Development of Drying Process Combining Hot Air with Drying Cyclone for High Moisture Content Materials

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Abstract

This research presented the drying method which combined flowing hot air with drying cyclone for continuous production process development. Drying products are focused on the crushed durian peel to use as raw material in Carboxymethyl cellulose production and shredded coconut to offer alternative method instead the conventional production, which roasted by hot pan. An experimental was conducted from designed and fabricated drying process system, which employed centrifugal blower to generate air flow and electric heater as a heat source. Continuous feeding rate of fresh durian peel and coconut was maintained at 200 g/min, and 15 rounds of feeding have been tested. Air temperatures at 70°C, 80°C, and 90°C and air velocities at 25.7 m/s, 32 m/s, and 38 m/s were tested. Experimental results founded that air temperature enhancement had more influenced on the rounds feeding than those air velocity factor. For temperature at 90°C and velocity at 38 m/s, drying rate represented the highest value. All experimental results could be concluded that the proposed development method that employed hot air with drying cyclone had an ability to dry the durian peel and to roast coconut as continuous production instead the convention method.

Keywords: Carboxymethyl Cellulose, Drying durian peel, Roasted coconut production, Processed coconut, Drying

I. Introduction

One of the most impact to the world environment is a plastic pollution. Finding new raw material to reduce the plastic use is an interest solution. Organic matter, i.e. by produce from fruit product industrial seem to be a good chance, especially for southernmost of Thailand. Processing of synthetic durian peel into Carboxymethyl cellulose, CMC is promising and interesting. This is because it can be used as a raw material for many products, creating packaging for agricultural products in the Thailand's southernmost province, or OTOP products. Therefore, it is expedient to grow business opportunities or upgrade to small businesses or SMEs (Petpradub, 2018).

However, the process to create a raw material from durian peel synthesis for obtaining CMC from conventional drying process was found that the process was costly and time-consuming. To give the process more practical to extend to industrial possibility, becoming mass product process, the study to obtain the method for preparing the drying durian peels, which have high moisture content, in sufficient product rate was important.

Phosee et al. (2013) studied the effect of the drying hot air at 55, 65 and 75 °C to the drying characteristic of mint leaves. The result shown that the temperatures at 55 °C presented the most suitable color of the mint leaves. But, at 75 °C, the minimum drying time was received, having three times lower than the temperature of 55 °C case. As a result of this study, the temperature level had a significant effect on the drying time. According to the study of Pintana et al. (2016), the study was focused on the effect of hot air to local product rice cracker drying rate. It was found that the tem-

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perature and hot air velocity were the most important parameters on drying time. The characteristic of the reducing rate of moisture content at the beginning shown that the rate was higher than that last period. The relationship between the remaining of moisture content and time corresponded to the quadratic polynomial relation. Wisaiprom et al. (2018) experimented that the effect of relative low humidity of drying air, which was maintained the range of 35-55%, to the shrimp drying process by deploying hot air at 40, 50 and 60 °C was focused. The tests shown that the hot air at 60 °C gave the lowest drying time, which was equal to 150 min. and 13.51% (d.b) of remaining moisture content.

Literature reviews as mentioned above can be concluded that drying system by employing the hot air is widely used for drying application of various products. Then, the aim of this study is to experiment the use of hot air combining with drying cyclone to introduce alternative method of the drying system. The test products are durian peel and crushed coconut to study the drying characteristic of difference initial moisture content to extend the understanding of presented drying system and to introduce the drying method that can develop to be continuous process.

II. Study procedure and data processing

2.1 Experimental set-up

Fig.1 represents vital details of the experimental set-up of drying system that conjugates hot air with cyclone. The hot air is supplied from centrifugal type blower, which is powered by a 5.5 kW DC motor. At the blower inlet, 180 mm dia. (D_1) and 900 mm long pipe with expanded entry cross section including with pack of 10 mm dia. tubes and 100 mm long insertion at the entrance region to regulate the streamline is installed to use as the velocity measurement portion. at the distance 300 mm prior the blower inlet, the uppermost portion of the pipe was drilled to allow to insert the velocity measurement tool probe. Velocity magnitudes along vertical direction with increment of 10 mm for each position were measured by employing the hot wire anemometry, Extech® model SDL350 having 0.2-25 m/s range of measurement and ±5% accuracy from reading value.

The 3 velocity profiles as shown in Fig.2 were adopted to calculate the average air velocity on the discharge side by estimating from equation (1) as continuous flow without leak at the blower.

$$V_{1,avg} = \frac{\sum_{i=0}^{17} V_i}{18} \qquad (1)$$

Then, average air velocities at discharge side ($V_{2,avg}$), using 83 mm dia. pipe (D_2), were obtained by calculating from equation (2).

$$V_{2,avg} = V_{1,avg}\,(D_1^2/D_2^2) \qquad (2)$$

Then, the average velocities of 25.7 m/s, 32 m/s and 38 m/s were obtained according to the suction side

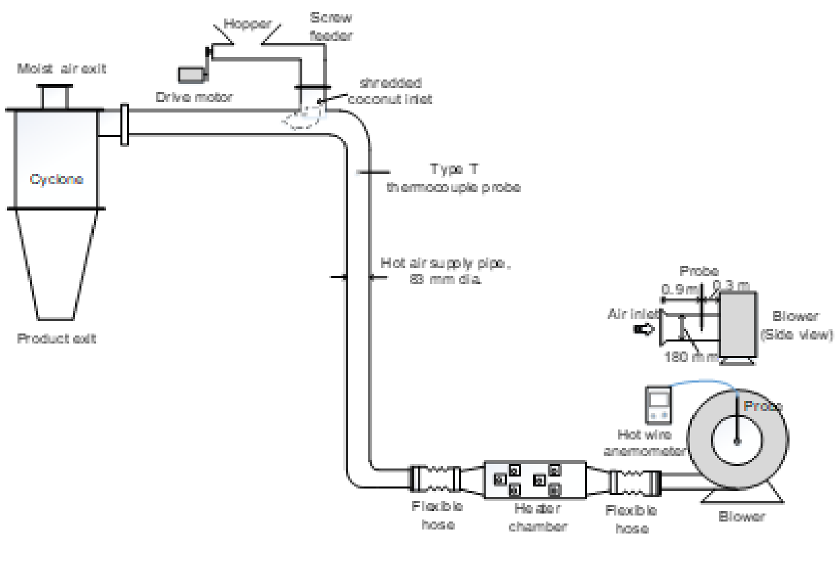

Figure 1. Experimental set-up of drying system combining hot air and drying cyclone

velocities of 4.3 m/s, 5.5 m/s and 6.8 m/s ($V_{1,avg}$), respectively. Flow conditions on both sides by representing from Reynold number, Re=$V_{1,avg}$ D/ν, base on pipe diameter D and velocity average were shown in the Table 1. Kinematic viscosity, ν, was chooses at 27°C and 80°C for suction and discharge sides, respectively. Discharged air flows through the heater chamber, having 6x1,000 W, to heat up for accelerating the moisture transfer from the product. The PID control unit with T type thermocouple was employs to measure the air temperature locates prior the exit of product, which is conveyed from screw feeder driving by adjustable speed DC motor to maintain 200 g/min feed rate. The temperature of hot air was controlled at 70°C, 80°C, and 90°C for study the effect of temperature to drying characteristics. After hot air and the product collision at exit of product, the air dragged the product by shear fore effect into the drying cyclone. Due to the geometry of the cyclone as shown in the Fig. 3, occurrence of the swirling flow induces the product to rotate along the cyclone wall while descent to the product exit at the bottom.

2.2 Experiment

Crushed durian peel and crushed coconut as shown in the Fig. 1 for drying products was reparation as the raw product was used to study the drying characteristic when employed fabricated drying system. Drying products for 1 kg were load in a hopper that closed with the firm lid for preventing higher pressure of the hot air leaking to ambient air. Subsequently, screw feeder, which was driven by adjustable speed DC motor, was constantly fed into discharge pipe at the rate of 200 g/min. The product after interacting with hot air was dragged along hot air flow into drying cyclone by shear force of high velocity air flow. Effect of cyclone geometry led the both incoming fluid and product to be rotated movement while product decent to the product exit, which connect to the collecting product bottle. So, the hot air with moisture was forced to flow out from the exit at uppermost section of the cyclone.

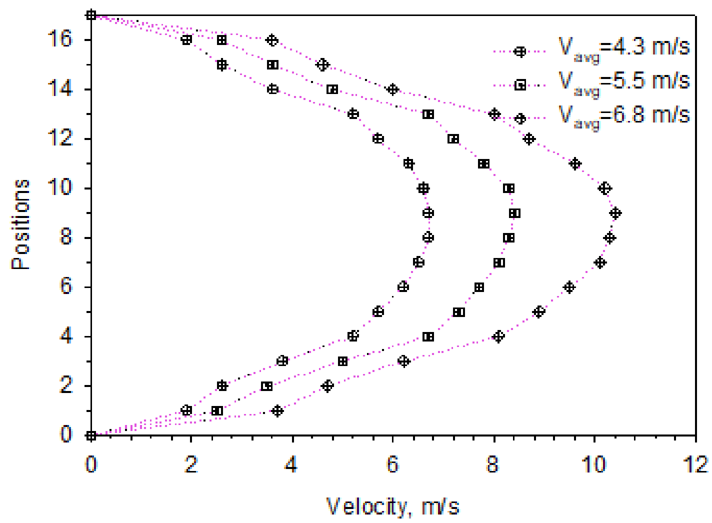

Figure 2. Velocity profiles in the suction side along tube centerline for calculating average velocity

Table 1. Reynold number base on pipe diameter and velocity average on the both sides of blower

$V_{1,avg}$	$V_{2,avg}$	R_e	
		Suction side	Discharge side
4.3	25.7	48,266	227,004
5.5	32	61,736	290,354
6.8	38	76,328	358,983

2.3 Moisture content examination

Moisture content decrease of the product after drying for each round was determined by the difference of net moisture content between pre-drying and post-drying product. Product example from the drying process with amount of 20 g of each round drying by using digital scale (SHIMADZU Model TW3202L) which has ±0.002 g linearity was measured before making complete dry by using electric oven for 24 hours at 70°C. Then, weights of pre-drying and post-drying product were compared to examine the decrease of moisture for each round of drying. The present study limited the maximum round of drying at 15 for each product. Moisture content for bet basis can calculate according to the eq. (3).

$$\text{Moisture content} = \frac{w-d}{w} \times 100\%, \% \text{ (wb)} \quad (3)$$

Where w was product wet weight before drying and d referred to the dry weight after drying with oven.

III. Results and discussion

Experimental results of the drying product of durian peel product are categorized into 3 topics; 1. effect of hot air temperature 2. effect of hot air velocity and 3. physical of dried product for each round of drying.

3.1 Effect of hot air temperature

Fig.3 shows drying characteristic of durian peel that is affected from hot air temperature. This experiment maintains air velocity at 38 m/s. Preferable air temperatures at 70°C, 80°C, and 90 °C are studied in order to avoid burning the product and still productively accelerate the moisture removal from product.

The air temperature has an important effect on the drying characteristic of durian peel. Pre-test moisture of the durian peel in the range of 82.1±1.7% by weight gradually decreases after finishing for each round. Rate of drying for higher air temperature exhibits clearly faster of moisture removal than the lower especially at the beginning of the test. For first 7 rounds from start, linear relationship between moisture content and round of drying is observed. At the lower air temperature condition, moisture content presents lower drying rate according to the tested temperature level which can notice from gradient of curves. After passing the linear section, lower drying rate is obtained from this section before reaching the constant drying rate condition. The pattern of drying rate is quite similar for all temperature levels but show difference the drying rate. As higher temperature level has better ability to remove the moisture from product, the test at 90°C reaches the constant condition at first after finishing 13 rounds of drying with residual of moisture content of 1.9 percent. After finishing 15 rounds of drying, residual of moisture contents shows that 80°C and 70°C conditions cannot reach the constant condition.

Fig.4 presents the effect of the hot air velocity with constant temperature of 90°C to drying characteristic of crushed coconut. The product has an initial moisture content of 50.2±1.3%. Drying characteristic at the beginning of the test shows that the drying rate has higher than the later round. Enhancement of the air temperature can accelerate the moisture removal from the product. Then, round of drying before reaching the constant moisture constant state can be reduced to compare to the lower air temperature condition. To compare with the durian peel, the results exhibit that all of 3 levels of air temperature can reduce the residual moisture content into constant state within 15 rounds of drying because the crushed coconut has a considerably lower initial moisture content. The case of 90°C is the lowest drying rounds which needs only 8 rounds of drying before going to constant state.

3.2 Effect of hot air velocity

Fig.5 shows the effect of hot air velocity to the drying characteristic of durian peel by investigating at 25.7 m/s, 32 m/s, and 38 m/s while air temperature is set at 90°C.

Decreasing rate of moisture content at the beginning of the 3 velocities obviously shows that the air velocity is also impact parameter to the moisture removal ability of the drying system. Nevertheless, in the case of velocity equal to 25.7 m/s and 32 m/s exhibit that residual moisture content after completing 15 rounds of drying cannot reach to the moisture constant condition. To compare with the case of shredded coco-

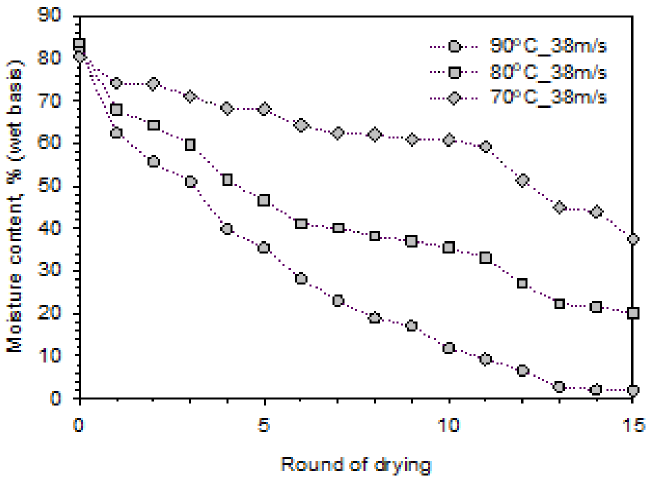

Figure 3. Effect of drying temperature, 70°C, 80°C, and 90°C, to the drying characteristic of durian peel at constant hot air velocity of 38 m/s

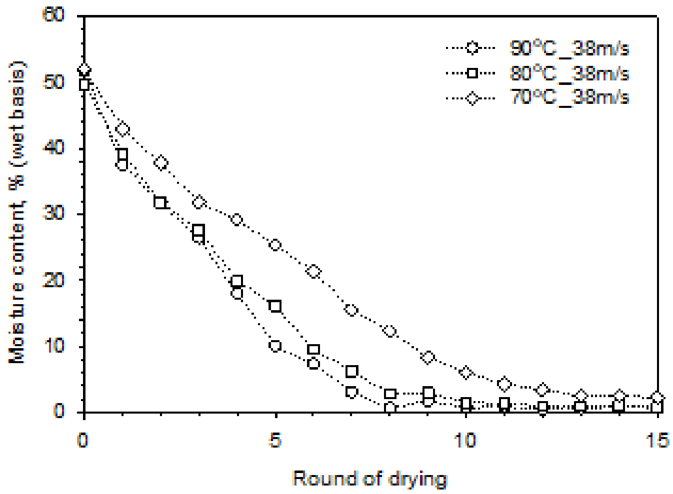

Figure 4. Effect of drying temperature, 70°C, 80°C, and 90°C, to the drying characteristic of crushed coconut at constant hot air velocity of 38 m/s

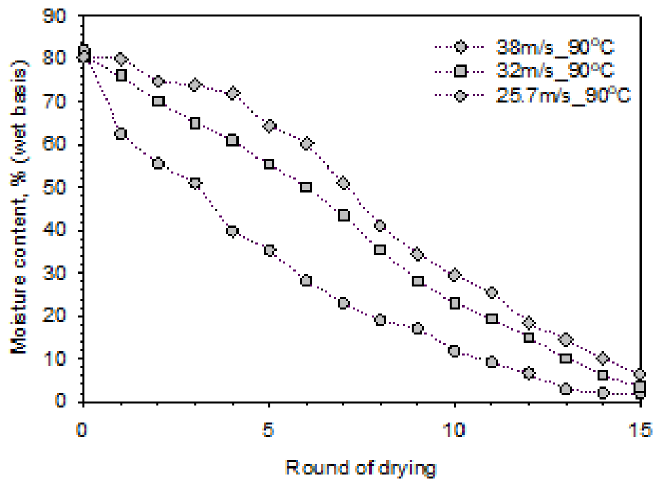

Figure 5. Effect of hot air velocities, 25.7 m/s, 32 m/s and 38 m/s, to drying characteristics of durian peel at constant hot air temperature, 90°C

nut which has less initial moisture content, the result in Fig. 6 shows that the residual moisture content at the beginning of all 3 levels of air velocity are similar. In the case of 32 m/s and 38 m/s, there is a tendency for the moisture to remain almost constant when entering the 8 and 10 cycles respectively. From the above results, it shows that the case of shredded coconut drying requires wind speed. 32 m/s can be dried to a constant humidity of less than 15 cycles, which is different from the case of durian rind that requires only 38 m/s.

IV. Physical characteristics

Fig. 7 shows that the dried durian peel examples are obtained from each round of drying. Due to relatively high of initial moisture content, the characteristics before drying characterizes as sticky material. After feeding few rounds, the durian peel starts to crumble and shows the fibers more clearly. Decreasing of the moisture can be overserved visually. For the first three rounds, it is found that drying process has few affects to the color changing.

Fig. 8 presents dried coconut after finishing 15 rounds of drying. For hot air condition of 90°C with 25.7 m/s, 32 m/s, and 38 m/s, color intensity and grain sizing of crushed coconut are similar. Comparing to the roasted coconut from the local market, Narathiwat province, Thailand, shows that the texture is quite difference. The cause could be explained by the remaining moisture making color lighter than absent moisture product from the market. Finer grain of roasted coconut from market clearly observes because roasting in hot pan promotes the coconut movement resulting to reduce sizing of the grain by chaotic crushing from stir process while presented process utilized moisture transfer from product to moving hot air technic, leading to low crushing opportunity between grains and container wall.

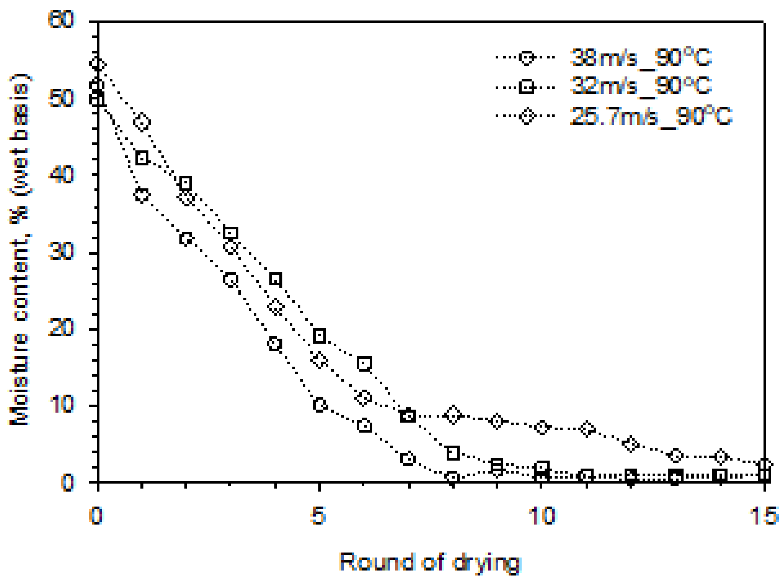

Figure 7. Effect of hot air velocities, 25.7 m/s, 32 m/s and 38 m/s, to drying characteristics of crushed coconut at constant hot air temperature, 90°C

Figure 7. Physical characteristics of durian according round of drying

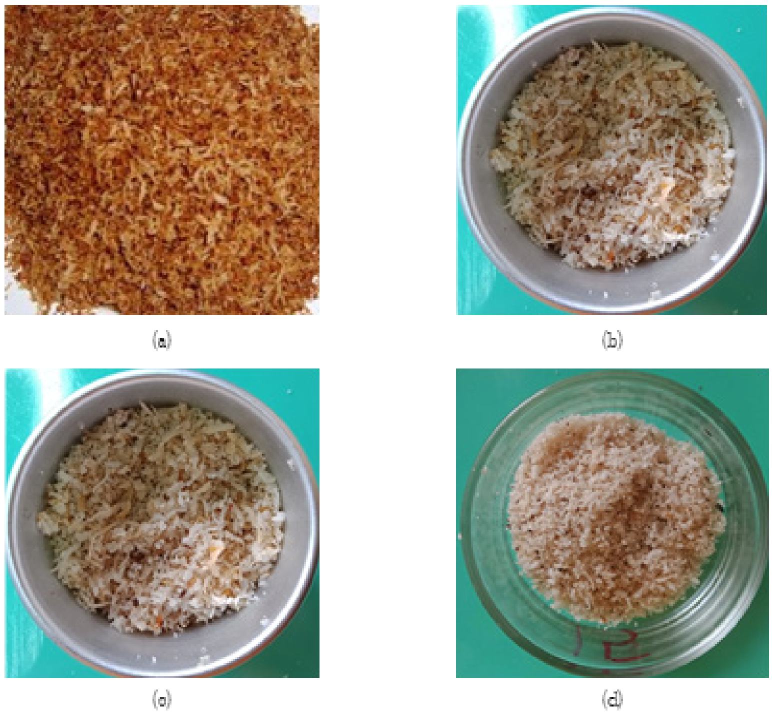

Figure 8. Comparison of the crushed coconut drying products for various velocity levels to selling product from local market in Narathiwat province; (a) product from local market (b) 25.7 m/s (c) 32 m/s and (c) 38 m/s at 90°C

V. Conclusion

The present study intended the results of hot air drying with drying cyclone for preparing of dried durian peel in the process of transforming durian peel into Carboxymethyl cellulose and drying of drying shredded coconut for developing a continuous roasted coconut production process. The results of the experiment can be summarized as follows.

1. rying system that was developed by using hot air with drying cyclone has the potential to be used for drying durian peel and shredded coconut as it can reduce the humidity until moisture content reached a constant remaining state. And it can be applied to a continuous process by connecting cyclones equal to the required number of drying cycles.

2. Durian peel drying requires a higher temperature and hot air velocity than that of coconut due to higher initial moisture content. To consider the same drying conditions, temperature and hot air velocity), round of drying of coconut is less than that of the durian peel.

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