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The Effect of Temperature on Vermicelli Drying under Dehumidified Air

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Abstract. Vermicelli, called Sohun, is a white noodle made of arenga starch. The vermicelli is commonly produced by small to medium enterprises. The process consists of mixing starch with hot water forming gel, forming the vermicelli noodle, drying, and packaging. Vermicelli drying is an important part, since it influences the product quality. Currently, the drying was simply done under sunlight. The drawback of the process is weather dependency both quality and continuity. The convective dryer with air dehumidification can be an option to substitute sunlight dryer. In this case, the air as drying medium was passed to adsorbent for reducing the absolute humidity. The dry air was then heated up to certain drying temperature. The research studied the effect of air temperature varied from 313.15 – 353.15 K on vermicelli drying. As a response, the moisture content in vermicelli was observed and thermal efficiency was estimated. Results showed that after 60 minutes drying under 353.15 K, the moisture content in vermicelli can reach below 14.0% and thermal efficiency was about 54%. The dry vermicelli also had good swelling capacity. Upper 353.15 K, the drying is not recommended since it probably reduces the vermicelli quality.
Keywords : vermicelli; drying; thermal efficiency; tray dryer; air dehumidification

1. Introduction

Noodle industries has been widely developed in Indonesia. The product uses imported wheat flour as a main raw material. The variation of raw material becomes important issue to substitute wheat flour in order to reduce imported material dependency as well as utilizing local flour such as arenga starch, cassava starch, or rice flour. Generally, the noodles were classified as two types namely wet and dry noodles [1].

Vermicelli called as ‘Sohun’, is a dry white noodle made of arenga starch. Arenga starch is isolated from wood of a palm tree called arenga. The wood of arenga tree is milled and extracted by water. The starch suspended in water is separated filtration and the remaining wood fiber is disposed. The suspension is then decanted to find the arenga starch. The advantages of arenga starch is able to form elastic gel in which can form the long noodle. The quality of vermicelli is significantly influenced by composition and quality of raw material. The high quality of vermicelli is resulted from suitable raw material with proper viscosity during the heating [2]. Arenga starch contains amylase about 24% and amylopectin rounding 76% [3]. The higher amylopectin, the affinity to the water is higher [4].

The vermicelli is commonly produced in four steps that include gelatinization with water, noodle formation, drying, and packaging. The drying is a method to remove water from wet vermicelli by introduction of heat. The drying is important to prolong storage life of vermicelli (white noodle) before used as well as inhibiting microorganism activities [5]. The water content affects the storage life of food product significantly. The lower moisture/water content, the growth of microorganism can be inhibitted, and the product can be preserved, and vice versa. Based on Indonesia National Standard (SNI) called SNI number 01-3723-1995, the moisture content in dry food such as noodle, rice, and etc, is around 14%.

The drying process involves mass and heat transfer. Several variables influence the process including air velocity, temperature and relative humidity. Firstly, the air evaporates free moisture content in the surface of product. At this step, the rate of drying is constant. After that, the air removes the bounded moisture in which the drying rate decreases. In this step, the drying rate was driven by mass transfer or moisture diffusivity inside the product [6].

Currently, most of vermicelli drying in small to medium enterprises has been conducted under sunlight. The process is simple and low energy cost. However, the drying process was absolutely weather dependency both drying continuity and vermicelli quality. The process also needs wide open door for placing the material. Several dryer types have been also developed to substitute the sunlight dryer, such a convective tray dryer. The key performance of the dryer is the equity distribution of air in all trays [7]. So, the quality of vermicelli can be mostly same or homogeneous. Beside the product quality, the energy efficiency is also the important aspect in the drying. A large part of heat is used for the drying. The low of heat efficiency is due to inefficient of mass and heat transfer. In tropical region, the ambient has high moisture content where daily relative humidity is 70-80%. With this condition, the driving force for water transfer from wet product to air becomes low. Therefore, the evaporation rate of moisture is slow [8].

The air dehumidification can be an option to enhance the driving force for the vermicelli drying. With low moisture content, the water transfer from wet product to air becomes higher. Therefore, the drying time can be reduced. This paper discussed the vermicelli drying with air dehumidified by zeolite under various temperatures. Zeolite was firstly heated up to increase moisture loaded or adsorbing capacity [9]. The zeolite was then used to dehumidify air as drying medium. The dry air was heated at certain termperatures before passing to the dryer. By this way, it can be expected the driving force can be improved [10].

2. Materials and Methods

The research used arenga starch (from Daleman Village, Klaten Regency), water, activated zeolite 3A (provided by Zeochem, Switzerland), and the vermicelli extruder (Ardin CM2020). Meanwhile, the KW0600561 sensor (produced by Krisbow®, Indonesia) was used for measuring temperature and relative humidity of air. The air velocity was measured with anemometer KW0600562, Krisbow®, Indonesia. The work was conducted in the Laboratory of Chemical Process, Department of Engineering, Diponegoro University.

2.1 Vermicelli preparation

The 6 grams of arenga starch was mixed and heated with 18 ml of water (1:3). The mixture formed gel as a binder for vermicelli. The gel was mixed with 24 grams of arenga starch. The mixture was then extruded to form wet vermicelli yarns. The vermicelli was quenched by cold water around 278.15 K for 30 seconds. The cold water was prepared by mixing the water with ice. The liquid phase can be used for quenching.

2.2 Vermicelli drying

The wet vermicelli yarn with diameter around 0.1 cm and 10 cm length was placed in the tray dryer. As a drying medium, the dehumidified air was used. Firstly, the ambient air was contacted with the zeolite column to reduce moisture content. Secondly, the dry air was then heated up to certain temperature. The hot air was passed to the drying chamber where the wet vermicelli was placed. The drying process was conducted for 150 minutes and the moisture content in vermicelli, inlet and outlet dryer temperatures were observed by gravimetric every 15 minutes. The temperatures data were used

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for estimating thermal efficiency as presented in equation 1. In doing so, the vermicelli quality in term of swelling capacity was analyzed for dry vermicelli [11]. After usage, the zeolite was saturated by water. The zeolite can be regenerated by heating at 383.15 K for 2 hours. This process was repeated for operating temperatures 313.15, 323.15, 333.15, 343.15, and 353.15 K. As comparison, vermicelli drying with direct sunlight was also conducted.
The thermal efficiency can be estimated as follows:

$$\eta = \left(1 - \frac{T_o - T_{amb}}{T_i - T_{amb}}\right) \times 100\% \quad (1)$$

Where, η was the thermal efficiency at sampling time (%), T_o T_i were outlet and inlet air temperature at the dryer (K), and T_{amb} was ambient temperature (K).

3. Result and Discussion

3.1 The Effect of Temperature on Moisture Removal

This step was to study the effect of air temperature on moisture content in vermicelli every drying time. As a comparison, the vermicelli drying with direct sunlight was also conducted. The data was presented in Figure 1. For all operational temperatures, the performance of tray dryer showed the faster moisture reduction compared to that of direct sunlight. With the increase of drying temperature, the moisture reduction was faster [12]. For example, at operational temperature of 353.15 K, the moisture content was below 14% for 60 minutes drying time. Below 353.15 K, the drying time process was longer. At such low temperatures 313.15 K and 323.15 K, the moisture was removed due to mass transfer carried away by flowing drying air. In drying, the moisture in wet product was transferred to the air as drying medium. So, the moisture content in product reduced corresponding to the operational time [13]. Firstly, the air heated up the surface of wet product. Secondly, the moisture in the surface was gradually evaporated, and transferred to the air due to the concentration different. The higher temperature or lower relative humidity, or combination of both conditions, the evaporation rate of moisture became faster.

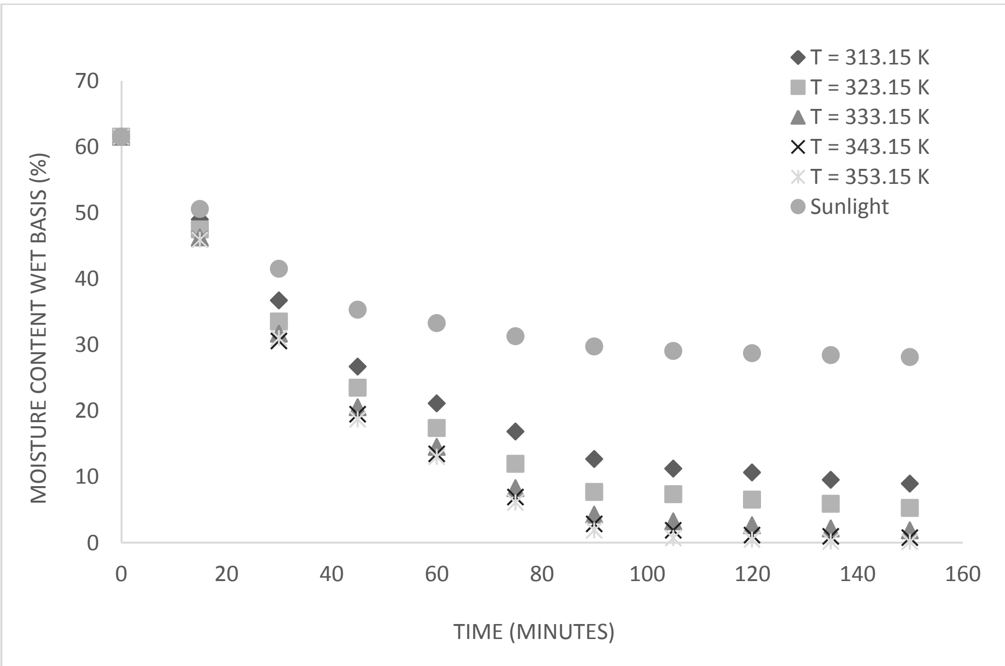

Figure 1. Moisture content reduction in vermicelli versus time at different drying temperatures (T)

Based on Indonesia National Standard called as SNI number 01-3723-1995, the moisture content in food product such as vermiccelli was recommended about 14%. Using experimental data, at 313.15, 323.15, 333.15, 343.15, and 353.15 K, it can be noted that the quick process was resulted at 353.15 K with drying time around 50 - 60 minutes yielding moisture content 13-14%. At 313.15 K, it needed about 75 – 90 minutes. Meanwhile, the direct sunlight dryer with longer drying time (supposed 150 minutes), the vermicelli cannot be fully dried. So, based on the operational time, the convective drying with zeolite was more effective in term of operational time (see also Table 1).

Table 1. Estimated drying time for vermicelli at various operational temperatures

Air Temperature (K)	*constant of drying (1/ minute)*	*Drying Time Experiment* (minute)	*Estimated Drying Time* (minute)	*% error*
313.15	0.083	83.43	75.49	9.52
323.15	0.100	67.99	62.21	8.51
333.15	0.103	60.06	60.41	0.58
343.15	0.124	57.41	50.13	12.69
353.15	0.126	56.09	49.36	12.00

3.2 The Effect of Temperature on Thermal Efficiency

Based on the experimental data and using equation 1, the thermal efficiency for vermicelli drying was estimated. For all cases, with longer drying time, the thermal efficiency tended to decrease (Figure 2). This was due to the low of free moisture availability in the surface of the vermicelli product. Thus, the sensible heat of air cannot be effectively used for water evaporation. It was proved by the temperature different between inlet and outlet dryer in which became smaller. Meanwhile, the thermal efficiency increased at higher temperature. At higher temperature, the latent heat for water evaporation is lower. So, the water is easier to be evaporated in which improved the thermal efficiency significantly [14].The average efficiency for each operational temperatures were 43.12%, 46.55%, 49.98%, 52.75%, and 53.68% for 313.15, 323.15, 333.15, 343.15, and 353.15 K, respectively. Compared to the other dryer performance, this achievement was comparable [15,16,17]. This implied that the vermicelli drying with air dehumidification was potential option.

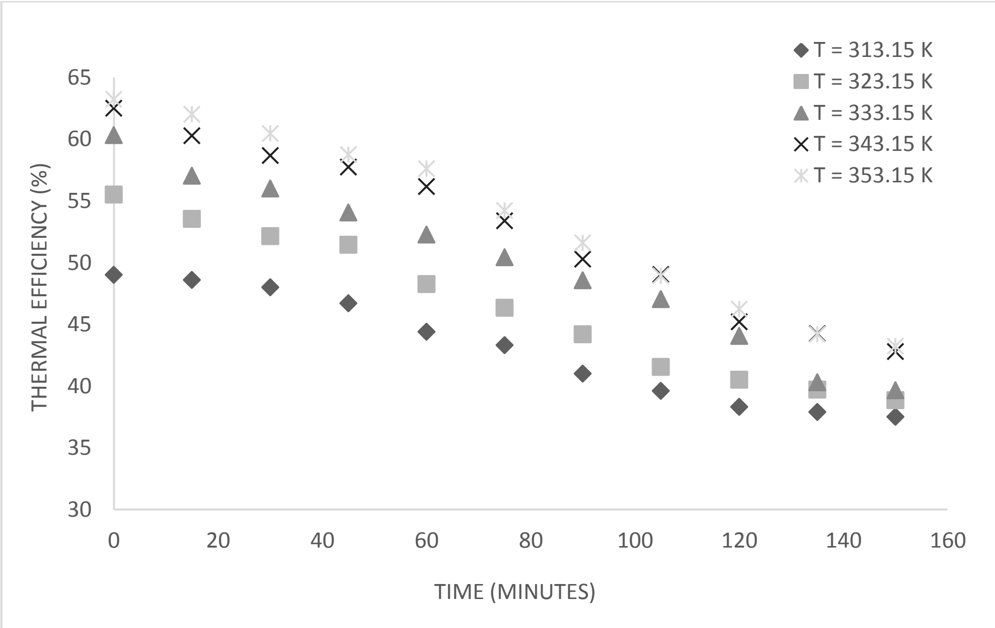

Figure 2. Thermal efficiency estimation versus time at different drying temperatures (T)

3.3 Swelling Capacity Evaluation

Swelling capacity is capacity of material to adsorb water. The swelling capacity depends on by the molecular structure of chemical compound in product [18]. In starch, the amylopectin compound takes part on water affinity. The higher amylopectin, the capability of starch to load water increases [4]. After the drying, the swelling capacity of vermicelli was analysed. Results as depicted in Table 2 showed that at lower temperature, the re-hydration or swelling capacity was bigger. This phenomena was probably due to the change of chemical structure of starch with heat introduction. In addition, at higher temperature, the voids porosities of vermicelli shrink because of surface shrinkage as well as case-hardening. As consequence, the dried vermicelli cannot adsorb water maximally.

Table 2. Swelling capacity for dry vermicelli at various drying temperatures

Operational Temperature (K)	Initial Volume of water (ml)	Volume of water after 18 hours (ml)	*Swelling Capacity* (ml/gr *dry sample*)
Direct Sunlight	10	2.40	15.2
313.15	10	2.70	14.6
323.15	10	4.50	11.0
333.15	10	4.80	10.4
343.15	10	5.0	10.0
353.15	10	5.4	9.2

4. Conclusion

The vermicelli drying was conducted for different temperature under air dehumidified by zeolite. Research showed that the convective drying with zeolite had an effectiveness in term of drying time. At higher operational temperature, the moisture reduction became faster. Furthermore, the average thermal efficiency for higher drying temperature also increased significantly. However, at higher operational drying temperature, the re-hydration or swelling capacity decreased. At higher temperature, the porosity of vermicelli became smaller due to the surface shrinkage or molecular structure of starch probably changed as heat introduced. With this case, the operational drying temperature 353.15 K was still recommended. In this condition, the drying time was about 50 - 60 minutes with thermal efficiency rounding 54%, and swelling capacity of 9.2.

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