Drying Spices by Utilizing the Dehumidification Process and the Heat Condensor in the Refrigeration System

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Abstract. The results of spices in Indonesia are very abundant. Its use is also very much like for cooking, cosmetics, medicine, and so on. To maintain the quality and quality of spices are usually stored in dry form. For this reason, equipment is needed in the drying process. This study aims to investigate the use of the dehumidification process and the heat of the refrigeration system condenser for the drying process of spices. Several performance measurements want to be studied, namely; energy consumption, system performance, and refrigeration system performance. This research was conducted using an experimental method whose implementation includes several stages, namely; design and manufacture of experimental equipment, calibration, and installation of measuring instruments, retrieval of experimental data, data processing, and analysis of results. Data processing is carried out using thermodynamic methods to obtain the desired quantities such as; system energy consumption, system performance, and effect on the refrigeration system. The results showed that the developed heat pump drying system could function properly. Thus it can be concluded that the closed cycle heat pump drying system can be used effectively to dry spices.

Keywords: Spices dryer, dehumidification, condenser heat,and performance.

1 Introduction

In the industrial world, the drying process has a very important role. The drying process in its application can be carried out in different ways, depending on the needs where the system is applied. In the food industry, the drying process is used for food preservation, namely by reducing the water content to a certain extent in the food, to be stored for some time [1,2]. The food in question is usually in the form of vegetables or fruits that contain lots of water such as ginger, peanuts, broccoli, grapes, strawberries, and others. The drying process can also be carried out by flowing hot air on the material in a closed room (closed drying). There are many advantages of closed-type drying, namely clean materials, natural colors, low contamination of impurities, and better taste [3]. Drying that is too fast can damage the material because the surface of the material dries too quickly so it can't be balanced with the speed of water movement in the

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material towards the surface of the material. On the other hand, drying operations with temperatures that are too high can damage the material [4].

Ginger contains phytochemical groups, (n) gingerol, zingerone, and (n) shogaol which function as anti-oxidants and anti-cancer. 6-Gingerol is sensitive to temperature and can change when dried at high temperatures for a long time [5]. Many dried ginger products have low gingerol content due to the drying process at high temperatures [6]. Therefore, in the ginger drying process, a dryer with a low temperature is needed so that the content of (n)gingerol, zingerone, and (n) shogaol is not damaged during the drying process. Therefore we need a drying machine with a low drying temperature [7,8,9].

The drying process of rack-type breadfruit chips using a heater has also been investigated where the results are the thicker the breadfruit slices, the longer the time required with drying temperatures ranging from 33°C [10]. For the drying of Daucus carota with the bed drying method with a heater compared to the adsorption refrigeration drying system, there is almost no significant effect on the color of the product produced by these two methods [11].

There are several drying machines that have been developed including using heat energy, vacuum systems, and heat pumps. Drying machines using heat energy as a water vaporizer in the product have been developed with various models for various purposes [12,13]. Meanwhile, drying machines using heat pumps have also been developed for the drying process at relatively low temperatures so that the texture of the product does not change. This drying process utilizes the dehumidification process on a heat pump [14,15].

This research will integrate the dehumidification process and the heat released in the condenser as a heater for the product to be dried. This drying model utilizes wasted energy so that it can increase the energy efficiency used in the drying process. Also, this drying model can be used in various weather conditions

2 Methodology

2.1 Test-rig of Spices Drying

The test rig is designed from a showcase with a capacity of 190 liters. In order for this showcase to function as a dryer, several modifications were made, including adding air ducts and closing the condensing unit from the outside air. This drying system works with closed air circulation as shown in the picture. The sketch of the experimental equipment design and positioning of the measuring instrument is shown in Fig-1. Tests are carried out using refrigerant R134a. The observed data include; refrigeration system pressure, the temperature in each state, current and voltage used, and compressor power consumption. Data for the airflow include; flow velocity, temperature, and humidity as shown in Fig-1.

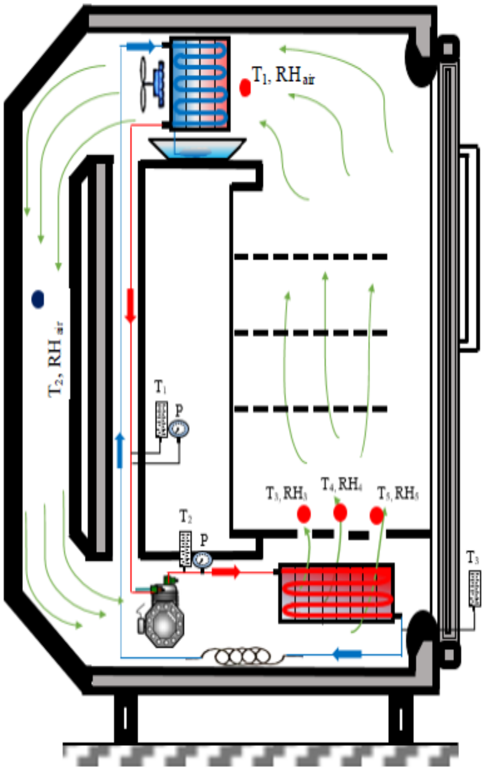

Fig. 1. Shcematic diagram of spices drying

2.2 Data Acquisition and Data Analysis

A digital AC clamp power analyzer (LT Lutron DW-6092) use to measure the compressor power consumption system. Bourdon tube pressure gauge measures the refrigerant pressure of the out evaporator which is suitable for the refrigerant system with the 5. psi accuracy level. In this study, pressure drops in both condenser and evaporator were ignored due to the effect on the end of the result was not significant. The K-type thermocouple records the temperature in each state of the refrigerant and the air circulation of the drying systen at predetermined measurement points. Temperature measurement using a Pico USB TC-08 temperature data logger. Meanwhile, to measure the water content in materials that have undergone a drying process or have not undergone a drying process, a moisture meter is used.

Based on Arora and Moran [16,17], the desired parameter is calculated by using equations (1) to (4). Equation (1) is used to calculate the compressor power consumption. Equations (2), (3), and (4) are used to calculate Mass flow rate, cooling capacity, and system performance

$$W_k = V.I.\text{Cos}\varphi \quad (1)$$

$$m_{ref} = Wk/(h_1\text{-}h_2) \quad (2)$$

$$Q_r = m_{ref}.(h_1\text{-}h_4) \quad (3)$$

$$COP = Q_r/W_k \quad (4)$$

In all equations, enthalpy of the out evaporator, compressor, and expansion are expressed by h_1, h_2, and h_4 consecutively. Data processing is done by using thermodynamic and psicrometrict diagram methods to get compressor power consumption pice drying process., coefficient of performance (COP) and spice drying process

Based on Tjukup Marnoto [18], et all. 2012), The specific moisture extraction rate (SMER) is the ratio of the amount of water that can be evaporated from the material to the electrical energy used every hour or the energy required to remove 1 kg of water. Expressed in kg/kWh. SMER calculation using the following equation (5)

$$SMER = X / \{\dot{m}_{air} \text{ x } Cp \text{ x } (T_{in} - T_{out}) + Wc\} \quad (5)$$

where :

$\dot{m}_{air}$ = mass flow rate of air (kg/s)
C_p = specific heat of air (kJ/kg.°K)
T_{in} = air temperature entering the evaporator (°C)
T_{out} = air temperature leaving the evaporator (°C)
W_c = compressor power (kW)
X = water absorbed (kg/hour)

3 Results and Discussions

The tests carried out have produced data on the refrigeration system, data on the distribution of air temperature in the drying process, and data on the water content in the dried product. For each weight of turmeric, the test was carried out three times until the water content was less than 10%. Based on the results of data processing, it was found that the performance(COP) of the refrigeration system,heat pump and total performance during the drying process was relatively constant, as shown in graph below

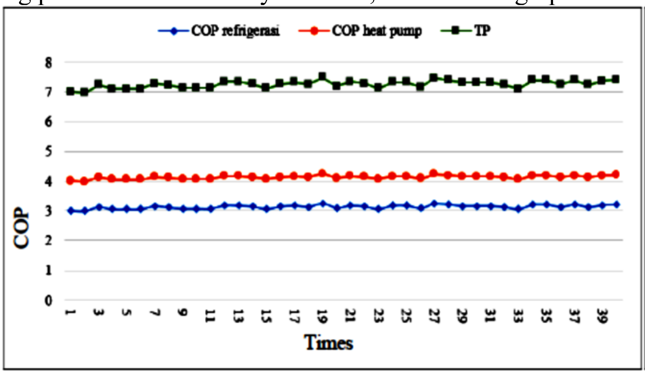

Fig. 2 COP of refrigeration system,heat pump and total performance

The temperature distribution in the drying chamber during the drying process slightly decreased, as shown in the picture below.

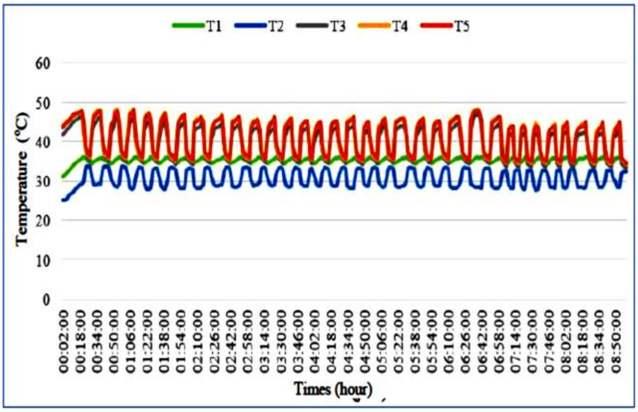

Fig. 3 Distribution of air temperature in the drying process

From the characteristics shown in Fig-4 it can be seen, the graph of the decrease in product moisture content against drying time in two turmeric drying capacities, namely a capacity of 1500 grams and a capacity of 3000 grams with four-time tests with different time variations. The form of the graph shows that the stage of decreasing the water content is fast at the beginning of the process, and the stage of decreasing the water content is slow at the end proces. At the beginning of the drying process, there is a rapid decrease in moisture content, because the mass of water contained on the surface of the material is very large, which is called free water. When the drying process begins, the air carrying hot steam will contact the entire surface of the material, so that the water vapor pressure will increase, and vice versa when the water vapor pressure on the surface decreases, the mass transfer of water vapor decreases

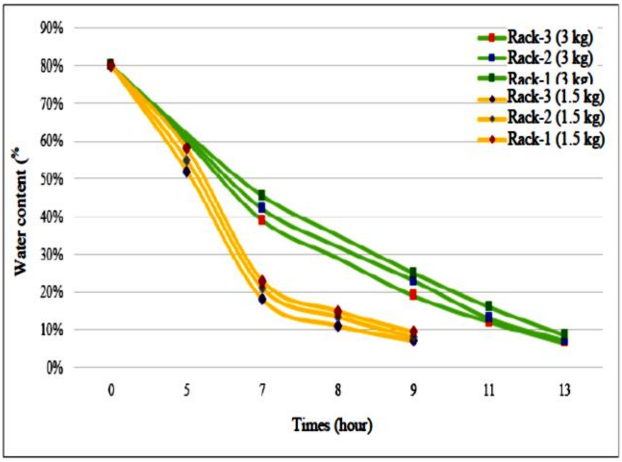

Fig. 4 Graph of product moisture content against drying time.

The figure-5 shows that the specific moisture extraction rate (SMER) increases with increasing drying time

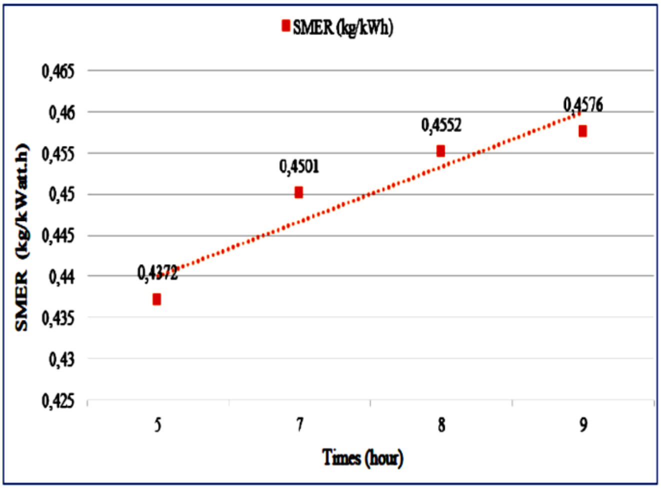

Fig. 5 Graph of specific moisture extraction rate (SMER)

4 Conclusions

Based on the results of the experimental tests and analysis that has been carried out above and referring to previous studies, it can be concluded as follows:

- Based on the results of data processing, it was found that the performance of the refrigeration system (COP) during the drying process was relatively constant
- The stage of decreasing the water content is fast at the beginning of the process, and the stage of decreasing the water content is slow at the end proces
- The less capacity the paster the drying process
- The specific moisture extraction rate (SMER) increases with increasing drying time

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