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Kinetics of *Cucurbita moschata* Puree Drying with Maltodextrin as Drying Aid

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ABSTRACT

The objective of this research was to investigate the influence of maltodextrin addition of pumpkin puree drying as well as studied the drying kinetics. Several thin layer drying kinetics model comprised of Page, Lewis, Henderson Pabis, Two Term, Weibull as well as diffusion model were used to study the behavior of pumpkin drying. The puree drying was conducted by added 15% of maltodextrin on pumpkin puree. The drying temperatures were varied of 60-70$°C$ The research result show that temperature influence the pumpkin puree drying in which added with maltodextrin as the drying aid. Pumpkin puree drying with addition of maltodextrin performed at temperature of 70$°C$ for 150 minutes is considered as the relatively suitable condition as it gives low moisture ratio of 0.07. The thin layer drying kinetics, Midili, give good fittest to the experimental data followed by Page and Weibull. The effective diffusivity is in range of $5.3x10^{-4} - 7.3x10^{-4}$ m/s with the obtained activation energy is 30.36 kJ/mol.

keywords: pumpkin, maltodextrin, drying, kinetics

1. INTRODUCTION

Longer shelf life, product variations and nutritious products are three main demands in nowadays food industry. Those demands lead to research and development in term of quality innovation in food engineering. Research and innovation on drying as one of preservation method are numerous and gaining interest since it intended to prolong food shelf life and provide varied products. Application of drying process also impacts on minimization of its transportation, storage, as well as packaging cost while preserving food nutrients from degradation is the biggest challenge of drying process [1], [2].

Drying aid such as maltodextrin is reported as a good physical barrier agent in which act in minimizing degradation reactions of bioactive molecules. The addition of maltodextrin was also reported retained food color of the dried product [2], reduce the stickiness of product and improve the flow characteristics of dried powder [3]. Maltodextrin is applied in production of tamarind powder [3], avocado pulp powder [2] and asparagus powder [4]. Those researches reported the beneficial of the application of maltodextrin in fruit and vegetables pulp drying thus the application of maltodextrin in other type of fruit and vegetables pulp drying is need to be studied.

Pumpkin (Cucurbita moschata), a seasonal crop indigenous to the central South America that belongs to the Cucurbitaceae family, is a potential material for food drying with the addition of maltodextrin as drying aid. Pumpkin pulp is dominated by moisture (75.8-91.33%) and has low content of proteins, fats, and carbohydrates [5], in which the protein and carbohydrate of pumpkin pulp are 0.2 - 2.7% and 3.1-13%, respectively [6]. Due to its low carbohydrate, fat and protein content, pumpkin is prized for its low-calorie (30 kcal/100 g) and easily digestible characteristic [5].

Pumpkin pulp is also sources of dietary fiber, essential amino acids, phenolic compounds, minerals, flavonoids, carotenoids and vitamins [5]–[7]. β-carotene, vitamin A, vitamin B2, α-tocopherol, vitamin C, vitamin E are predominat vitamins found in pumpin [6], [7]. While alanine, arginine, aspartic acid, glutamic acid, histidine, leucine, isoleucine, glycine, lysine, methionine, phenylalanine, serine, threonine, valine and tyrosine are essential amino acids on pumpkin [6]. The bioactive compounds found on pumpkin lead to its numerous pharmacological such as antidiabetic, antibacterial, antitumor, anti-inflammatory, immunomodulation, antifungal, antihypertensive and antioxidant activities [6], [8]. The health benefits and the chemical composition of pumpkin lead to its broad applications. Pumpkin powder is utilized as pigment in confectionery, bakery, pasta, and dairy products [5].

Considering the benefits of the utilization of maltodextrin in puree drying and of the potential health benefits of pumpkin, herewith, the kinetics of pumpkin puree drying with maltodextrin as dryimg aid is presented.

2. MATERIALS AND METHODS

2.1. Materials

Pumpkin was obtained from local market in Bandungan Kabupaten Semarang. The pumpkin fruits were washed, peeled and separated from the seeds. The fruits was then chopped and milled to form puree. Maltodextrin (Zhucheng Donxiao, ltd) with ash content of 0.6% was used in this research.

2.2. Drying process

50 grams of pumpkin puree was mixed with 15% of maltodextrin and laid on pan with 0.2 cm of thichkness. The pan was then inserted into tray drier. The drying process was performed at temperature of 60-70°C and the weight loss was recorded at interval of 10 minutes until constant weight of pumpkin puree was achieved. The moisture content of the fresh and dried samples was determined according to AOAC (1995). The drying rater was determined by the removal of moisture (dry basis) and represented in g/g^{-1}/min.

2.3. Data analysis

The moisture content data were used to calculate the moisture ratio (Eq 1).

$$MR = \frac{M_t}{M_0} \qquad [1$$

Where M_0 is the initial moisture content and M_t is the moisture content at certain time.

2.4. Thin layer drying kinetics

The experimental data was used to validate the thin layer drying kinetics models (Table 1) and the RSS was calculated according to Eq 2.

$$RSS = (MR_{pre,i} - MR_{eks,i})^2 \qquad [2$$

Table 1. Drying kinetics models

	Kinetics models	Reference
Lewis	$MR = \exp(-kt)$	
Page	$MR = \exp(-kt^n)$	
Henderson Pabis	$MR = a\exp(-kt)$	[1], [9]
Midili	$MR = a\exp(-kt) + bt$	
Two term	$MR = a\exp(-k_0 t) + b\exp(-k_1 t)$	
Weibull	$MR = \exp\left[-\frac{t^{\alpha}}{\beta}\right]$	

2.5. Effective Diffusivity

Galves et al. [9] mentioned that drying process of most food is take place during the falling rate period and the transport phenomena in that period can be described by Fick's second law of diffusion. Crank (1975) provide the solution for the diffusion equation for slab geometry with assumption that the moisture distribution in initial condition is uniform, the external resistance is negligible, the diffusivity is constant and the no shrinkage (Eq. 3).

$$MR = \frac{8}{\pi^2}\sum_{i=0}^{\infty}\frac{1}{(2i+1)^2} exp\left[\frac{-(2i+1)^2 D_{eff}\pi^2 t}{4L^2}\right] \qquad [3$$

3. RESULT AND DISCUSSION

Maltodextrin has been added as drying aid in drying process of several products such as in infrared drying of avocado pulp [2], freeze drying of Lactobacillus plantarum [10], and spray drying of soybean oil [11]. It was reported that together with sucrose and inulin, maltodextrin act as cryoprotectant, preservative and prebiotic in freeze drying process of L. plantarum, while maltodextrin provide a beneficial in avoiding the reduction of total polyphenols, total chlorophylls, and antioxidant activity as well as minimizing of lipid oxidation in avocado pulp [2], [10].

Considering the benefits of maltodextrin addition, in this research the influence of maltodextrin addition in pumpkin puree drying was evaluated in three different temperatures i.e. 60°C, 65°C and 70°C and the moisture ratio profiles were depicted on Figure 1a. It can be seen that the decrease of moisture ratio of pumpkin puree drying at temperature of 70°C with 15% of maltodextrin addition as drying aid is faster than the ones of 60 and 65°C. It is also supported by the drying rate profile as shown on Fig 1b. The phenomenon is logic since the higher the temperature applied; the more energy involves and transferred to the drying system. Similar result is reported from the convective drying of Cucurbita moschata conducted by Potosí-Calvache et al. [12] who dried squash at temperature of 45-65°C. They found that the higher the temperature applied the faster the dyring rate.

Figure 1a show that pumpkin puree drying process at temperature of 70°C for 150 minutes with moisture ratio obtained of 0.079 can be considered as the relatively best choice since prolong the drying time longer than 150 minutes the profile of the moisture content is asymptotic. The method applied here is also considered better than the drying applied on pumpkin puree without the addition of maltodextrin reported by Hartati et al. [13]. It was found prior this research that drying process at temperature of 70°C for 165 minutes gave pumpkin powder with moisture ratio of 0,04.

Furthermore, this drying process of pumpkin puree with addition of maltodextrin applied in this research can also be considered as a better method as compared to convective drying of pumpkin reported by Calvache et al. [12]. They reported that pumpkin flour moisture content of 6.34 ± 0.10% (db) was obtained from convective drying at temperature of 55°C, air velocity of 7 m.s-1, and drying time 390 min. Longer drying time of pumpkin puree was also reported by Caliskan and Dirim [14] who apply vacuum drying on pumpkin puree with puree depth of 3 mm, condenser temperature of - 48 ºC, plate temperature of 30ºC, pressure of 13.33 Pa and drying duration of 8 hours. The process condition applied gave pumpkin puree powder with moisture ratio of less than 0,1 [14].

The drying process of pumpkin puree with maltodextrin addition was investigated for its kinetics by applied Lewis, Page Henderson-Pabis, Midili dkk, Two term, and Weibull models (Figure 2). It can be seen that Midili, Page and Weibull model presented good fits with the experimental data of moisture content. Moreover, from the RSS values (Table 2), Midili shows the lowest one compared to the others models. The RSS values of Midili models are in range of 0.02-0.006. It is interesting that the other two models, Page and Weibull, gave similar value of their RSS for the three temperature applied. It was mentioned by Buzrul [15] that Page Model has same fit as Weibull Model with low parameter. In case of conventional drying process of pumpkin puree, in which no addition of maltodextrin, Midili was also gave the highet fit with the experimental data [13].

The validation of thin layer kinetics models i.e. Lewis, Henderson-Pabis and Two Term, the kinetics rate constants are increase with the increase of temperature applied while for Page and Midili, the kinetics rate constant are showing deviation on temperature of 65°C. The value of the kinetics constant for Midili are $1x10^{-6} - 1{,}7x10^{-5}$1/min. Those values are higher than the ones obtained from the pumpkin puree drying at the same temperature range but without the addition of maltodextrin which in range of $9x10^{-8} - 2{,}4x10^{-7}$1/min [13] 60-70°$C$. From the value of the kinetics rate constant, it can be conclude that the addition of matodextrin fasten the drying process of pumpkin puree. The kinetics rate constant found in this research were slightly lower than the one obtained from freeze drying of pumpkin reported by Caliskan and Dirim [14]. They used Henderson Pabis model and kinetics rate constant of $9{,}36x10^{-5}$ was reported [14].

Moreover, the effective diffusivity was also investigated in this research (Figure 3). The obtained effective diffusivities are $5.3x10^{-4} - 7.3x10^{-4}$ m/s. From the plot of $1/D_{eff}$ versus $1/T$ with the universal gas constant of 8.314 J/mol/K, the obtained activation energy is 30.36 kJ/mol. This activation energy value is higher than the activation energy of olive cake drying in which reported as low as 12.43 kJ/mol [9]. The activation energy found in this research was similar with the one obtained from convective drying of squash (Ea of 33.55 kJ/mol) at air velocity of 8 m/s [12].

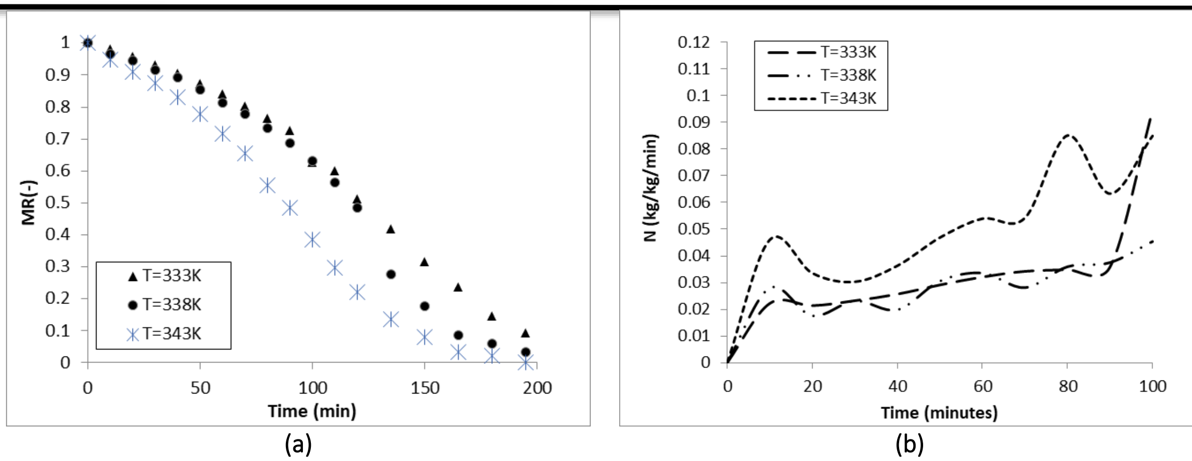

Figure 1. (a) Moisture Ratio (MR) and (b) drying rate of pumpkin puree drying at temperature of 60-70°C with 15% of maltodextrin addition as drying aid

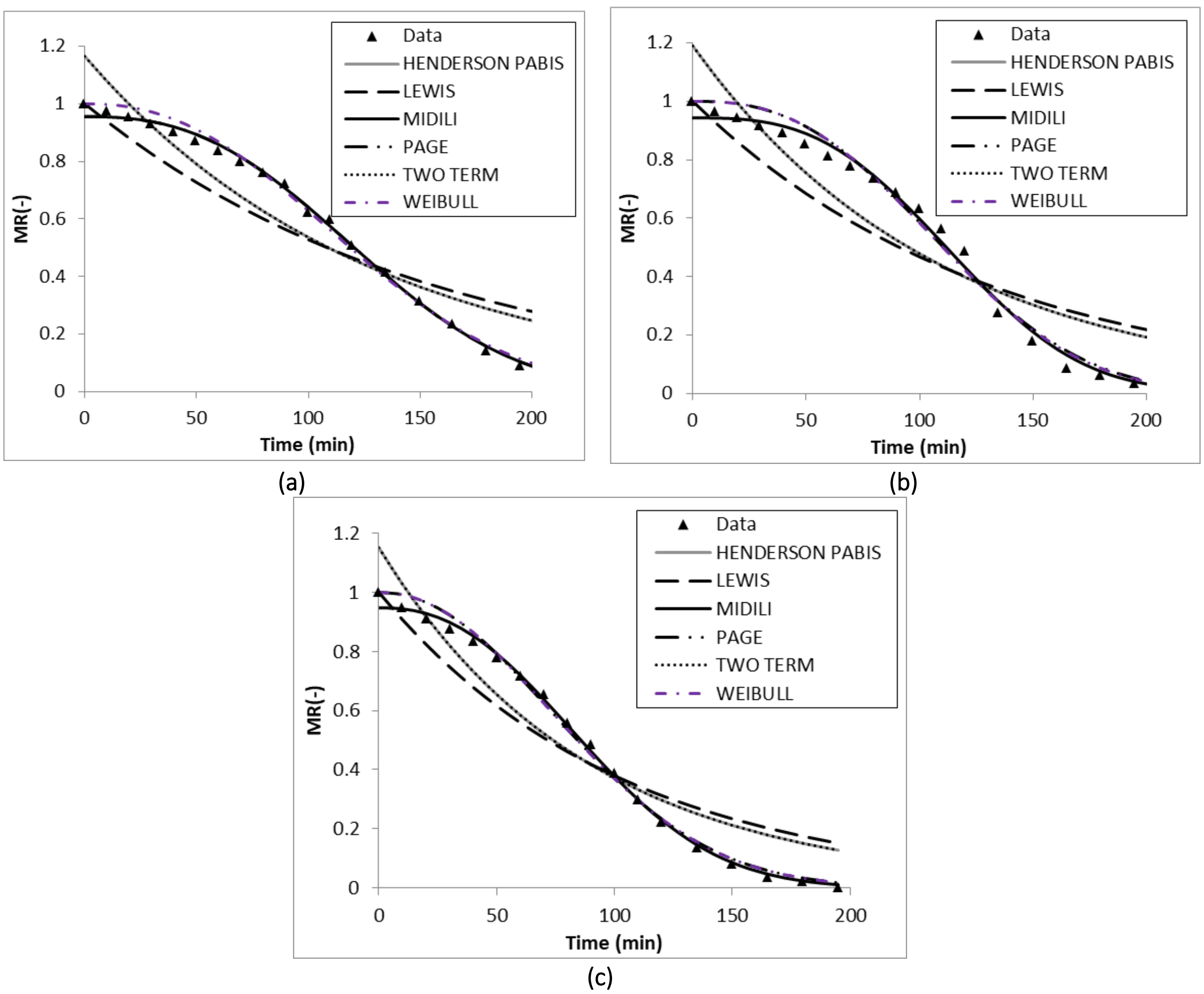

Figure 2. Comparison of obtained MR value obtained from drying at temperature of (a) 60°C, (b) 65°C and (c) 70°C; and its calculated ones obtained from Lewis, Page Henderson-Pabis, Midili dkk, Two term, and Weibull models.

Table 2. Constant of thin layer kinetics models

Drying Kinetics Models	T	Drying kinetics constant							RSS
		k1	N	a	b	k2	alpha	Beta	
Lewis	333K	0.006392							0.35899
	338K	0.007608							0.50666
	343K	0.009682							0.26017
Page	333K	0.000011	2.317						0.01416
	338K	0.000004	2.558						0.03579
	343K	0.000064	2.094						0.01347
Midili	333K	0.000003	2.573	0.955	0.0000010				**0.00688**
	338K	0.000001	2.936	0.943	0.0000245				**0.02009**
	343K	0.000017	2.368	0.948	0.0000010				**0.00567**
Henderson Pabis	333K	0.007760		1.165					0.26044
	338K	0.009113		1.189					0.38013
	343K	0.011275		1.150					0.19554
Two term	333K	0.007759		1.165	0.0000010	0.020			0.26044
	338K	0.009113		1.189	0.0000245	2.937			0.38014
	343K	0.011275		1.150	0.0000000	36.416			0.19554
Weibull	333K						2.313	139.214	0.01416
	338K						2.576	127.059	0.03569
	343K						2.096	100.368	0.01347

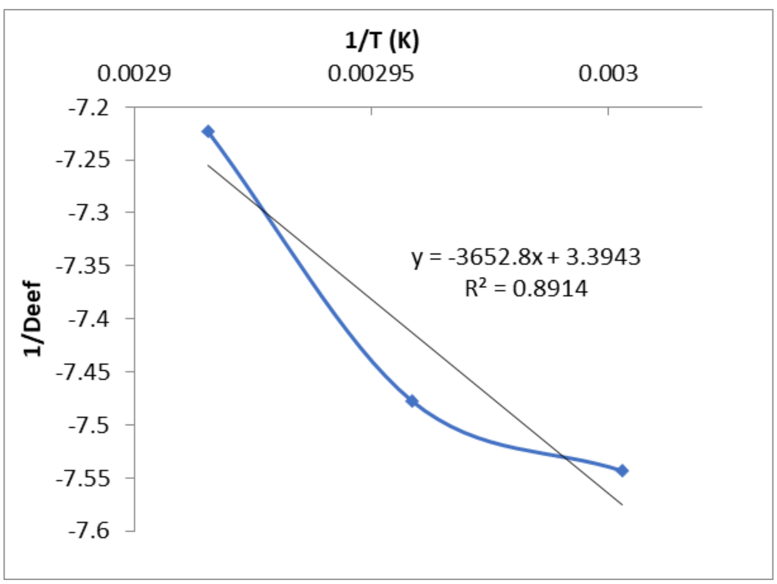

Figure 3. Correlation between effective moisture diffusivity and drying temperature

4. CONCLUSION

The influence of maltodextrin addition in pumpkin puree drying was investigated in this research. Several thin layer drying kinetics model and diffusion based drying kinetics was used to studied the behavior of pumpkin drying. It can be concluded that temperature influence the pumpkin puree drying in which added with maltodextrin as the drying aid. Pumpkin puree drying with addition of maltodextrin performed at temperature of 70$°C$ for 150 minutes is considered as the relatively suitable condition as it gives low moisture ratio of 0.07. The thin layer drying kinetics, Midili, give good fittest to the experimental data followed by Page and Weibull. The effective diffusivity is in range of $5.3x10^{-4} - 7.3x10^{-4}$ m/s with the obtained activation energy is 30.36 kJ/mol.

REFERENCES

[1] U. E. Inyang, I. O. Oboh, and B. R. Etuk, "Kinetic Models for Drying Techniques — Food Materials," pp. 27–48, 2018.

[2] T. Nguyen, Q. Nguyen, and T. Nguyen, "Effects of Infrared Drying Conditions and Maltodextrin Addition on Some Physicochemical Characteristics of Avocado (Persea americana) Pulp Powder," 2021.

[3] A. Ekpong, W. Phomkong, and E. Onsaarrd, "The effects of maltodextrin as a drying aid and drying temperature on production of tamarind powder and consumer acceptance of the powder," vol. 23, no. 1, pp. 300–308, 2016.

[4] J. W. Siccama _et al._, "The effect of partial replacement of maltodextrin with vegetable fibres in spray-dried white asparagus powder on its physical and aroma properties," _Food Chem._, vol. 356, no. March, p. 129567, 2021.

[5] B. Kulczynski and A. Gramza-Michałowska, "The Profile of Secondary Metabolites and Other Bioactive Compounds in Cucurbita pepo L. and Cucurbita moschata Pumpkin Cultivars," vol. 24, no. 2945, pp. 1–22, 2019.

[6] S. Sandhya and S. S. Sisodia, "Phytochemical and Pharmacological Aspects of Cucurbita moschata and Moringa oleifera UK Journal of Pharmaceutical and Biosciences Available at www.ukjpb.com Phytochemical and Pharmacological Aspects of Cucurbita moschata and Moringa oleifera," no. August, 2019.

[7] S. Enneb _et al._, "Phytochemical profiles and nutritional composition of squash (Cucurbita moschata D .) from Tunisia South African Journal of Botany Phytochemical pro fi les and nutritional composition of squash (Cucurbita moschata D .) from Tunisia," no. January, 2020.

[8] N. Y. Abu-thabit, A. Abu, A. S. Hakeem, A. Ul-hamid, Y. Umar, and A. Ahmad, "International Journal of Biological Macromolecules Isolation and characterization of microcrystalline cellulose from date seeds (Phoenix dactylifera L .)," _Int. J. Biol. Macromol._, vol. 155, pp. 730–739, 2020.

[9] A. Vega-gálvez, M. Miranda, L. Puente, L. Lopez, K. Rodriguez, and K. Di, "Bioresource Technology Effective moisture diffusivity determination and mathematical modelling of the drying curves of the olive-waste cake," vol. 101, pp. 7265–7270, 2010.

[10] S. O. Oluwatosin, S. L. Tai, and M. A. Fagan-endres, "Sucrose , maltodextrin and inulin efficacy as cryoprotectant , preservative and prebiotic – towards a freeze dried Lactobacillus plantarum topical probiotic," vol. 33, 2022.

[11] J. Zhu, X. Li, L. Liu, Y. Li, B. Qi, and L. Jiang, "Preparation of spray-dried soybean oil body microcapsules using maltodextrin : Effects of dextrose equivalence," _LWT_, vol. 154, p. 112874, 2022.

[12] D. C. Potosí-calvache, P. Vanegas-mahecha, and H. A. Martínez-correa, "Convective drying of squash (Cucurbita moschata): Influence of temperature and air velocity on effective moisture diffusivity , carotenoid content and total phenols" vol. 84, no. vitamin C, pp. 112–119, 2017.

[13] I. Hartati, S. E. Setiawati, and Suwardiyono, "Kinetika Pengeringan Lapis Tipis Puree Labu Kuning (Cucurbita moschata)," _J. Inov. Tek. Kim._, vol. 6, no. 2, 2021.

[14] G. Caliskan and S. N. Dirim, "Determination Of The Freeze Drying Kinetics Of Pumpkin

(Cucurbita Moschata) Puree (Cucurbita Moschata) Puree," July 2015, 2014.

[15] S. Buzrul, "Reassessment of Thin-Layer Drying Models for Foods :," *Processes*, vol. 10, no. 118, 2022.