0):

$$R_0 = \frac{dM}{dt}\Big|t_0 = \frac{1}{k_1} \tag{3}$$

From formula (1) known, when t = 0, then M_t=M_0, that is to sayM_0 is the initial moisture content, when $t \to \infty$, formula (4) can be gained. M_e is equilibrium moisture content, formula (4) gives the relation between equilibrium moisture content (M_e) and k_2:

$$M_e = \lim_{t\to\infty} M^t = M_0 + \frac{1}{k_2} \tag{4}$$

Statistical analysis: Fit quality of the Peleg model was evaluated by Root Mean Square Deviation (RMSD), sum of square error (SSE) and Relative Average Deviation (RAD), which are defined as (Sopade *et al*., 1992):

$$RMSD = \frac{1}{n}\sqrt{\sum_{i=1}^{n}(M_{ei} - M_{ci})^2} \tag{5}$$

$$SSE = \frac{1}{n}\sum_{i=1}^{n}(M_{ei} - M_{ci})^2 \tag{6}$$

$$RAD = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{M_{ei} - M_{ci}}{M_{ei}}\right| \tag{7}$$

RESULTS AND DISCUSSION

Therehydration data at different rehydration temperatures for dumplings: The change of moisture content of dumplings during rehydration process at different rehydration temperatures shows in Fig. 1. It can be seen from Fig. 1, at the same temperature, moisture content increased rapidly with time during initial phase and increased slowly in the final phase until equilibrium, Similar behavior was observed by other authors who experimented different food materials such as green pea, banana, carrot, pumpkin, onion, mushroom, corn, potato, tomato, pepper and amaranth grains (Krokida and Marinos-Kouris, 2003). At the initial phase of rehydration, dumplings have less moisture content and large concentration difference so that it has rapid rehydration rate from external environment. With the increase of rehydration time, moisture content of dumplings is increasing, moisture concentration difference is decreased, which cause slow rehydration rate in the final phase, which accordances with the Fick's second law. Moisture diffusion rate is also affected by temperature, water molecules move faster at higher temperature (Yan *et al*., 2013). At the same time, the higher the temperature is, the faster the diffusion of the water into the material.

The rehydration kinetic and Peleg equation: The experimental data was correlated with Eq. (1). The estimated parameters and statistical values of RMSD, SSE and RAD for freeze-dried dumplings at different temperatures using non-linear regression analysis are shown in Table 1 and 2.

As we all know, k_1 is related to mass transfer rate, the smaller k_1 is, the higher water uptake rate is, which is in accordance with the fact that rehydration rate at higher temperature is higher too. The eq. 1 is properly transformed and the linear equation with $t/(M_t\text{-}M_0)$ as the dependent variable can be obtained by using t as the independent variable, through linear regression analysis, therefore slope k_2 and constant k_1 can be

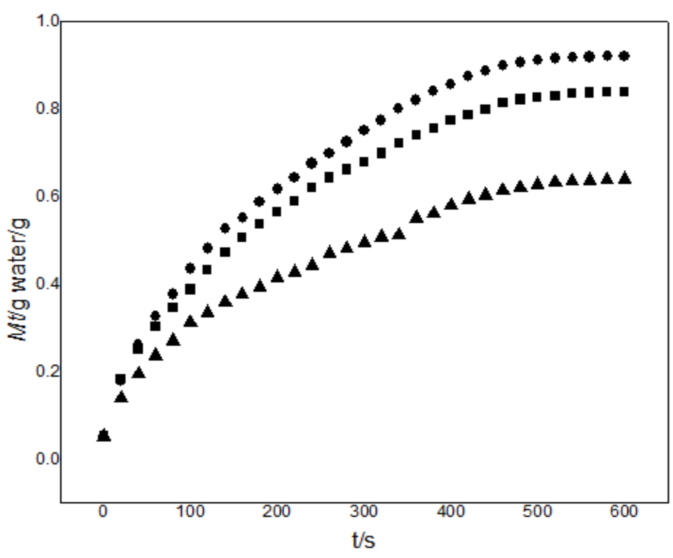

Fig. 1: Moisture content for rehydration of dumplings at different temperatures ▲, 308K, ■ 343K, ●368K

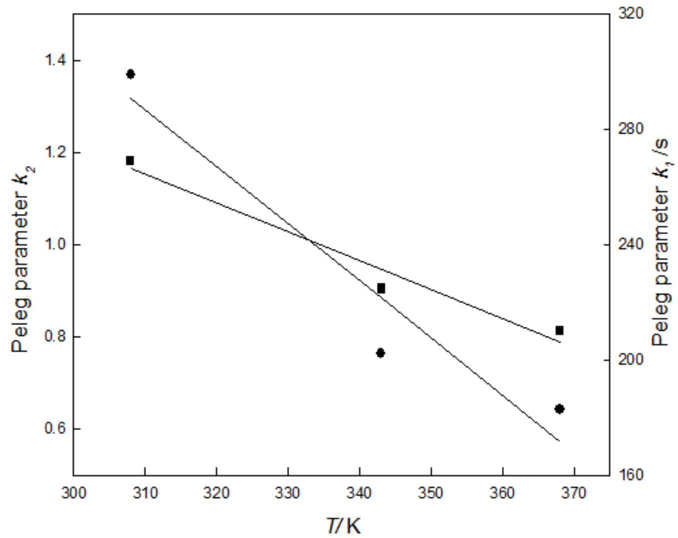

Fig. 2: Peleg constants k_1, k_2 at different rehydration temperatures, ● *k*1,■ *k*2

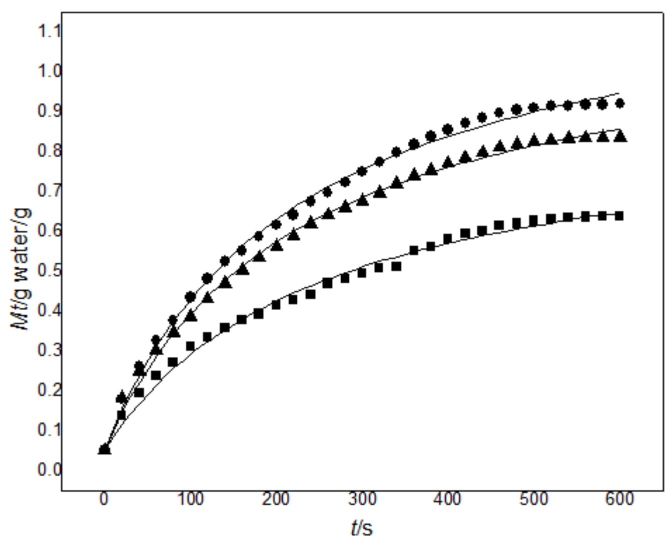

Fig. 3: Experimental and predicted moisture content for rehydration of dumplings at different temperatures, ■308K,▲ 343K, ● 368K, — predicted data

Table 1: Parameters of Peleg model for freeze-dried dumplings at different temperatures

Temperature/K	k_1/s	k_2	R^2	X_e/g water/g
308	298.989	1.182	0.992	0.846
343	202.302	0.905	0.996	1.105
368	182.865	0.813	0.997	1.230

Table 2: The values of RMSD, SSE and RAD for freeze-dried dumplings at different temperatures

Temperature/K	RMSD (%)	SSE (%)	RAD (%)
308	0.260	0. 021	3.481
343	0. 230	0. 017	2.342
368	0. 253	0. 020	2.171

gotten. k_2 is related with the character of the stuff. It can be seen from Table 1, k_1 and k_2 both decreased with the increase of temperatures, which was also found by authors with regard to the rehydration of other products (Moreira *et al*., 2008)., therefore two equations are applied to illustrate the correlations, shown in Eq. (8), (9) and Fig. 2:

$$k_1 = -1.98852T+903.48466 \quad (8)$$

$$k_2 = -0.00626T+3.0941 \quad (9)$$

The relationship between experimental and predicted moisture content by Peleg model for rehydration of dumplings at different temperatures is showed as the following Fig. 3. It can be seen from Table 1, the correlation coefficient (R^2>0.99) indicate that the model proposed by Peleg is adequate to describe rehydration kinetics of dumplings.

CONCLUSION

The effect of temperature on rehydration of freeze-dried dumpling is investigated; rehydration of food is greatly influenced by temperature. At the initial phase of rehydration, dumplings have less moisture content and large concentration difference from external environment so that it has rapid rehydration rate, with the increase of rehydration time, moisture content is increasing, moisture concentration difference is decreased, which cause rehydration rate reduced in the final phase. The parameters of Peleg's model k_1 and k_2 both decreased with the increase of temperatures, meaning rehydration rate and water holding capacity at equilibrium increased with the increase of temperatures. Peleg equation has a good agreement with the rehydration experimental data and can be successfully applied to describe the rehydration kinetics of food.

REFERENCES

Corzo, O., N. Bracho and J. Rodriguez, 2012. Comparison of Peleg and Azuara *et al*. models in the modeling mass transfer during pile salting of goat sheets. LWT-Food Sci. Technol., 46(2): 448-452.

Deng, K.S. and L.Z. Gu, 2004. The principle and application of freeze drying process. Hebei Chem. Ind., 56(1): 24-25.

Krokida, M.K. and D. Marinos-Kouris, 2003. Rehydration kinetics of dehydrated products. J. Food Eng., 57(1): 1-7.

Moreira, R., F. Chenlo, L. Chaguri and C. Fernandes, 2008. Water absorption, texture and color kinetics of air-dried chestnuts during rehydration. J. Food Eng., 86(4): 584-594.

Peleg, M., 1988. An empirical model for the description of moisture sorption curves. Food Sci., 53(4): 1216-1219.

Sopade, P.A., E.S. Ajisegiri and M.H. Badau, 1992. The use of Peleg's equation to model water absorption in some cereal grains during soaking. J. Food Eng., 15(4): 269-283.

Turhan, M., S. Sayar and S. Gunasekaran, 2002. Application of Peleg model to study water absorption in chickpea during soaking. J. Food Eng., 53(2): 153-159.

Xu, J., H. Zhang and X.N. Guo, 2011. The study of absorption dynamics of brown rice and germinated brown rice. Food Sci. Technol., 32(7): 150-153.

Yan, Y.Q., B.S. Li and Z. Ruan, 2013. Application of Peleg equation in evaluation of water absorption in fried and hot air dry noodle during soaking. Mod. Food Sci. Technol., 29(1): 107-111.

Yu, S.F., Y. Ma and H.L. Zhang, 2009. The study of water absorption and dynamics of indica rice, polished round-grained and Thai fragrant rice. Food Sci. Technol., 30(6): 86-90.

Zhao, H.G., Y.Q. Xu and D. Lin, 1995. Freeze drying of food and its economic benefits. Packing Food Mach., 13(2): 34-40.