Application of A Thermoelectric Cooling System and Heater as A Dryer for Spices

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Abstract. Spices are grown by numerous farmers throughout Indonesia. It is also quite useful for a variety of other things, such as pharmaceuticals, cosmetics, and cooking spices. Spices are often kept dry, with less than 10% water content, to preserve their quality. During this process, a drying machine is required. The purpose of this study is to investigate the drying of spices using a thermoelectric refrigeration system. The experimental approach was selected, and it consists of many phases of implementation: designing and building the apparatus, installing and calibrating the measuring instruments, gathering and processing the experimental data, and analyzing the outcomes. This study looks at the following quantities: specific moisture extraction rate (SMER), drying rate, energy consumption, and system performance. The drying equipment performed well, according to the findings. At the start of the procedure, the water content reduction stage happens swiftly, and at the finish, the water content reduction step happens slowly. With an average specific water content extraction (SMER) of 0.7, the thermoelectric drying system performs admirably.

Keywords: Drying Spice, Thermoelectric, SMER

1 Introduction

In both the medium and home industries, the drying process plays a critical function in the industrial sector. A stage in the refining process that reduces the water content of the material from a high water content to a low water content is the drying process. This is done to achieve a variety of benefits, such as the extension of the expiration life, the facilitation of additional processes, and the increase in folate compounds. The conventional drying procedure is energy, space, and time-consuming. A drying machine is the optimal solution; however, not all drying machines are equally effective in the drying process. Problems that often come up during the drying process with a machine include drying time, drying efficiency, heat spread, temperature stability, and the process of turning the material, all of which will impact the quality of the result. According to (Anisah et al., 2018; Sudirman et al., 2021) the drying process in its application can be carried out using various methods, depending on the needs and place of application of the system. The drying process is used in the food business to keep food ingredients fresh for a longer time. It does this by freezing the water content of

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food ingredients below a certain level. The food ingredients in question are usually vegetables or fruits that contain a lot 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 dryer). Closed-type drying has many advantages, namely clean materials, natural colors, low contamination of impurities, and a better taste (Wang et al., 2021). A drying process that is too fast can damage the material because the surface of the material dries too quickly so that it cannot be balanced with the speed of movement of water in the material towards the surface of the material.

Likewise, it has been explained (Patel et al., 2013) that the drying process at too high a temperature can damage the material. Ginger spices contain a lot of phytochemical groups (n) gingerol, zingerone, and (n) shogaol. These substances function as antioxidants and anticancer agents while 6-Gingerol is sensitive to temperature. 6-Gingerol can change when dried at high temperatures for a long time. Many dried ginger products have low gingerol content due to the drying process at high temperatures (Chapchaimoh et al., 2016; Phoungchandang & Saentaweesuk, 2011). To maintain these substances properly, a proper drying process is required. For ginger, a low-temperature dryer is needed so that the (n) gingerol, zingerone, and (n) shogaol content is not damaged. With a low-temperature drying machine, the quality of ginger can be maintained properly (Braun et al., 2002; Catalano et al., 2008; Uthpala et al., 2020). The drying process of breadfruit chips using a rack-type heater has also been studied (Rukmana & Bindar, 2018; Suhendar & Novita, 2017). This study concluded that the thicker the breadfruit slices, the longer the drying time required with the same drying temperature of around 33°C.

Likewise, research conducted by (Nandhu et al., 2022) comparing two drying methods the bed dryer drying method with a heater against the adsorption refrigeration drying system using Daucus Carota material concluded that it had almost no significant effect on the color of the products produced by the two methods. Until now, several drying machines that have been developed, including those using heat energy, vacuum systems, and heat pumps . Drying machines using heat energy from infrared lamps as water evaporators in Apple products have been developed with various models (Salli & Fat, 2015). For drying machines, a combination of indirect heating and vacuum methods has been developed (Rukmana & Bindar, 2018). 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 in the heat pump (Abeyrathna & Amaratunga, 2017; Wang et al., 2021). The dehumidification process and the heat released by the condenser have been studied before. The condenser heats the object to be dried. This drying model can increase the efficiency of energy used in the drying process and can be used in various weather conditions (Ardita et al., 2023). This study will utilize a thermoelectric refrigeration system for the spice drying process. On the hot side, thermoelectric is used to heat the product while on the cold side, it is used for the dehumidification process. The purpose of this dehydrating method is to create a machine that is more energy-efficient and efficient.

2 Methodology

2.1 Spice Drying Test Rig

Experiment-based methods are used in this study, and they include; designing and manufacturing experimental equipment (test rig), installation of measuring instruments, data processing, and yield analysis. As shown in Figure 1), the dryer machine works with closed air flow. The test rig was drawn in a sketch.

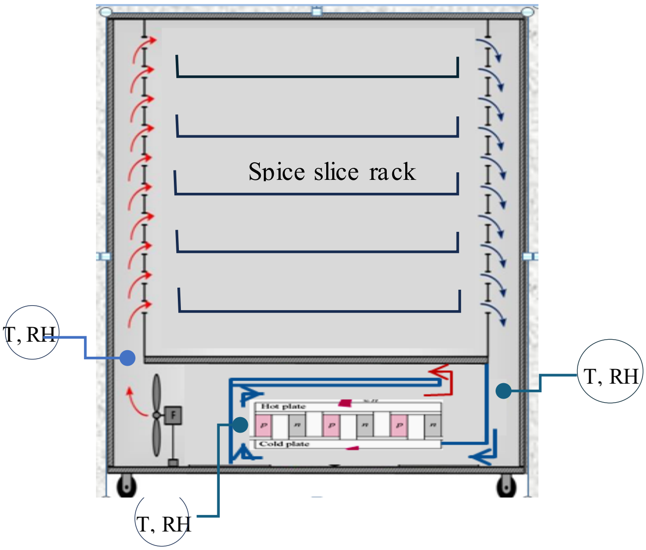

Figure 1. Diagram of spice drying

2.2 Data Acquisition and Data Analysis

As shown in the Figure 1, temperature data, relative humidity data, product water content data, and system power consumption data will all be collected as part of this study. A TC-08 Thermocouple data logger with a type K thermocouple is used to measure temperature (T). A relative humidity meter data logger is used to measure relative humidity, and a GM-640 grain moisture meter is used to figure out the water level of a product. A digital clamp power meter (LT Lutron DW-6092) is used to check how much power the system has used.

The study process consists of multiple phases: the preparation of ginger slice test material with a 1 mm thickness, weighing the material, arranging the sliced ginger on each shelf, getting ready the measurement equipment, and then the test starts. The variables observed include; temperature and relative humidity in each place, system power consumption, material weight before and after testing, and the test duration. The air heating process is carried out by utilizing the hot side of the thermoelectric, and then this hot and dry air will be passed to the product to be dried. This air will absorb the water vapor of the product so that the water content in the product is reduced until it reaches the desired content. The dehumidification process takes place on the cold side of the thermoelectric so that the humid air becomes dry again. The performance of the drying system can be measured by the specific moisture extraction rate (SMER) (Chua et al., 2002), which is defined as:

The specific moisture extraction rate (SMER)

$$SMER = \frac{Amount\ of\ water\ evaporated}{Energy\ input\ to\ the\ dryer}\ (\mathrm{kg/kWh}) \quad (1)$$

Drying rate (Wa)

$$\mathrm{Wa} = \frac{m_o - m_1}{t} \quad (2)$$

Where; Wa = amount of water vapor released by the material (kg/s)
m_o = mass of the material when wet (kg)
m_1 = mass of the material when dry (kg)
t = time during the process (seconds)

3 Result and Discussion

3.1 Result

The tests gave information on how the temperature and humidity changed during the drying process, how much air was in the dried product, and how much energy was used during the drying process. Three times of testing were done until there was less than 10% water. According to the outcomes of the data processing, it was found that the system performance was quite satisfactory. Concerning how well the temperature of the house air worked during the drying process, it can be described in Figure 2.

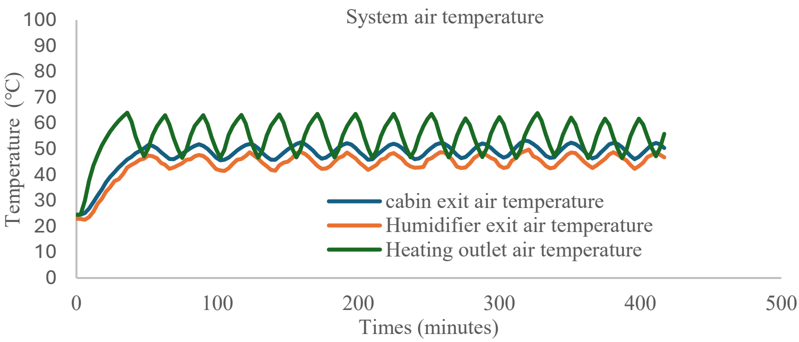

Figure 2. Temperature distribution in the system

Figure 2 shows that the drying process can go smoothly as long as the temperature of the hot air coming into the cabin, the temperature of the air leaving the cabin, and the temperature of the air leaving the humidification process stay mostly the same.

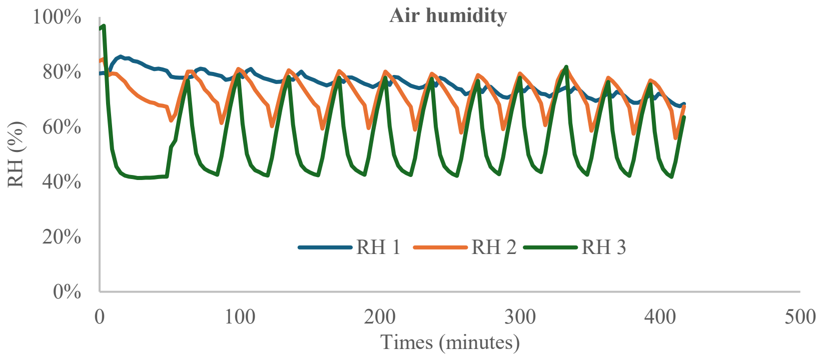

Figure 3. Temperature distribution in the system

Figure 3 shows that the humidity drops when the air is heated, when it is dried, and when it is dehumidified. This is proof that the drying process is going well.

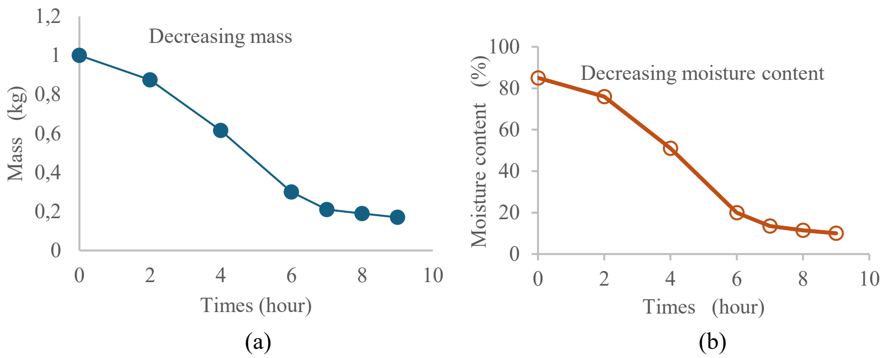

Figure 4. (a) Mass reduction of spice ingredients and (b) Moisture content reduction of spice

The mass and water content drop quickly at the start of the drying process (Figure 4), but they drop more slowly at the end. At the beginning of the drying process, there is a rapid decrease in water 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 touch 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 will decrease. Based on drying standards, Figure 3 also shows that it takes 9 hours for one kilogram of material to dry to a water level of less than 10% (Chua et al., 2002).

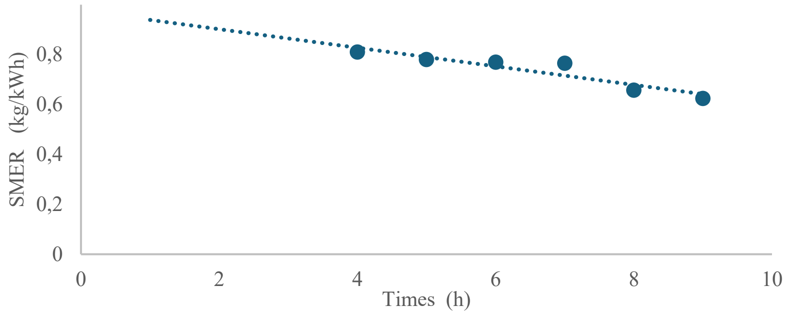

Figure 5. Specific moisture extraction rate (SMER) of spice ingredients

The specific moisture extraction rate (SMER) in this test is quite large as seen in Figure 5 with an average of around 0.7. This shows that the dryer is very efficient, since it takes less energy to remove the same amount of water vapor as the SMER number goes up.

3.2 Discussion

The performance of the thermoelectric drying system is quite promising. The specific moisture extraction rate is quite high, with an average of 0.7. It is higher than using a heat pump drying system, which has an average SMER of 0.55 (Ardita et al., 2023) for the same amount of capacity. However, the drying rate using a heat pump system is slightly faster than using a thermoelectric system.

4 Conclusion

Based on the tests and analyses of the experiments, along with references to previous research, the thermoelectric drying system demonstrates effective functionality. It is observed that the water content reduction happens rapidly at the beginning of the process, while it slows down toward the end. Overall, the system's performance is quite satisfactory, with an average specific moisture extraction rate (SMER) of 0.7, indicating its efficiency in reducing water content.

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