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Drying Time Estimation of Carrageenan-Egg White Mixture At Tray Dryer

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Abstract **-** The drying is the last step to find carrageenan product. Currently, the carrageenan drying still deals with too long drying time. This because, during the process carrageenan and water forms gel stucture in which hampers the water diffusion to the surface. Foaming agent introduction such as egg white can be considered to break the gel structure and make the drying process being smooth and fast. This paper discusses the effect of egg white as foaming agent on the drying time of carrageenan. In this study, the carrageenan was mixed with egg white to form foam that can break the gel and create the pore for improving the surface area. The carrageenan and egg white mixture was then dried at different air temperature and humidity. Results showed that the drying time was shortened with the presence of egg white as well as the increase of air temperature. For example, the drying time at air temperature 80^{o}C with 20% egg white was about 100 minutes shorter than that of without foam. In addition, the lowering air dehumidification affected the drying time positively.

***Keywords*—** carrageenan , drying time, diffusion, dehumidification

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Introduction

In food industry, carrageenan is widely used for stabilizing and texturing some food product: a chocolate, frozen desserts, ready-to-eat deserts, soy milk, and cottage cheese dressings (1, 2). Carrageenan was isolated from the seaweeds such as Euchema*cottonii* (3). The process consited of the extraction of seaweed by alkali followed by precipitation and filtration. The extract was then dried to get dry carrageenan (2).

Currently, the carrageenan drying has faced the difficulty especially for finding the dry product at short time. Normally, the drying time for carrageenan was about 2.5 hours at operational temperature above 80^{o}C (2). Tari and Pekcan (2008), reported that the drying time of carrageenan was about 5 hours at 50°C with shrinkage value ranging from 70-80% of their initial volume (4). The main problem in drying carrageenan is the formation of gel between polysaccharide and water which inhibits the diffusion of water to the surface.

Foam-mat drying under low or medium air temperature is a potential for improving drying performance (5, 6). The foam-mat drying is a process in which the transformation of products from liquid to stable foam follows air drying at relatively low temperatures to form a thin porous honey-comb sheet. Foam structure increases interfacial area of foamed materials; as a consequence it can accelerate transport of liquid water to the evaporation interface. The stable foam was produced by foaming agents such as soluble proteins. Protein can move through the aqueous phase and can be spontaneously adsorbed at the air–aqueous interface where the visco-elastic films are subsequently formed. The protein adsorption reduced surface tension, which improved the foam formation (7).

The foam-mat drying produces better quality, porous structure during water evaporation, and easily reconstituted product (8). Recently, the foam-mat drying has been widely used in drying process of vegetable extract, spirulina, and fruit juice commodities (5, 9, 10, 11). Besides that foamed materials had lower density, so that the mass load of the foam-mat dryer was also lower (12). Some research informed that foam structure played a major role in moisture movement during drying process and influenced product quality (10, 13). Foam mat drying method was suitable for heat sensitive material, sticky, viscous, and product with high content of sugar or protein (14, 15). The carrageenan is the product having heat sensitivity. Therefore, the foam mat drying method was recommended to produce carragenan powder. The previous research showed that application of foam in carrageenan improve moisture diffusivity as well as retaining product quality (16). This research discussed the effect of foaming agent and air temperature on drying time of carrageenan with foam.

Materials and Methods

Material and Drying Process

The process referred the procedures that was previously published (16). The carrageenan was extracted from the seaweed using alkali solution. The extract was mixed with egg white at composition 20% in the mixture. The mixture was preliminary dried to find 4.50 g water/g dry carrageenan (90% moisture wet basis). The wet carrageenan was then dried in the tray dryer until moisture content to be 0.10 g water/g dry carrageenan. In this process, the moisture content in carrageenan and air conditions were measured every 10 minutes. The moisture in carrageenan was measured by gravimetric method, and air conditions (ambient air, air entering and leaving the tray dryer) were measured by temperature and relative humidity sensors KW0600561, Krisbow®, Indonesia, (see Figure 1). The air flow entering the dryer was manually regulated. The air velocity was measured with an anemometer thermo-anemometer KW0600562, Krisbow ®, Indonesia. The experiments were conducted in various drying air temperatures (60^0, 80^0 and 100^0C) with air velocity entering dryer 3.5 m.s^{-1}. The procedure was repeated for drying with under dehumification.

Data Collection

The moisture in carrageenan was estimated by the equation 1, as follows:

$$X = \frac{M_w - M_d}{M_d} \quad (1)$$

Where, X is the mositure in carrageenan (g water/g dry carrageenan), while M_w and M_d are weight of wet and dry carrageenan (g).

The moisture in carrageenan versus time, was used to find moisture diffusivity (2). The equation of diffusion can be described by:

$$\ln\left(\frac{X_e - X}{X_e - X_0}\right) = \ln\left(\frac{8}{\pi^2}\right) - \left(\frac{\pi^2 Dt}{L^2}\right) \quad (2)$$

where X (g water/g dry carrageenan) is the average moisture content at time t, X_e is moisture content at equilibrium (g water/g dry carrageenan), X_0 is the initial moisture content (g water/g dry carrageenan), and L is the half thickness of the sheet.

The equilibrium moisture content for carrageenan can be calculated using the GAB equation (17):

$$X_e = \frac{BDKa_w}{(1 - Ka_w)(1 - Ka_w + BKa_w)} \quad (3)$$

The value of constants B (23.3199), D (0.1136), K (0.8544) were found in the GAB constants for carrageenan (17), a_w is assumed to the relative humidity (RH) (2).
Using experimental data, diffusivity can be calculated using relation in equation 1, 2, and 3. By finding the moisture diffusivity, the drying time for water evaporation in extrapolated and interpolated condition can be estimated.

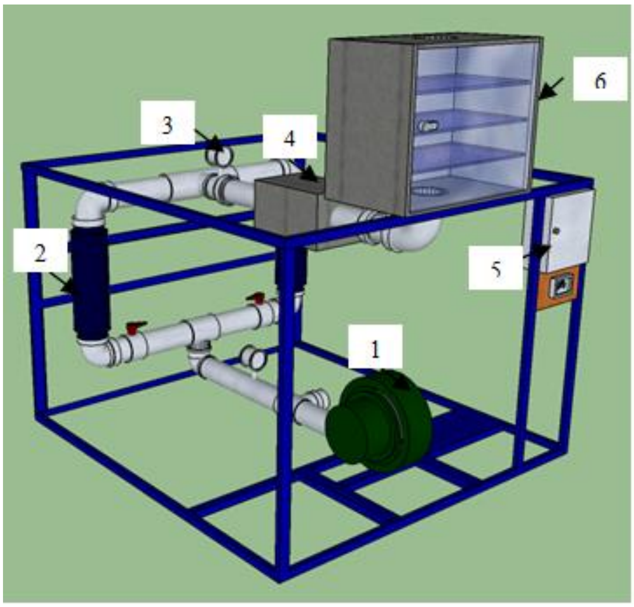

Figure 1. The schematic overview of *tray* dryer with air dehumidification by zeolite: 1: blower; 2: zeolite column; 3: Thermal Indicator and RH; 4: Heater; 5: Automatic thermo controller 6.Tray column.

Results and discussions

Effect of egg white as foaming agent

The effect of foam mat drying on drying time was presented at Figure 2 and 3. In line with previous research (16), the carrageenan drying with 20% egg white showed the shorter drying time (Figure 2). With equation 2, the time for carrageenan drying from 4.50 to 0.10 g water/g dry material was 100 minutes shorter than that of non-foam mat one. As comparison, Ratti and Kudra (2006) reported that foaming of liquid and semi-liquid materials has long been recognized as one of drying methods to reduce the drying time (5). Applying foam mat drying to the apple juice foam significantly reduced drying time from 500 to 200 minutes.

The physical structure of the material plays major role in the diffusion of moisture. As indicated in Figure 3 part b, the foam created the porous structure which can be well identified by TEM analysis (see also Figure 3 part a for carrageenan without egg white). The pores improved the surface area for drying as well as water evaporation (16).

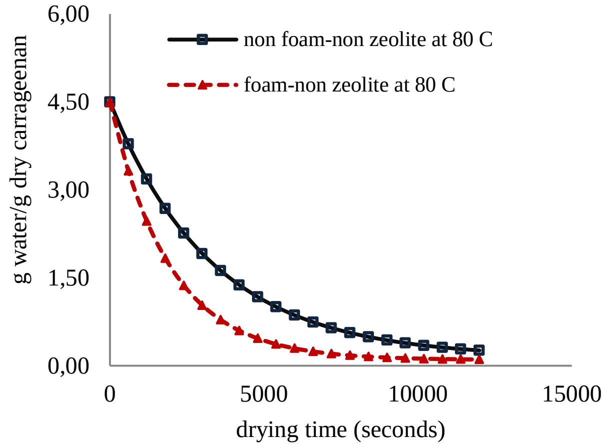

Figure 2. The moisture content versus time in the carrageenan drying at air temperature 80°C

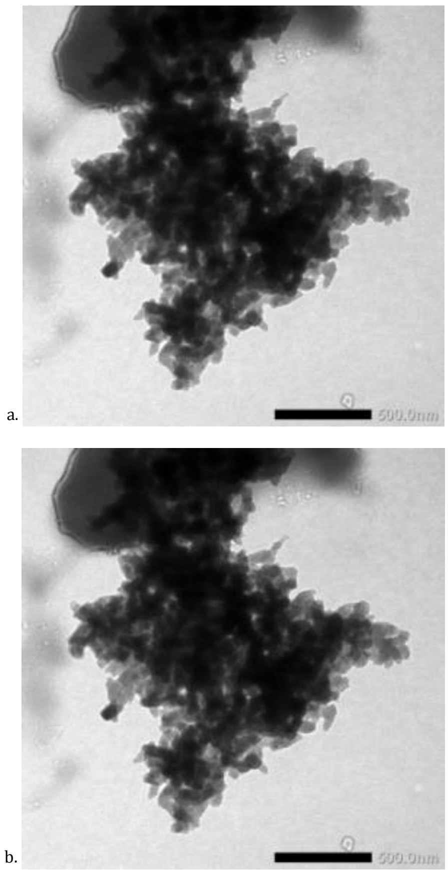

Figure 3. TEM image of carragenan powder without foam (a) and with foam (b) (Djaeni et al, 2013)

Effect of Drying Temperature

Figure 4 presented the moisture content in carrageenan versus time. The water evaporation increased with the increase of air temperature. Based on drying data in this research and applying equation 2 the diffusivity increases, the moisture diffusivity for foam drying increased from 3.8×10^{-8} to 2.0×10^{-7} $m^2.s^{-1}$ by increasing air temperature from 60^0 to 80^0C (16). This values are higher than that of the carrageenan drying without foam (2). With the higher diffusivity, the drying time became shorter.

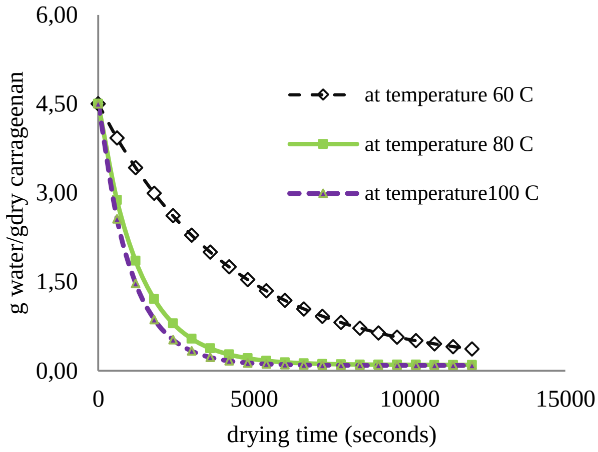

Figure 4. The moisture content versus time in the carrageenan drying at different temperature

Effect of Air dehumidification

Air dehumidification with adsorbent such as zeolite, can be an option to improve the driving force of drying. As presented in Figure 5, the air dehumidification affected water evaporation positively. The drying time for removing 98% of moisture content in carrageenan needed about 110 – 120 minutes. Using air dehumidification, it can be 20 - 25 minutes shorter (Figure 5). The result was still in line with the previous result (12).

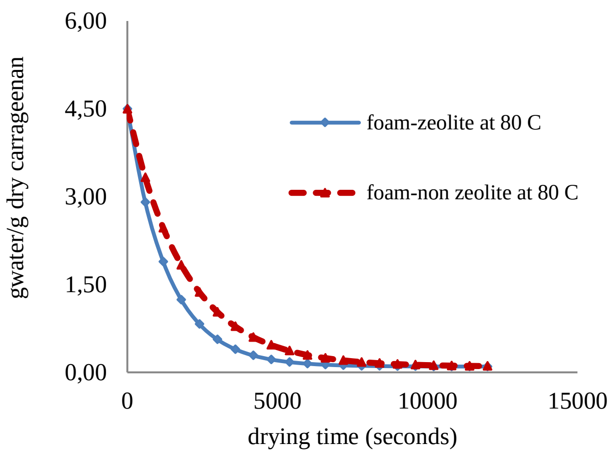

Figure 5. The moisture content versus time in the carrageenan drying with and without zeolite

Conclusion

The combination of foam mat drying method can improve carrageenan drying. The foam created the porous structure in which increased the surface area for drying process. As a result, drying time can be shortened.

With lower humidity, higher temperature, or combination of this parameters, the driving force of drying can be improved as indicated in shorter drying time. However, the operational temperature of carrageenan drying must be constrained at 80°C or below for avoiding quality degradation.

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