Foam-mat drying of shrimp: characterization and drying kinetics of foam

Mehran Azizpour, Mohebbat Mohebbi*, Mohammad Hossein Haddad Khodaparast, Mehdi Varidi

(*Department of Food Science and Technology, Ferdowsi University of Mashhad, Mashhad, Iran*)

Abstract: The effects of water: shrimp ratio and xanthan gum (XG) concentration on characteristics of shrimp foam were investigated. Foams were prepared from shrimp puree by adding several xanthan gum concentrations (0.1, 0.2, 0.3% w/w), water: shrimp ratios (2:1, 3.5:1, 5:1 w/w) and whipped for five minutes. Incorporation of 0.2% w/w XG with 3.5:1 w/w water: shrimp ratio was selected because of having better characteristics of produced foams and then dried at 50, 60 and 70°C. Results showed that stability and density of foam increased with increasing xanthan gum concentration. However, increasing water : shrimp ratio caused to decrease in stability and density of foam. As the temperature increased from 50 to 70°C, the drying time decreased to 55 minutes. Only the falling rate period could be observed during the drying process. The average values of effective diffusivities of dried samples at mentioned temperature range were estimated to be between 3.24–6.49×10^{-9} m^2 s^{-1}. The Arrhenius equation with the activation energy value of 32.16 kJ mol^{-1} described the influence of temperature on the diffusion coefficient. Seven thin-layer drying models were fitted to the experimental data. Among all the drying models, the Midilli–Kucuk model was found to give better prediction than the others.

Keywords: activation energy, effective diffusivity, foam-mat drying, foam characteristics, modeling, Shrimp

Citation: Azizpour, M., M. Mohebb, M. H. H. Khodaparast, and M. Varidi. 2013. Foam-mat drying of shrimp: characterization and drying kinetics of foam. Agric Eng Int: CIGR Journal, 15(3): 159−165.

1 Introduction

Shrimp is a rich source of amino acids, peptides, protein and mineral compounds which may be recovered for utilization as ingredients in various food applications (Simpson et al., 1998).

Foam is a high volume fraction of gas in liquid (Narsimhan, 1991). Foam-mat drying is an effective method of food preservation which is carried out by conversion of liquid or semi-liquid foods into foams by incorporation of gasses, basically air into dispersion. Then, stable foam can be spread into a thin mat or sheet and dried by several conditions such as hot-air (the most common method) and freeze drying (Kadam et al., 2010; Muthukumaran et al., 2008; Thuwapanichayanan et al., 2008). The advantages of the foam-mat drying process are rapid drying rate at lower temperature, retention of nutritional and organoleptic quality, higher reconstitution properties of powder, being suitable for heat sensitive and viscous cost effective compared with the non-foamed material dried (Kadam et al., 2010). Foaming ability and foam stability are two main characteristics of the foams. Foaming ability or foam expansion can be measured by its expansion ratio or density. Foam stability is defined as the rate and/or amount of drainage of liquid from the foam (Bag et al., 2011). In foam-mat drying method, adequate amount of stabilizer must be added during foam production. The stable foam structure is desirable for rapid drying and ease of removing the dried material from the tray. Over the years, foam-mat drying was tried for drying of tomato

Received date: 2012-11-25 **Accepted date:** 2013-05-29

*** Corresponding author: Mohebbat Mohebbi,** Email: mohebbatm@gmail.com, m-mohebbi@um.ac.ir.

juice (Kadam et al. 2011), mango (Rajkumar et al., 2007), soymilk (Akintoye and Oguntunde, 1991), star fruit (Karim and Wai, 1999), cowpea (Falade et al., 2003), banana (Thuwapanichayanan et al., 2008), and yogurt (Krasaekoopt and Bhatia, 2012).

Different empirical models may be used to describe the drying process and help its optimization, and assist the effective design of dryers (Kiranoudis et al., 1992). The developed models have been used to estimate drying time of several products and to generalize drying curves (Midilli et al., 2002).

The aim of this research was studying of: (1) effects of water : shrimp ratio and xanthan gum concentration on stability and density of foam; (2) effect of drying temperature on the drying characteristics of foam; (3) select suitable drying models for describing the drying process, calculate the effective moisture diffusivity and activation energy of foam during drying.

2 Materials and method

2.1 Preparation of the shrimp puree and foam

Shrimps (*Penaeus* species.) were purchased from local market in Mashhad, Khorasan Rzavi province, Iran and were deshelled, cleaned and then frozen. Before running the test, the shrimps were thawed at 4°C for 24 h, then were washed and boiled in 2% (w/v) salt solution (NaCl solution) for 3 min to deactivate or reduce the number of microorganisms to a safe level and inactivate enzymes (Posomboon, 1998; Niamnuy et al., 2007). After cooling, samples were crushed by the kitchen blender (Tefal, 210 W) to change into a uniform mixture. Xanthan gum (XG) (made by Sigma Chemical Company, USA) used as a stabilizer and thickener. For preparation of 0.1% solution of gum, 1 g XG powder was dissolved in 100 mL distilled water and stirred with a magnetic stirrer up to complete hydration. The samples were kept at refrigerator temperature (4°C) for 18 h.

In 100 mL beakers, the definite amount of XG solutions, shrimp and distilled water were added. Then it was whipped with a kitchen mixer (model no. SM88, Sonny) with maximum speed (1,500 r min^{-1}) for 5 min. The foamed mixture samples were removed from the foaming device and analyzed for FD and DV.

2.2 Foaming properties

2.2.1 Determination of foam stability

Measuring the rate of draining liquid from foam is a method of foam stability determination (Kampf et al., 2003). Drainage volume was determined using a method described by Sauter and Montoure (1972), with slight modification. Fifty grams of foam were poured into a Buchner filter (80 mm diameter) and placed on a 50 mL graduated cylinder. The volume per ml of liquid separated after 30 min intervals was recorded.

2.2.2 Determination of foam density

The density of prepared foam was measured by weighing 50 mL of the foam in a 50 mL graduated cylinder (Bag et al., 2011). Foam density was calculated using the following Equation (1):

$$Foam\ Density = \frac{Weight\ of\ foam\ (\mathrm{g})}{Volume\ of\ foam\ (\mathrm{cm^3})} \qquad (1)$$

2.3 Statistical analysis

The randomized block and the 3×3 factorial design with two replications were adopted in this part. Statistical analysis of the data was carried out with MINITAB Release 16.0 (Minitab Inc). Duncan's test was used to establish the multiple comparisons of mean values (p<0.05).

2.4 Drying experiment

The foam with composition 3.5:1 of water: shrimp ratio and 0.2% xanthan gum was selected for drying treatment. Shrimp foam was put in aluminum trays with a foam thickness of 4.0 mm. The drying experiment was performed at three drying temperatures of 50, 60 and 70°C in a batch cabinet drier with a constant air velocity of 1.5 m s^{-1} (Soroush Medical Company). Moisture loss from the samples was determined by weighing the sample tray outside the drying chamber at regular intervals of time using a balance digital (±0.01 g).

2.4.1 Mathematical modeling of drying curves

The drying curves were fitted with seven different thin-layer drying models (Table 1). In these models, the moisture ratio (MR) was simplified to M/M_0 instead of the $(M-M_e)/(M_0-M_e)$ as the value of M_e is relatively small compared to M or M_0 (Doymaz, 2004), where M is the moisture content at any time, M_0 is the initial moisture content and M_e is the equilibrium moisture content.

Table 1 Empirical thin layer-drying models applied to the drying curves

Model no.	Model name	Model equation	References
1	Newton	'R = exp(−*kt*)	Lewis (1921)
2	Page	'R = exp(−*kt*^{n})	Page (1949)
3	Henderson and Pabis	'R = *a*exp(−*kt*)	Henderson and Pabis (1961)
4	Two term	'R = *a*exp(−*bt*)+*c*exp(−*dt*)	Sharaf-Eldeen, Blaisdell, and Hamdy (1980)
5	Logarithmic	'R = *a*exp(−*kt*)+*c*	Chandra and Singh (1995)
6	Diffusion approach	'R = *a*exp(−*kt*)+(1−*a*)exp(−*kbt*)	Kassem (1998)
7	Midilli–Kucuk	'R = *a*exp(−*kt*^{n})+*bt*	Midilli et al. (2002)

Correlation coefficient (R^2), reduced chi-square (χ^2) and root mean square error (*RMSE*) were used as the primary criterion to evaluate the goodness of fit of the models (Akpinar, 2006; Ertekin and Yaldiz, 2004; Ozdemir and Devres, 1999). The highest values of R^2, lowest values of χ^2 and *RMSE* were chosen for goodness of fit. These parameters can be calculated using Equations (2) and (3) as below:

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

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{\exp,i} - MR_{per,i})^2}{N-n} \quad (3)$$

where, $MR_{exp,i}$ is the *i*th experimental moisture ratio; $MR_{pre,i}$ is the *i*th predicted moisture ratio; N is the number of observations; n is the number of constants in the drying model.

2.4.2 Calculation of effective diffusivity and activation energy

The effective moisture diffusivity of the foam is estimated using Fick's diffusion equation. The solution of this equation developed by Crank (1975) and the form of Equation (4) can be used for particles with slab geometry, assuming uniform initial moisture distribution:

$$MR = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\exp\left[-\frac{(2n+1)^2\pi^2 D_{eff}t}{4L^2}\right] \quad (4)$$

where, D_{eff} is the effective diffusivity coefficient (m^2 s^{-1}) and L is the thickness of the slab (m). For long drying time, Equation (5) can be further simplified to only the first term of series (Tutuncu and Labuza, 1996).

$$LnMR = Ln\frac{8}{\pi^2} - \frac{\pi^2 D_{eff}t}{4L^2} \quad (5)$$

The slope (k_o) is determined by plotting Ln(*MR*) versus time (t) according to Equation (5) the effective diffusivity determination (see Equation (6)).

$$k_0 = \frac{\pi^2 D_{eff}}{4L^2} \quad (6)$$

The dependence of the diffusion coefficient with the temperature can often be described by the Arrhenius-type relationship Equation (7) (Madamba et al., 1996; Sanjuan et al. 2003).

$$D_{eff} = D_0 \exp\left(-\frac{E_a}{RT}\right) \quad (7)$$

where, D_0 is the constant in Arrhenius equation (m^2 s^{-1}); E_a is the activation energy (kJ mol^{-1}); R is the universal gas constant (kJ mol^{-1} K^{-1}); and T is the absolute temperature (K).

3 Results and discussion

3.1 Foaming properties of shrimp

3.1.1 Foam stability

Film drainage is a process which the liquid around the bubbles migrates from the cell wall into the intersection of the bubbles. DeVries (1958) pointed out that foam stability is influenced by the thickness of the interface, foam size distribution, interface permeability and surface tension. Analysis of variance showed that water : shrimp ratio and xanthan concentration had significant effect on the drainage volume (at 5% level of significance). Table 2 illustrates the effects of water : shrimp ratio and concentration of xanthan on drainage volume. It can be seen that foam with higher ratios of water: shrimp exhibited greater drainage. This is due to the increase of dilution rate and decrease of solid content of the mixture. It has been reported by Falade et al (2003) that foam stability reduces by the decrease in the total solid content of the food material. However, increasing the xanthan concentration reduced the drainage of shrimp foams (increased the stability). Increasing the concentration of xanthan affects the increase in viscosity of continuous phase. In addition, xanthan aids the formation of strong film and stabilizes the interfacial film. In this field, DeVries (1958) and Prin (1988) reported that, foam is more stable at high viscosity and this would protect the interfacial wall from breaking easily. Similar results were reported for bael fruit pulp (Bag et al., 2011).

Table 2 Effects of water: shrimp ratio and concentration of xanthan on the characteristics of the shrimp foam

Water : shrimp ratio (w/w)	Concentration of xanthan/% (w/w)	Foam density /g cm^{-3}	Drainage volume /mL
2:1	0.1	0.52^{bcd}	1.5^{d}
	0.2	0.56^{ab}	0.0^{f}
	0.3	0.61^{a}	0.0^{f}
3.5:1	0.1	0.49^{cd}	4.5^{b}
	0.2	0.53^{bcd}	0.5^{e}
	0.3	0.55^{abc}	0.0^{f}
5:1	0.1	0.47^{d}	8.0^{a}
	0.2	0.50^{bcd}	2.0^{c}
	0.3	0.52^{bcd}	0.0^{f}

Note: * The same letters indicate there were no significant different at 95% confidential level.

3.1.2 Foam density

Decrease in the foam density indicates that more volume of air was trapped in the foam during whipping treatment. The effects of water: shrimp ratio and xanthan concentration on foam density are shown in Table 2. It can be seen more evidently that the foam density increased significantly with increasing XG concentration. This is because of increasing the thickness of mixture. According to Bikermans' (1973) findings, a high viscosity liquid phase would prevent the trapping of air during whipping or mechanical mixing operations. This observation is in marked contrast to the finding of Karim and Wai (1999) for star fruit puree. On the other hand, water : shrimp ratio had the adverse effect on the foam density. As the water : shrimp ratio increased, the foam density decreased significantly (p<0.05). That might be due to the fact that increasing the dilution during foaming cause in reduction of the viscosity of the shrimp mixture and hence foam density decreased.

3.2 Drying characteristics

The influences of drying temperature on the drying characteristics of shrimp foam-mats were studied. Curves of moisture ratio versus drying time for different drying air temperatures are illustrated in Figure 1. The moisture ratio of foam-mat reduced with the increasing of drying time. At higher temperature, due to the quick removal of moisture, the drying time was less. The required time for shrimp foam drying was obtained 135, 105 and 80 min at 50, 60 and 70°C of drying air temperature, respectively (from initial moisture content of 2335 ± 10% (dry basis) to the final moisture content of 7.25 ± 1% (dry basis)).

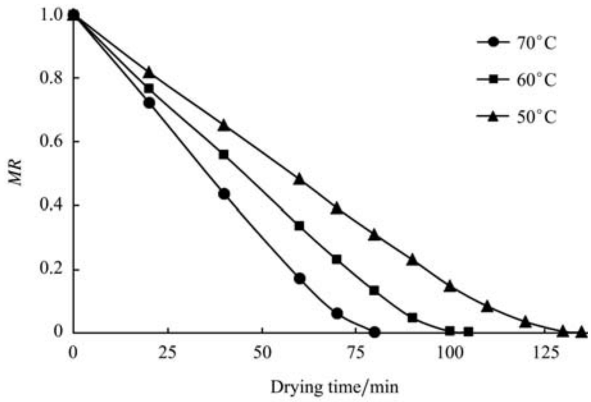

Figure 1 Curves of moisture ratio versus drying time

The drying rate curves are presented in Figure 2. A constant rate period was not observed at the three working temperatures, the drying process took place in a falling rate period. However, two falling rate periods can be observed. The first falling rate period occurred when moisture contents were larger than 351 ± 30% (dry basis). Thereafter, the drying rates decreased continuously with the decreasing moisture content and the second falling rate period occurred when moisture contents were less than 351 ± 30% (dry basis). Similar result has been reported for foam-mat drying of the banana (Thuwapanichayanan et al., 2007).

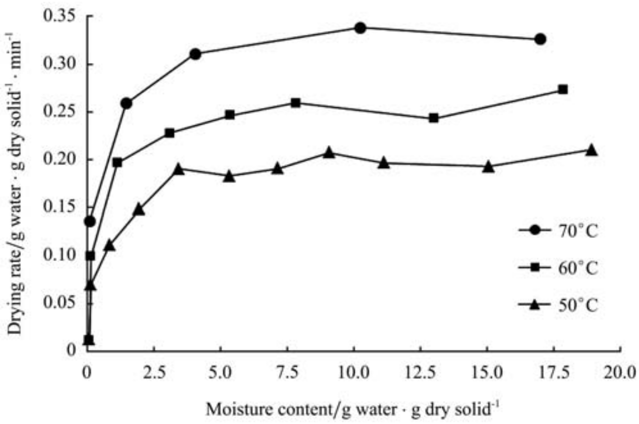

Figure 2 Drying rate curves of shrimp foam-mat

3.2.1 Mathematical modeling of drying curves

The summary of the statistical evaluation of each model is presented in Table 3. In all models, the R^2 value was in the range of 0.9269-0.9993, indicating that all models could suitably describe the drying behavior of shrimp foam. The statistical results of the different models show that Midilli–Kucuk model, as the best model gave the highest value of R^2 and the lowest value of χ^2 and *RMSE* in all drying temperatures. Curves of experimental and predicted moisture ratio for Midilli–Kucuk model are shown in Figure 3. It can be observed that there was a good agreement between the experimental and predicted values of moisture ratio.

Table 3 Statistical results obtained from different thin-layer drying models

Model no.	Temperature/°C	R^2	χ^2	*RMSE*	*k*	*n*	*a*	*b*	*c*	*d*
1	50	0.9269	0.09701	0.08992	0.01603	—	—	—	—	—
	60	0.9329	0.07778	0.09296	0.02121	—	—	—	—	—
	70	0.9373	0.05943	0.09953	0.02618	—	—	—	—	—
2	50	0.9879	0.01765	0.03836	0.00069	1.719	—	—	—	—
	60	0.9884	0.01539	0.04135	0.00112	1.709	—	—	—	—
	70	0.9931	0.00819	0.03695	0.0015	1.74	—	—	—	—
3	50	0.9364	0.09291	0.088	0.01717	—	1.089	—	—	—
	60	0.9397	0.0799	0.09422	0.02241	—	1.074	—	—	—
	70	0.9424	0.06826	0.1067	0.02739	—	1.058	—	—	—
4	50	0.9535	0.08493	0.08412	—	—	113.3	0.0271	-112.4	0.0273
	60	0.9743	0.04759	0.07272	—	—	26.64	0.0421	-25.57	0.0438
	70	0.9799	0.04773	0.08918	—	—	1.595	0.0378	-0.594	1.386
5	50	0.9963	0.00605	0.02246	0.00494	—	2.155	—	-1.139	—
	60	0.9963	0.00579	0.02538	0.00638	—	2.14	—	-1.127	—
	70	0.9976	0.00385	0.02535	0.00619	—	2.641	—	-1.63	—
6	50	0.9784	0.035	0.054	0.03363	—	-31.87	0.9676	—	—
	60	0.9336	0.10264	0.1068	0.02366	—	-0.934	0.9444	—	—
	70	0.9872	0.02016	0.05797	0.05783	—	-115.4	0.9898	—	—
*7	50	0.9984	0.003	0.01582	-0.0222	0.7851	0.9974	-0.0211	—	—
	60	0.9978	0.00403	0.02119	0.00335	1.348	0.994	-0.0017	—	—
	70	0.9993	0.00159	0.01631	0.00389	1.393	0.9983	-0.0022	—	—

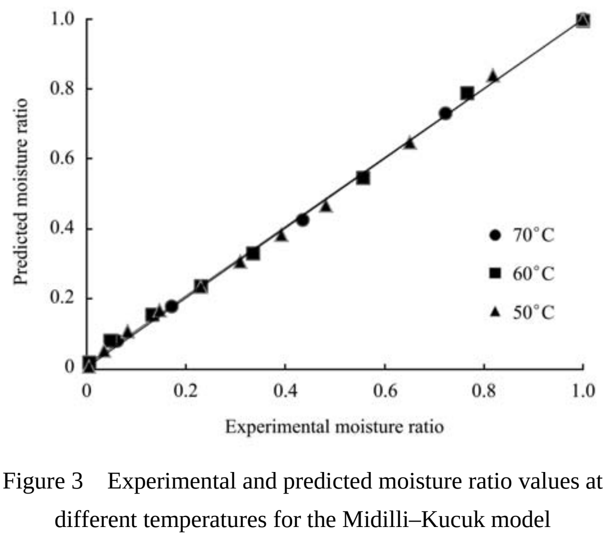

Figure 3 Experimental and predicted moisture ratio values at different temperatures for the Midilli–Kucuk model

3.2.2 Determination of effective diffusivities and activation energy

In the present study, two falling rate periods were obviously observed (Figure 2), each corresponding to an approximately constant slope from which the effective diffusion coefficients are calculated. The values of D_{eff} for the different working temperatures are presented in Table 4. The average values of effective diffusivity of dried samples varied in the range of 3.24–6.49×10^{-9} m^2 s^{-1} at 50-70°C. It can be seen that the D_{eff} increased with the increase of drying temperature. Additionally, these values are comparable to 0.729–3.51×10^{-8} and 0.288–1.71×10^{-8} m^2 s^{-1} for drying foamed and fresh mango pulp at 60°C, respectively (Rajkumar et al., 2007) and 2.026 – 3.039×10^{-8} m^2 s^{-1} for foam-mat drying of tomato juice in temperature range of 60–70°C (Kadam and Balasubramanian, 2011).

The natural logarithm of D_{eff} versus the reciprocal of absolute temperature was plotted in Figure 4 from the slope of the straight line described by the Arrhenius equation, the E_a and D_0 were obtained 32.16 kJ mol^{-1} and 5.53×10^{-4} m^2 s^{-1}, respectively. Similar results were obtained by Alakali et al. (2010) for osmo-foam-mat

Mango Pulp (E_a= 22.3 kJ mol^{-1}).

Table 4 The effective diffusion coefficients obtained for shrimp foam at different temperatures

Temperature /°C	Effective diffusivity /m^2 s^{-1}		
	First period	Second period	Average two period
50	1.9474×10^{-9}	1.2983×10^{-8}	6.4915×10^{-9}
60	1.9474×10^{-9}	1.4281×10^{-8}	5.8423×10^{-9}
70	3.2457×10^{-9}	2.0772×10^{-8}	3.2457×10^{-9}

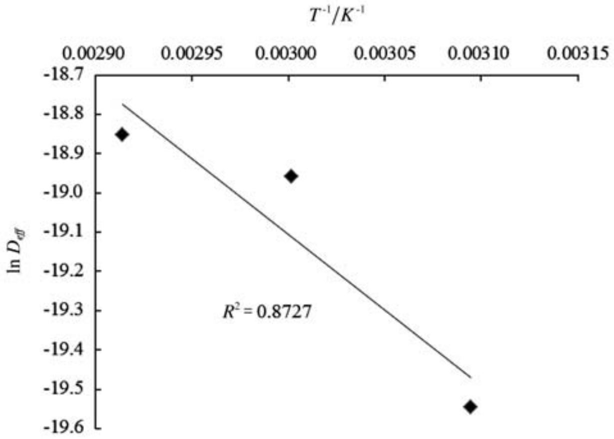

Figure 4 Influence of air temperature on the effective diffusivity

4 Conclusion

In this research, the effects of water : shrimp ratio and xanthan gum concentrations on characteristics of shrimp foam were investigated. As the concentration of xanthan in the foam increased, the foam stability and foam density increased significantly (p<0.05). However, increase in the water : shrimp ratio decreased foam density and foam stability. As the temperature rose from 50 to 70°C, drying time decreased to 55 min. In drying process a constant rate period, was not observed, the whole of drying rate curves of shrimp foam consists of two falling rate period. The average values of effective diffusivity was calculated for drying air temperature ranged from 3.24–6.49×10^{-9} m^2 s^{-1}. The dependence of the diffusion coefficient with the temperature indicated an Arrhenius relationship with the Ea 32.16 kJ mol^{-1}. The results also indicated that Midilli–Kucuk model are acceptable to express the drying behavior of shrimp foam at working temperature.

References

Akintoye, O. A., and O. A. Oguntunde. 1991. Preliminary investigation on the effect of foam stabilizers on the physical characteristics and reconstitution properties of foam-mat dried soymilk. *Journal of Drying Technology,* 9(1): 245-262.

Akpinar, E. K. 2006. Determination of suitable thin layer drying curve model for some vegetables and fruits. *Journal of Food Engineering*, 73, 75–84.

Alakali, J. S., E. I. Kucha, and C. C. Ariahu. 2010. Drying characteristics of osmo-foam-mat mango pulp**.** *Journal of Agriculture, Biotechnology & Ecology*, 3(1): 87-98.

Bag, S. K., P. P. Srivastav, and H. N. Mishra. 2011. Optimization of process parameters for foaming of bael (Aeglemarmelos L.) fruit pulp. *Food and Bioprocess Technology*, 4: 1450-1458.

Bikerman, J. J. 1973. *Foams*. New York, USA: Springer- Verlag.

Crank, J. 1975. *The mathematics of diffusion***.** 2nd ed. Oxford, UK: Clarendon Press**.**

DeVries, A. J. 1958. Foam stability: a fundamental investigation of the factors controlling the stability of foam. *Rubber Chemistry and Technology*, 31: 1142-1205.

Doymaz, I. 2004. Pretreatment effect on sun drying of mulberry fruits (Morus alba L.). *Journal of Food Engineering*, 65(2): 205-209.

Ertekin, C., and O. Yaldiz. 2004. Drying of eggplant and selection of a suitable thin layer drying model. *Journal of Food Engineering*, 63(3): 349-359.

Falade, K. O., K. I. Adeyanju, and P. I. Uzo-Peters. 2003. Foam-mat drying of cowpea (Vignaunguiculata) using glycerylmonostearate and egg albumin as foaming agents. *European Food Research Technology*, 217(6): 486-491.

Kadam, D. M., and S. Balasubramanuan. 2011. Foam mat drying of tomato juice. *Food Processing and Preservation*, 35(4): 488-495.

Kadam, D. M., R. T. Patil, and P. Kaushik. 2010. Foam mat drying of fruit and vegetable products. In *Handbook of Drying of Foods, Vegetables and Fruits*. eds. Jangam, S.V., C. L. Law, and A. S. Mujumdar, Vol. 1: 111-124. Published in Singapore,

Kampf, N., M. C. Gonzalez, M. G. Corradini, and M. Peleg. 2003. Effect of two gums on the development, rheological properties and stability of egg albumen foams. *Journal of Rheologica Acta*, 42: 259-68.

Karim, A. A. and C. C. Wai. 1999. Foam-mat drying of starfruit (Averrhoacarambola L.) puree, Stability and air drying characteristics. *Food Chemistry*, 64(3): 337-343.

Kiranoudis, C. T., Z. B. Maroulis, and D. Marinos-Kouris. 1992. Drying kinetics of onions and green pepper. *Drying Technology*, 10(4): 995-1011.

Krasaekoopt, W., and S. Bhatia. 2012. Production of yogurt powder using foam-mat drying. Faculty of Biotechnology, Assumption University Bangkok, Thailand, 15(3): 166-171.

Madamba, P. S., R. H. Driscoll, and K. A. Buckle. 1996. The thin layer drying characteristics of garlic slices. *Journal of Food Engineering*, 29(1): 75–97.

Midilli, A., H. Kucuk, and Z. Yapar. 2002. A new model for single layer drying. *Drying Technology*, 20(7): 1503-1513.

Muthukumaran, A., C. Ratti, and V. Raghavan. 2008. Foam-mat freeze drying of egg white and mathematical modeling Part I optimization of egg white foam stability. *Drying Technology*, 26(4): 508-512.

Narsimhan, G. 1991. A model for unsteady state drainage of a static foam. *Journal of Food Engineering,* 14(2): 139-165.

Niamnuy, C., S. Devahastin, and S. Soponronnarit. 2007. Quality changes of shrimp during boiling in salt solution. *Journal of Food Science,* 72(5): S289-S297.

Ozdemir, M., and Y. O. Devres. 1999. The thin layer drying characteristics of hazelnuts during roasting. *Journal of Food Engineering*, 42(4): 225-233.

Posomboon, W. 1998. Processing effect on quality of dried shrimp. M. Eng. Thesis, Asian Institute of Technology, Bangkok, Thailand.

Prin, A. 1988. Principles of foam stability. In *Handbook of Advances in Food Emulsions and Foam.* eds. E, Dickinson, and G. Stains,91-122. London: Elsevier Applied Science.

Rajkumar, P., R. Kailappan, R. Viswanathan, and G. S. V. Raghavan. 2007. Drying characteristics of foamed alphonso mango pulp in a continuous type foam mat dryer. *Journal of Food Engineering,* 79(4): 1452-1459.

Sanjuan, N., M. Lozano, P. Garcia-Pascal, and A. Mulet. 2003. Dehydration kinetics of red pepper (Capsicum annuum L var Jaranda). *Journal of the Science of Food and Agriculture*, 83(7): 697-701.

Sauter, E. A., and J. E. Montoure. 1972. The relationship of lysozyme content of egg white to volume and stability of foams. *Journal of Food Science*, 37(6): 918-920.

Simpson, B. K., G. Nayeri., V. Yaylayana, and I. N. A. Ashieb. 1998. Enzymatic hydrolysis of shrimp meat. *Food Chemistry*, 61(1-2): 131-138.

Thuwapanichayanan, R., P. Somkiat, and S. Somchart. 2008. Drying characteristics and quality of banana foam mat. *Journal of Food Engineering*, 86(4): 573-583.

Tutuncu, M. A., and T. P. Labuza. 1996. Effect of geometry on the effective moisture transfer diffusion coefficient. *Journal of Food Engineering*, 30(3-4): 433-447.