Foam Mat Drying of Carrot Puree (Daucus Carota L): The effect of foaming agent and kinetics evaluation

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Abstract

Carrot is a type of orange vegetable that grows abundantly and susceptible to rot if there is no special treatment after harvest. One effort to extend the shelf life of carrots is to dry them using the foam mat drying method. The drying process is carried out by adding foaming agents in the form of egg white (15%, 20% 25%, 30%) and fillers in the form of maltodextrin (15%, 20% 25%, 30%). Drying is carried out at temperatures of 60°C, 65°C and 70°C. The purpose of this study was to determine the effect of foam mat drying process parameters and to examine its drying kinetics. The results showed that 70°C was the optimum temperature that could shorten the drying time. The optimum addition of maltodextrin concentration was 15%. The optimum addition of egg white concentration was 30%. Page's mathematical model equation that corresponds to the carrot drying process using the foam mat drying method with an SSE value of 0.009417-0.02442 and the highest β-carotene content at a temperature of 65°C of 1.635%.

Keywords: Carrots, foam mat drying, drying kinetics.

INTRODUCTION

Carrots (Daucus Carota L) are one of the abundant agricultural products in Indonesia and have quite high export commodity prospects. However, on the other hand, carrots have a weakness, namely that they are easily damaged after being harvested. Therefore, special treatment is needed to extend their shelf life. On the other hand, food products that people want today do not only consider nutritional elements, but must be practical, fast, and durable. Desrosier (1988) and Wirakartakusuma et al (1992) stated that ready-to-eat powdered food products are food products in powder form, crumbly texture, easily soluble in cold or hot water, easy to serve, easy to disperse and do not settle. One of the food ingredients that can be processed into instant powder is carrots (Daucus Carota L). To obtain carrot powder, a drying process is required first. The drying method can be done using several methods such as spray drying, freeze drying and foam mat drying. However, according to Karim & Wai (1999), the foam mat drying method is more suitable to be applied because this method has the advantage of being easy to apply and using additional materials that are easy to find and affordable. The foam mat drying technique has been applied to the drying of powdered milk by Khotimah (2006) who stated that the foam mat drying technique is a drying process by making foam from liquid materials added with foam stabilizer at a temperature of 70-75°C, then poured onto a baking sheet or container. Furthermore, it is dried with a tunnel dryer until the solution is dry and the next process is to crush the dry sheets.

Drying with the foam mat drying method can be done by adding foaming agents and binding agents. The foaming agent used is egg white, because it is affordable and easy to obtain. According to Wilde & D.C, (1996), the use of egg white at the appropriate concentration will increase the surface area and can also provide a porous structure to the material. This aims to increase the drying speed. In addition to foaming agents, the drying process with foam mat drying needs to be added with materials that have foam binding properties. One of the materials that can be used is maltodextrin. The characteristics of maltodextrin include high solubility, ability to form films, low browning properties, ability to inhibit crystallization, and strong binding power (Hui, 1992).

The drying process in food ingredients has different characteristics. According to Fitriyani (2016), the use of mathematical models aims to obtain data on drying kinetics parameters and predict the drying system. Drying kinetics in carrots can be studied using several mathematical models such as Lewis, Henderson Pabis, and Page.

Seeing that carrots are easily damaged, the advantages of the foam mat drying process, the advantages of egg white as a foaming agent, the advantages of maltodextrin as a binder, and the need for a study of drying kinetics, it is appropriate to conduct research on the foam mat drying of carrot puree (Daucus Carota L).

RESEARCH METHODS

Materials and equipment

The materials used in this study were carrots, egg whites and maltodextrin, ethanol. The tools used during the study were analytical scales, blenders, mixers, baking sheets, tray dryers and UV-Vis spectrophotometry.

Variables

The variables used in this study were the variation of maltodextrin and egg white. The drying process is carried out by adding foaming agents in the form of egg white (15%, 20% 25%, 30%) and fillers in the form of maltodextrin (15%, 20% 25%, 30%) which was varied by adding egg whites with a ratio of 15:15, 20:15, 25:15 and 30:15. All variables were carried out at temperatures of 60, 65 and 70°C by recording the weight loss carried out every 15 minute time interval.

Experimental Procedures

Preparation of materials

Carrots are washed until clean and then grated. Then 20 grams of grated carrots are poured into a baking sheet with a thickness of 0.2 cm and add a foaming agent in the form of egg white to the sample with a ratio that has been adjusted. Then stir until evenly distributed. After that, maltodextrin is added and stir until evenly distributed.

Drying process

The drying process in this study used a tray dryer. This tool is equipped with 5 trays in the drying room. Carrots that have been mixed with egg white and maltodextrin are placed on tray 3 which is located in the middle. This drying process is carried out at a temperature of 60-70°C by recording the decrease in sample weight at intervals of 15 minutes.

Analysis of β-carotene levels

Weigh 10 mg of the obtained β-carotene extract and dissolve it with ethanol in a 5 ml measuring flask. Then pipette 0.5 ml and make up the volume with ethanol in a 10 ml measuring flask. The solution was then measured by UV-Vis spectrophotometry at λmax 451 nm with ethanol as a blank (Anita, 2019).

RESULT AND DISCUSSION

Effect of temperature on carrot drying

Winarno (2022) stated that drying is a method of removing water content from a material by evaporating the material using heat energy. Research by Mrkic, et al (2006) obtained results that the drying rate experienced significant weight loss, according to this study. The drying rate in this study was calculated based on moisture ratio (MR) data. The MR of carrots during the drying process was calculated using the formula (Eq1):

$$MR=\frac{Mt\text{-}Me}{M0\text{-}Me} \qquad (1)$$

where, MR is the moisture ratio, Mt is the water content at a certain time, Me is the equilibrium water content and M0 for the initial water content (Ibrahim et al., 2009). The results of the data are depicted in a graph of the relationship between time and MR presented in Figure 1 with 3 different temperature variables, namely 60°C, 65°C, 70°C.

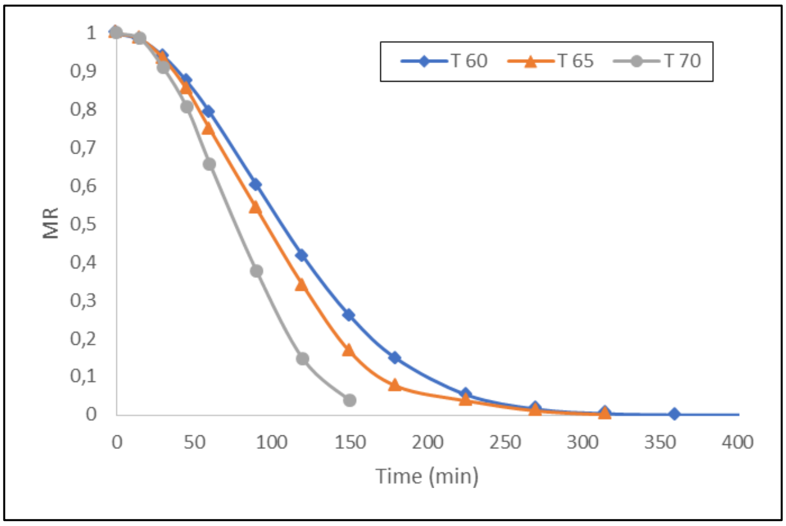


Figure 1. Moisture ratio graph of carrot samples at temperatures of 60, 65 and 70 °C with the addition of 30% maltodextrin and 15% egg white.

Figure 1 shows that faster moisture loss occurs at higher temperatures**.** As temperature increases from 60°C to 70°C, the moisture ratio decreases more rapidly. This suggests a direct correlation between temperature and drying rate, consistent with enhanced diffusion and evaporation mechanisms. Figure 1 also shows an initial steep decline**.** All curves exhibit a sharper drop in MR during the initial phase (up to 100 minutes), which indicates rapid surface moisture evaporation. This is most pronounced at 70°C, reinforcing the role of elevated temperature in accelerating drying kinetics. These results are in line with the research of Amiruddin (2013) which examines the production process of of carrot flour (Daucus Carota L) with variations of drying temperature. It was mentioned that the higher the drying temperature, the faster the decreasing of the water content of the carrots produced.

It can be seen also from Figure 1 the extended drying period. It shows that beyond 200 minutes, the MR curves begin to plateau, particularly at lower temperatures, indicating the transition to bound moisture removal. The approach toward equilibrium moisture content is slower at 60°C, suggesting that lower thermal energy limits moisture migration from deeper layers. Final moisture ratio trends was also depicted as the graph shows that the application of drying process at 70°C, reaches a lower final MR compared to 60°C and 65°C, implying more efficient moisture extraction under higher thermal conditions.

Effect of maltodextrin on drying rate

The amount of maltodextrin concentration as a filler in this drying method greatly affects the drying rate. The addition of maltodextrin to the sample can help maintain color. The graph depicting the effect of maltodextrin concentration with the relationship between moisture ratio and time is presented in Figure 2. The drying kinetics presented in the MR–time profile (Figure 2) highlight the impact of maltodextrin concentration on the moisture removal behavior during thermal processing. Several key observations and interpretations can be drawn including rapid initial decline in MR. It can be seen that all curves display a steep drop during the early drying phase, indicating efficient surface

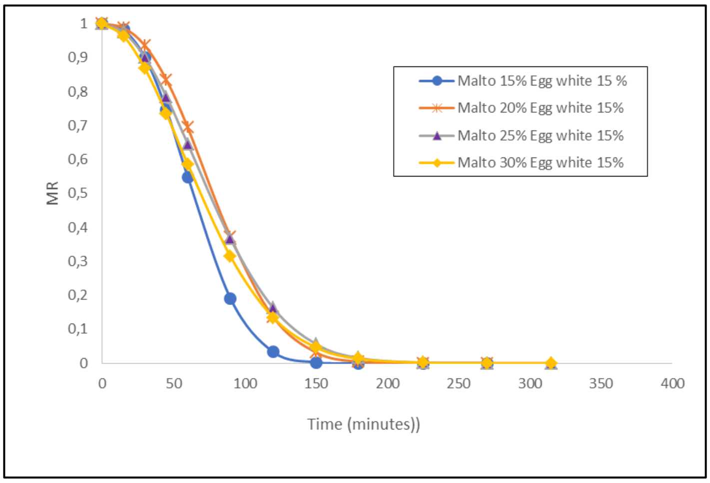


Figure 2. Moisture Ratio with the addition of 15%-30% maltodextrin and 15% egg white

moisture evaporation. 15% addition of maltodextrin performs fastest. The formulation with 15% maltodextrin shows the most pronounced reduction in MR, reaching lower values more quickly. This suggests that lower maltodextrin concentrations may reduce resistance to moisture diffusion, allowing faster drying.

In terms of role of maltodextrin, it was shown that the increasing of the maltodextrin addition give a significant impact on slow drying process. As maltodextrin concentration increases (from 15% to 30%), the curves become progressively less steep. This likely reflects a higher viscosity and denser matrix that inhibits moisture migration. Maltodextrin, as a bulking agent, may form a more cohesive structure at higher concentrations, impeding internal water mobility and delaying the drying process.

From the research results that show the lowest moisture ratio and the fastest drying time is the addition of 15% maltodextrin and 15% egg white. According to Figure 2, the higher the concentration of maltodextrin added to the sample, the longer the drying process will take. The results of this study are in line with the research of Yuliawaty & Susanto (2016), the higher the addition of maltodextrin, the more hydroxyl groups will be produced so that the hydroxyl groups will bind more water. This is because the water content in the sample will be higher and require a longer drying time.

Effect of egg white on drying rate

The addition of egg white in the foam mat drying method can affect the drying rate. The drying kinetics graph (Figure 3) shows the moisture ratio (MR) versus time for egg white formulations with fixed maltodextrin (15%) and varying egg white concentrations (20%, 25%, and 30%). It was shows that the formulation with 30% egg white exhibits the steepest MR decline, reaching near-zero moisture ratio by around 75 minutes. This suggests more efficient drying, potentially due to enhanced protein network formation that facilitates moisture release. Figure 3 also shows the gradual MR drop in 20% and 25% egg white**.** These samples take longer to reach low MR levels, approximately 150 minutes for 20% egg white, and 100 minutes for 25%. The slower kinetics may reflect lower solids content, which reduces structural integrity and hinders moisture migration.

Based on Figure 3, the short drying time is found in the addition of 30% egg white and 15% maltodextrin. The addition of egg white will produce porous materials so that it can increase the surface area and will make it easier for the drying air to come into direct contact with the material to be dried (Anindita, 2014). The more foam, the faster the drying time.

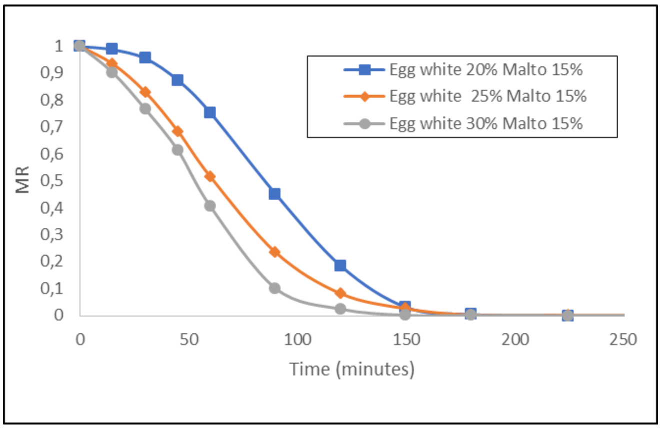
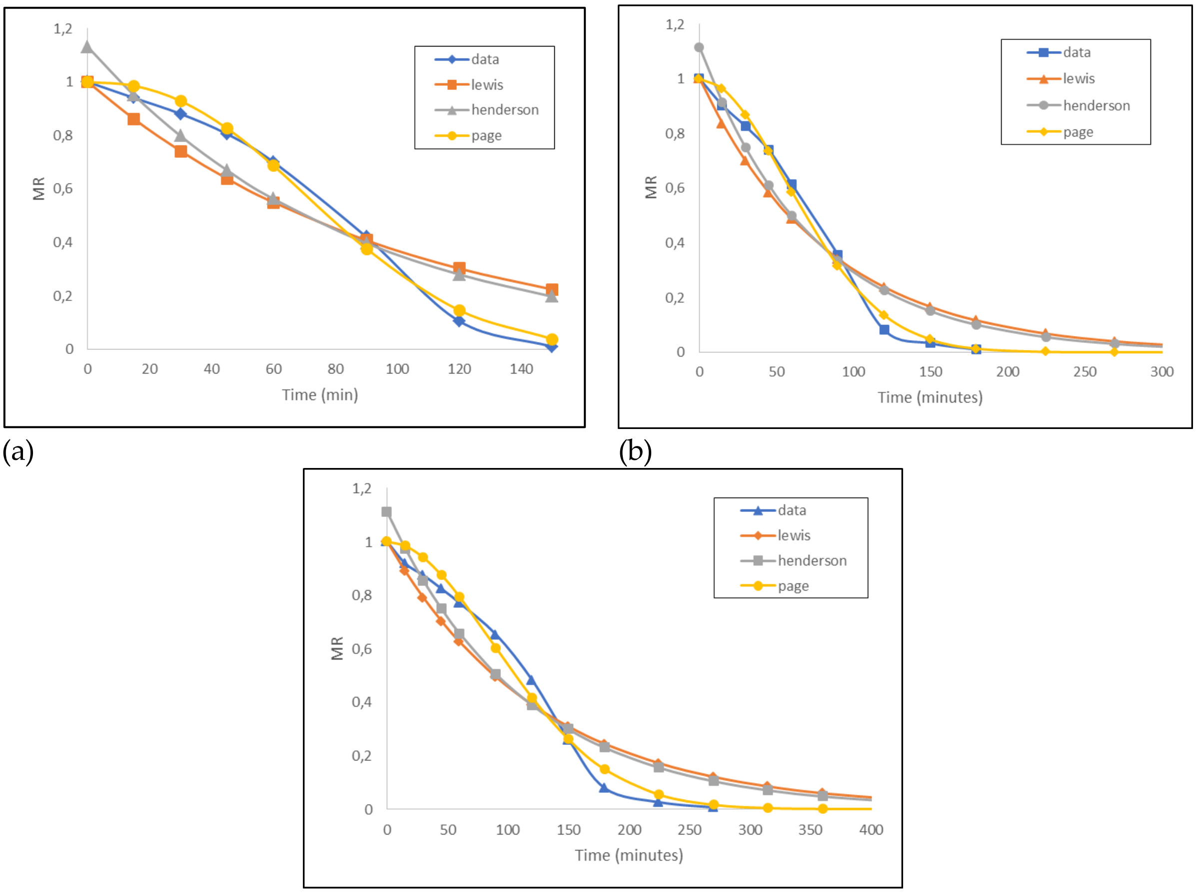


Figure 3. Moisture ratio with the addition of 20%-30% egg white and 15% maltodextrin

Mathematical model

Yadollahinia et al. (2008) stated that the mathematical model for this drying is determined based on experimental MR data that is connected to time into a graph and the mathematical equation is calculated to obtain the drying constants k, a and n. The values of k, a, and n resulting from the modeling are used to produce the MR model value. This study uses 3 mathematical equations, namely Lewis, Henderson Pabis and Page. The MR results of the calculations in this study are presented in Figures 4.



(c)

Figure 4. Comparison of the moisture ratio of the experimental results with the moisture ratio calculated based on the Lewis, Henderson Pabis and Page kinetic models for drying carrots with the addition of 30% egg white and 15% maltodextrin at a temperature of: (a) 60°C, (a) 65°C and (a) 70°C.

Based on Figure 4, it can be seen that the results of the mathematical model calculations that are in accordance with this study are the Page mathematical model, because the MR line of the Page model is close to the MR line of the data. This can also be seen in Table 1 which shows that the SSE value of the Page model is lower than other models, which is 0.009417-0.02442 for the carrot drying process at a temperature of 60-70°C. Identifying the appropriate and correct drying model can use the SSE (Sum of Squared Errors) indicator. The SSE value is the deviation between the model prediction value and the observation result value. The lower the SSE value, the higher the suitability of a model (Omolola et al, 2019)

Table 1. Values of carrot drying kinetic parameters based on the Lewis, Henderson Pabis and Page models.

Kinetics Model	Temperature	Parameter			SSE
		k	A	n	
Lewis	60	0.009979			0.160804
	65	0.011975			0.121379

	70	0.007847			0.153168
Henderson	60	0.011648	1.131191		0.127466
Pabis	65	0.013384	1.115		0.096225
	70	0.008775	1.110085		0.123348
	60	2.45E-05		2.354265	0.009417
Page	65	0.000215		1.909188	0.011055
	70	9.27E-05		1.913015	0.02442

Table 1 also shows that the constant value will be greater if the temperature in the drying process is higher. The constant value of drying kinetics based on the Page equation model is 2.45 × 10-5 – 9.27 × 10-5 for the carrot drying process at a temperature of 60-70°C.

β- CAROTENE LEVELS

The largest content in carrots is β-carotene. To determine the levels of β-carotene in the results of carrot foam mat drying, analysis using UV-Vis Spectrophotometry is needed. The results of the Analysis using UV-Vis Spectrophotometry are presented in Figure 5.

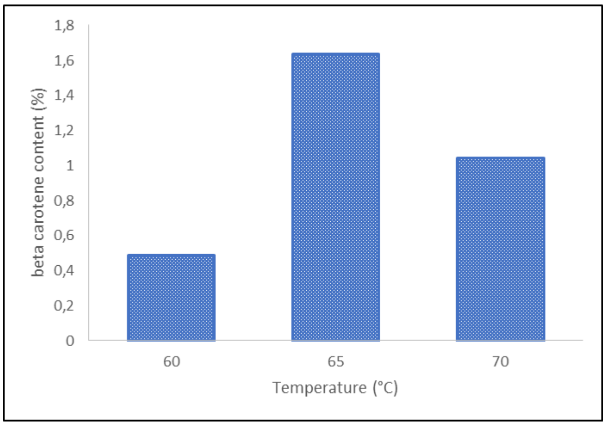


Figure 5. β-carotene levels in Foam Mat Drying Carrots with the addition of 15% egg white and 30% maltodextrin at temperatures of 60°C, 65°C, 70°C.

Based on Figure 5, it shows that the highest level of β-carotene in carrot powder with a composition of 15% maltodextrin and 30% egg white is at a temperature of 65°C, which is 1.635%. This is because at a temperature of 70°C there has been carotene degradation and at a temperature of 60°C the level of β-carotene is low due to the longer drying time so that the β-carotene content is damaged (Amiruddin, 2013). Meanwhile, in Anita's study (2019), the level of β-carotene in raw carrots was 34.94% and boiled carrots were 23.31%.

CONCLUSION

From the results of this study, it can be concluded that the higher the drying temperature, the lower the MR value and the shorter the drying time. The best treatment in the effect of adding maltodextrin on the drying rate is the addition of 15% maltodextrin and 15% egg white. The best treatment in the effect of adding egg white on the drying rate is the addition of 30% egg white and 15% maltodextrin. The mathematical equation that is suitable for this study is the page equation, because it has the lowest SSE value of 0.009417-0.02442. The highest β-carotene content is at a temperature of 65°C of 1.635%.

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