

## Research Article

### Enhancing The Food Product Drying with Air Dehumidified by Zeolite

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**Abstract:** The demand of powdered food products such as soups, sauces, dried yeasts and herbal medicine is increasing for consumer convenience. Mostly, these products have been produced with drying process either, direct sunlight, conventional, or modern dryer. The direct sunlight dryer depends on the daily weather both in the product quality and process continuity. Meanwhile, conventional dryer results high energy consumption as well as low product quality due to the introduction of hot air. In addition, modern dryer process can improve the product quality, but the energy efficiency was fair. This study discusses the design and application of adsorption dryer with zeolite for food product. As samples, the carrageenan isolated from seaweed and roselle extract were dried. Here, the air as drying medium was dehumidified by zeolite to enhance the driving force at lower temperature. The study was conducted in various air velocity, temperature and relative humidity. Results showed that the air temperature had the most superior effect both on product quality and drying rate. The higher temperature, the higher drying rate but the lower product quality. Air dehumidification had a positive effect on product quality and drying for low operational temperature. For all cases, it was recommended that the drying around 70°C or below was favorable for reasonable quality and drying rate.

**Keywords:** Carrageenan, dehumidification, roselle, sensitive, zeolite

## INTRODUCTION

Currently, the demand of powdered food products for example soups, sauces, dried yeasts and dry extract of agriculture product, marine and herbal medicine are increasing for consumer convenience. This is a big challenge how to serve these materials in high quality close to the fresh condition. The challenge can be overcome when in drying process, a basic operation in the industry, is well performed or improved. The drying is an important factor to preserve the product properties, reduce the costs for transportation and increase customer convenience. An example is milk powder that can be stored for a period longer than a year instead of some weeks (Birchal *et al.*, 2005) and for which the transportation volume is 8-10 times reduced.

In drying physical and chemical process can occur, e.g., browning, de-naturation of protein, shrinkage and texture change, evaporation of active component and degradation of vitamin (Djaeni, 2008). The term of browning in food refers to enzymatic and non-enzymatic reaction where the color of food changes to be brown (Anonymous, 2008). Enzymatic browning is

a less desirable series of reactions. It occurs in certain fruits and vegetables when phenolic compounds react with oxygen in the air, which results in brown complexes. Whereas, non-enzymatic can occur with several probability such as Maillard reaction, cracking of carbon chain and caramelization, or de-naturation of protein. The caramelization is a process when sugar or carbohydrate is heated higher than 120°C at less water. The protein deterioration can occur by introducing of heat above 50°C.

Meanwhile, vitamin C and volatile components are sensitive with temperature change. Vitamin C degradation increased corresponding to the increase of temperature (Matei *et al.*, 2008). Active volatile component can evaporate along with water evaporation during the drying process. The higher temperature and the longer process, more volatile component are losses.

Air dehumidification with zeolite can be potential option as drying medium for food or herbal medicine. In the methods the air as drying medium was contacted by zeolite, a material having high affinity to water vapor. As a result, the humidity of air dropped up to 0.1 ppm, while the air temperature increased about 10°C higher

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than that of intake due to the adsorption heat released (Djaeni, 2008). With lower moisture content, the driving force for drying can be kept high especially in low or medium operational drying temperature. Additionally, the adsorption heat released can reduce the heat for drying (Revilla *et al.*, 2006; Djaeni *et al.*, 2009, 2008).

However, the application cannot be straightforward. Several scientific questions have to be answered by research that involve: how is the description of mass and heat transfer under dehumidified air, how the method can shorter drying time minimize nutritional degradation, how is about the quality of product (powder size, final moisture, anthocyanin and vitamin C content) during the process and how are the effects of air velocity, temperature and relative humidity, on the drying rate, energy efficiency as well as product quality.

This study discusses the application of air dehumidification for roselle extract powder and carrageenan drying. Roselle extract powder was isolated from roselle flower (*Hibiscus sabdariffa* L.) that is a potential as natural food additive such as health food coloring agent to replace synthetic food additive like tartrazine and carmoisine. Roselle flower also contains high anthocyanin and vitamin C that is very beneficial as antioxidant for preventing cancer, diabetes, neuron degenerative and inflammatory diseases (Kiattisak *et al.*, 2008; Tsai *et al.*, 2002). Carrageenan is a sulfated polysaccharide isolated from red seaweed, *Euchema cottonii*. Carrageenan is a prominent component for the food and pharmaceutical industry where it is used as stabilizer, edible coating

and thickener (Voragen, 2002; Thommesa *et al.*, 2007; Djaeni *et al.*, 2012). Carrageenan has a strong affinity to water and the product quality is formed by drying. Thommesa *et al.* (2007) found that the carrageenan drying was shorter at higher temperatures, but the product quality was lower. Carrageenan degraded when exposed to temperatures upper 70°C. Regarding to the issues, the application of air dehumidification for both the products is very interesting. In this case, the effect of air condition on the drying rate and product quality are discussed.

## MATERIALS AND METHODS

**Product extract preparation:** About 150 g of red seaweed, *Euchema cottonii*, was mixed and extracted by 9 L of warm water at 70-80°C. After 2 h, the mixture was filtered with whatman paper aided by vacuum pump. The extract containing carrageenan was then coagulated by potassium chloride (2.5%). The slurry was then dried in oven at 60°C until moisture content about 80%. The product was ready for drying process with air dehumidification.

The roselle extract was obtained from the roselle calyces. The flower was provided from local farmer in Semarang, Indonesia. The product was weighed for 50 g and extracted using 1 L of water at 80°C. The mixture was then filtered with whatman paper. The filtrate containing roselle extract is then dried.

**Performing product extract drying:** The experiments were performed in a tray dryer illustrated in Fig. 1

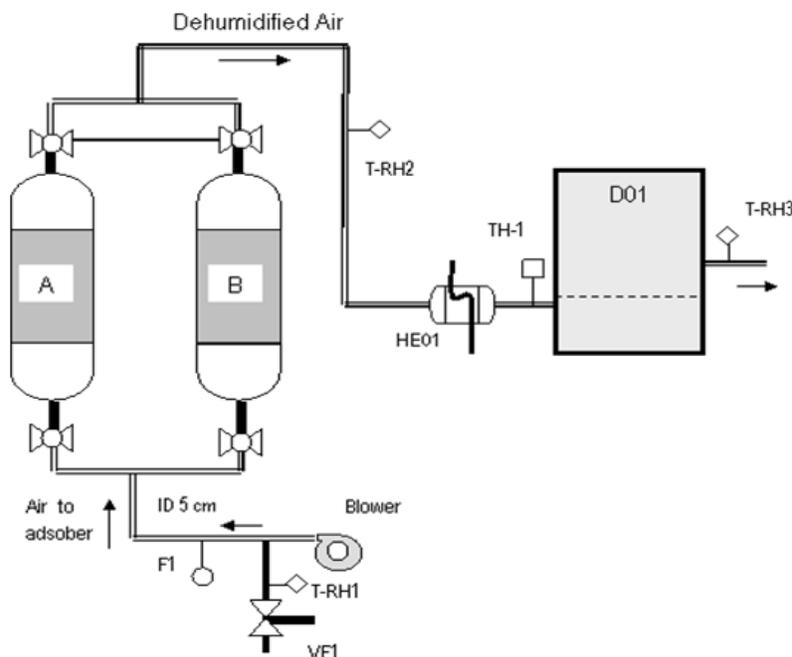


Fig. 1: Schematic overview of the experimental equipment. Internal diameter of columns A and B is 0.12 m, diameter of piping is 0.05 m, tray dryer size 0.40×0.25×0.60 m

(Djaeni *et al.*, 2012). Their temperature and humidity were measured by KW0600561, Krisbow®, Indonesia (presented as T-RH). The air velocity was measured with an anemometer KW0600562, Krisbow®, Indonesia (noted as F1). Ambient air with 70-80% Relative Humidity (RH), velocity 10 m/sec and 29-33°C passed the adsorber column (suppose A) which contains the activated natural zeolite (1.5 kg/column, particle size 2 mm). About 70-80% of water in air is removed and the air temperature increases 5-10°C due to the release of adsorption heat. Next, the dehumidified air was heated to the chosen drying temperature. The hot air was fed to the dryer where water evaporates from the wet products (suppose carrageenan) put in the thin plate with 4 mm thickness and 6×6 cm. When the zeolite approached saturation, the adsorption function was switched to column B, whereas, the zeolite in column A was regenerated at 200°C. Water content in carrageenan was measured by gravimetry every 15 min. The data was plotted in the graph and drying rate was estimated referring to Djaeni *et al.* (2012). The procedure was repeated for temperature 40, 60, 80 and 120°C, respectively (adjusted by PID controller). Process was also applied for roselle extract at temperature 70, 80, 90°C, respectively and air velocity in pipe 7 and 10 m/sec (about 0.16 m/sec in dryer).

**Product quality analysis:** The carrageenan quality indicators whiteness and gel strength were analyzed after drying with a brightness and color meter 68-50 (TMI, USA) and texture analyzer type TA1, LLOYD Material Testing, UK (Djaeni *et al.*, 2012). While the roselle extract quality indicators involving anthocyanin and vitamin C were analyzed by spectrophotometry and iodimetry, respectively.

## RESULTS AND DISCUSSION

**Carrageenan drying:** The result showed that the air dehumidified with zeolite affected the water evaporation positively (Fig. 2). The carrageenan can be dried shorter than that of without zeolite. Djaeni *et al.* (2012) mentioned that time the drying rate was dominated by the difference between actual and equilibrium moisture content. For both cases, at lower moisture content in product, the difference was not significant and the curves approached each other. Same story also occurred, when the air temperature increased upper 80°C. This because, the relative humidity between non-dehumidified and dehumidified air with zeolite was very close. Thus, the effect of air dehumidification on the carrageenan drying was not dominant.

The results for different operational air temperatures were given in previous research (Djaeni

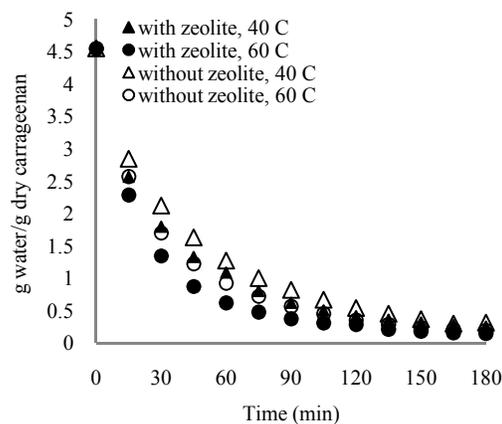


Fig. 2: Comparison of progress of drying with and without zeolite at different operational temperature

Table 1: Water diffusivity, whiteness and gel strength of carrageenan at different temperature for carrageenan sheets of 6×6 cm, 2 mm thickness (Djaeni *et al.*, 2012)

Temperature (°C)	Activation energy $E_a = 5502$ J/mol	Whiteness	Gel strength $g/cm^2$
40	4.83	53	116.0
60	5.16	50	105.1
80	5.51	44	98.8
100	5.89	40	87.5
120	6.31	36	63.0

*et al.*, 2012). However, the improvement was still positive compared to the other carrageenan drying as published by Thomessa *et al.* (2007). The results showed that higher temperature, higher drying rate as indicated in Table 1 (Djaeni *et al.*, 2012). However, at higher operational temperature, the product quality of carrageenan was poor. High gel strength is preferred for industrial use of carrageenan. At the higher temperatures the carbon chains in the carrageenan matrix deteriorated. In addition, the Maillard reaction also increased as indicated in the decrease of product whiteness.

### Roselle extract drying:

**Effect of air temperature:** Figure 3 presents the response of moisture in roselle extract versus time at different operational temperature. As mentioned in literature, the increase of air temperature increased the movement and diffusivity of water in product form inside to the surface (Djaeni *et al.*, 2012; Suherman *et al.*, 2012; Daniel *et al.*, 2012). Hence, the drying rate became faster and the product can be quickly dried. In addition, with ambient air for drying medium, the humidity of air is same. So, the higher air temperature decreases the relative humidity. As a result, the driving force for drying can be enhanced. Applying the models formulated by Newton, the constant of drying values were given in Table 2. From the data, it can be noted that the higher air temperature, the faster drying rate.

Table 2: Constant of drying rate at different air temperature

Air temperature (°C)	Constant of drying (s <sup>-1</sup> ), × 10 <sup>-4</sup>
60	1.80
70	1.80
80	2.30
90	3.90

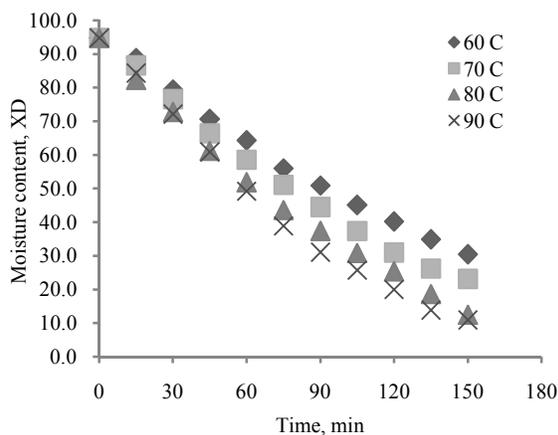


Fig. 3: The response of moisture in roselle extract versus time at different temperature and air flow 10 m/sec

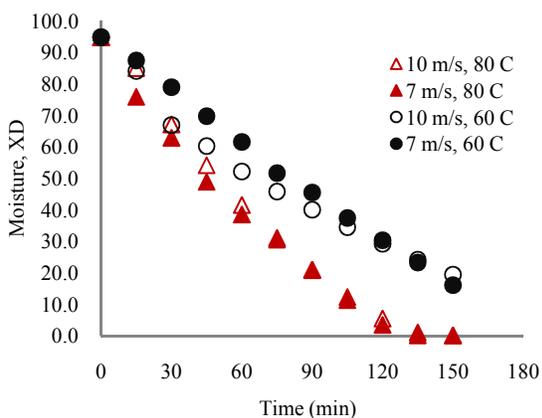


Fig. 4: The response of moisture in roselle extract versus time at different temperature and air flow

**Effect of air velocity:** Figure 4 presents the response of moisture in roselle extract versus time at different air velocity for operational temperature 60 and 80°C. The air velocity improved the capacity of air for evaporating water. However, at same the driving force for mass transfer didnot change. So, the effect of air velocity was not significant for speeding up drying process. Figure 4

Table 3: Vitamin C and anthocynine content in roselle extract (dry basis)

Air temperature	Vitamin C, g/100 g dry basis		Anthocyanin, g/100 g	
	Air velocity, 7 m/sec	Air velocity, 10 m/sec	Air velocity, 7 m/sec	Air velocity, 10 m/sec
60	4.04	3.30	3.07	1.71
70	2.90	2.30	1.48	1.76
80	1.25	1.00	1.37	1.12
90	0.42	0.34	0.71	1.06

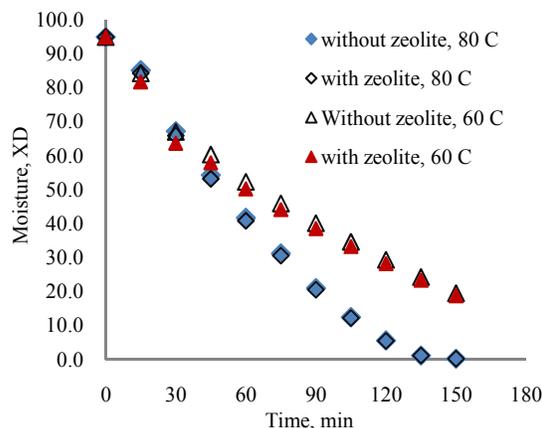


Fig. 5: The response of moisture in roselle extract versus time at different temperature and air flow

showed that at first 60 min, the air evaporated free moisture content in roselle extract. In this step, the effect of air velocity was very positive. However, after 60 min, the remained bound moisture was difficult to be released from extract. As a result, the effect was poor.

**Effect of air dehumidification:** The predicted estimation was used to analyze the impact of air dehumidification on drying rate. The model was considered based on the equilibrium moisture content roselle extract cited from Ashaye (2013). The drying kinetic was estimated for data in Fig. 3 using model equation from Djaeni *et al.* (2012). Figure 5 showed the moisture content in roselle extract as a function of time during drying at different air temperatures and humidity. At low temperatures (60°C) drying was enhanced and the drying time can importantly be reduced. At these temperatures dehumidification affected the vapor pressure sufficiently to increase the driving force for drying. Ambient air heated up till 80°C decreased the relative humidity. Thus, the dehumidification had a minor effect on the driving force for drying. The curves for the average moisture content for these temperatures were close for the full drying time.

**Product quality analysis:** The vitamin C and anthocyanin were analyzed at different operational drying temperature. Table 3 showed the estimated antocyanine and vitamin C content decreased corresponding to the increase of air temperature. The

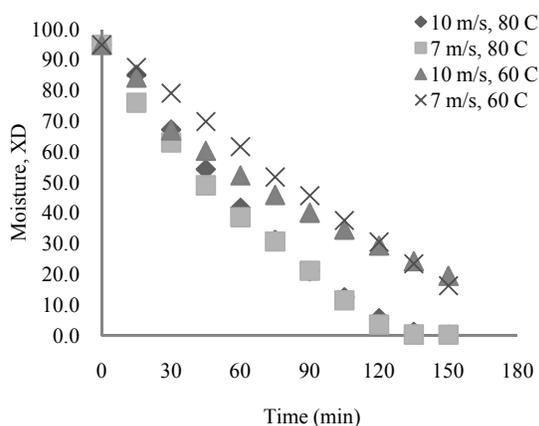


Fig. 6: The response of moisture in roselle extract versus time at different temperature and air flow

anthocyanin and vitamin C were oxidized and degraded due to the contact with warm or hot air. Hence, the operation temperature below 80°C was recommended for roselle extract drying. However, at this condition, the drying time is too long. For example, at operation temperature 60°C and air velocity 7 m/sec, the moisture content in roselle extract after 150 min drying, rounds 16.0 g water/g dry roselle (95% wet basis, Fig. 5 and 6). It means that the roselle extract still wet.

### CONCLUSION

The carrageenan and roselle extract drying has been done at different air temperature and velocity as well as relative humidity. Research showed that the air temperature affected the drying process dominantly in term of both product quality and drying rate. With the increase of temperature, the drying rate became higher, but the product quality was poor. In the carrageenan, the carbohydrate contents degrades at drying upper 80°C. While in the roselle extract, the vitamin C and anthocyanin degraded quickly. On the other hand, the drying below 80°C is good enough for retaining product quality. However, the product cannot get dry.

Meanwhile the air velocity and air relative humidity affected positively in the first hours. After that, when the moisture content in the products were low, these effects were not significant anymore. For all cases, it was recommended that the drying rounds 70°C or below is favorable for retaining quality as well as high drying rate. Applying air dehumidification with zeolite is a positive to enhance drying, to shorten the drying time and to improve product quality. However, the effect was poor at high operational temperature. System improvement with respect to process design, operational conditions and the potential for heat recovery to improve energy efficiency for this product became the next challenge.

### ACKNOWLEDGMENT

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