Application of Vapor Compression System in Dehumidification Based Drying Equipment

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Abstract: The refrigeration system is not only used for domestic and commercial air conditioning, but it can also be used to dry agricultural products. This article discusses drying using a dehumidification system that utilizes a vapor compression system, which is better known as a refrigeration system. With this system, the compressor, which is the heart of the refrigeration system, shows that it is safe to use for drying machines. The drying machine was tested on gemitir flowers, which have multiple functions that will decrease if dried at temperatures above 60 degrees Celsius. The machine was set at a temperature of 40 degrees Celsius and a humidity level of 40 percent. Test results show that the average weight loss of gemitir flowers is 85 percent, the product moisture content is 8 percent, and the energy consumed is 4.18 kWh/kg of gemitir flowers.

1 INTRODUCTION

Drying or dehydration is an ancient food processing method that has the potential to preserve and reduce packaging, storage, and transportation costs by reducing the mass and volume of dry or dehydrated products (Potisate et al., 2010). Dry or dehydrated food is microbiologically stable because microbial growth is controlled by low water activity. Protective packaging and several dehydration methods may be required to maintain product quality, including color, taste, and structure (Kerr et al., 2013).

In the drying process, heat is required to evaporate the moisture from the product and air flow to carry the evaporated water vapor, making drying a high-energy consuming operation (Jangam and Mujumdar, 2010). There are various heat sources available for drying, and these have been well discussed in many articles (Bailes, 2015). However, due to the increase in fossil and electricity prices and CO2 emissions in conventional drying methods, green energy-saving and other heat recovery methods for processing and drying products have become very important. Heat pump technology has been successfully used to dry agricultural products as well as for other domestic dehumidification/heating applications. It has been used for heating, ventilation, and air conditioning in the domestic and industrial sectors in most developed countries in the world, including Indonesia. However, heat pump drying (HPD) of fruits and vegetables is largely unexploited in Indonesia.

The purpose of this research is to develop a drying machine with a low-temperature using a vapor compression system, namely a refrigeration system. The refrigeration system has four main components, namely compressor, condenser, expansion valve, and evaporator.

2 MATERIALS AND METHODS

2.1 Material

The Gemitir flower (Tagetes erecta Linn.) is a plant that grows extensively in Central America and countries in Asia, including Indonesia (Aristyanti et al., 2017). Also known as the Marigold flower (Beti, 2020), it exhibits various pharmacological activities such as antibacterial, antioxidant, hepatoprotective,

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antiepileptic, antipyretic, carminative, and more (Siddhu et al., 2017). The flower's color is produced by two main pigments, namely a small number of flavonoids and carotenoids (Aristyanti et al., 2017). Gemitir flowers contain secondary metabolites in the form of terpenoids, essential oils, phenols, flavonoids, and carotenoids (Valvoya et al., 2012).

However, it's important to note that the flower's usefulness decreases or is lost when heated to a temperature above 60°C (Arun Kumar et al., 2010). The Gemitir flowers used as experimental material in this study were dried using a dehumidifier system dryer.

2.2 Dehumidification Drying Machine

Figure 1 shows the schematic of the dehumidification dryer used in this study. The dryer consists of a drying chamber with 7 shelves for placing the bitter flowers, an air circulation room with an evaporator, a fan, and an electric heater. Four fans between the drying chamber and air circulation room facilitate air circulation. Outside the dryer, there is a compressor, condenser, fan, and expansion valve.

The dehumidifier system drying machine works by directing air from the drying chamber to the fan and evaporator. The air in the evaporator is cooled, causing water vapor from the air in the drying chamber to turn into water, which is then discharged. The cold and dry air then flows into the electric heater, where it is heated before entering the drying racks filled with bitter flowers. The heated air helps to evaporate the water vapor from the gemitir flowers, which then flows upwards. The humidity of the drying air increases after passing through the bitter flowers and moves towards the evaporator. In the evaporator, the air is cooled, and the water vapor it carries is condensed. This process is repeated until the bitter flowers are dried to the desired level. The temperature in the drying chamber is regulated using a thermostat, while the humidity is controlled using a humidistat, which turns on the compressor when necessary.

2.3 Methode

This method assumes that the experiment is conducted on a small scale, and that there is only one batch of flowers being dried. If the experiment is conducted on a larger scale or over multiple batches, adjustments may need to be made to the method to ensure accuracy and consistency.

2.3.1 Drying Process:

a) Place one portion of the fresh flowers onto each shelf of the drying chamber, ensuring that each shelf contains 500 grams of flowers.
b) Start the timer and begin the drying process.
c) Monitor the temperature and humidity levels at point (4), point (12) and point (14) throughout the drying process.
d) Record the time it takes for the flowers to dry completely.

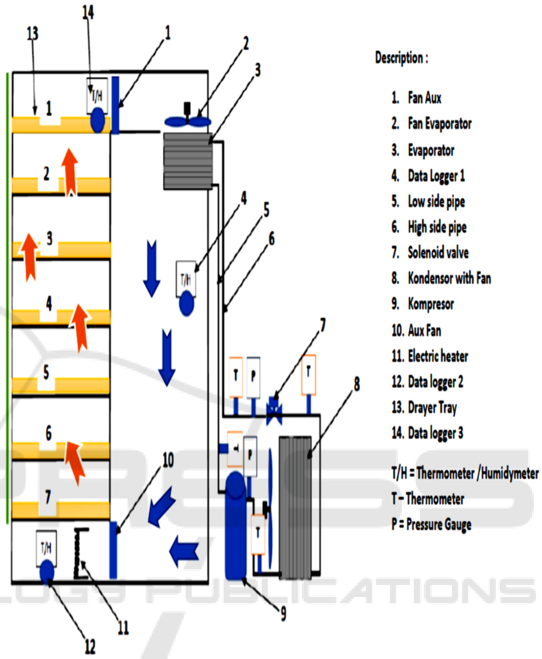

Figure 1: Drying machine dehumidification system.

2.3.2 Measurement:

a) Once the flowers are dry, remove them from the drying chamber and weigh them.
b) Record the weight of the dried flowers.
c) Calculate the moisture content of the flowers using the following formula: Moisture content (%) = (Initial weight - Final weight) / Initial weight x 100%

2.3.3 Analysis:

a) Analyze the data collected to determine the effectiveness of the drying process.
b) Evaluate the temperature and humidity levels at each monitoring point and their impact on the drying process.
c) Assess the overall efficiency of the drying process and determine any improvements that can be made.

3 RESULTS AND DISCUSSION

Based on the test results, weight measurements and data obtained from the data logger were used to create graphs and tables for easier analysis. Figure 2 shows the graph of the drying chamber temperature measured at three different points.

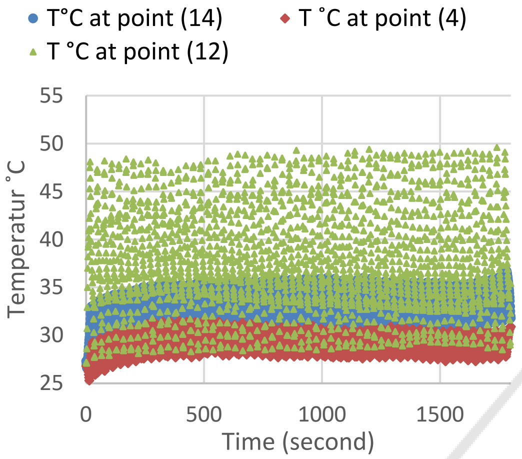

Figure 2: Graph of drying chamber temperature from 3 measurement points.

However, the measurements obtained from the data logger show a wide range of values, indicating that the airflow measured by the sensor is not laminar. The temperature at measurement point (12) tends to be higher than the others, as the air at that point has passed through the heater. After passing through the heater, the air then passes through the flower, which causes a slight decrease in temperature, as seen at point (14). Finally, the air reaches the evaporator and measurement point (4), which records the lowest drying air temperature.

To improve the accuracy of the measurements, it may be necessary to ensure that the airflow is laminar during the testing process. Additionally, future tests could be conducted to compare the results obtained from the data logger with those obtained from other measuring devices, to confirm the accuracy of the measurements.

Overall, the data obtained from the weight measurements and data logger provide valuable insights into the performance of the drying chamber, and can be used to optimize its operation in order to achieve more efficient and effective drying results.

The results of the drying chamber humidity measurements are shown in Figure 3. The highest humidity levels are recorded at point (12), as the air However, the humidity tends to decrease as the air passes through the load of bitter flowers, which absorbs some of the moisture. passes through the heater and its moisture content increases.

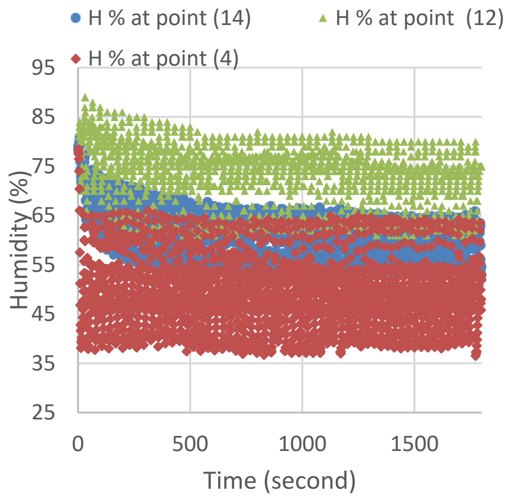

Figure 3: Drying chamber humidity graph from 3 measurement points.

Finally, the air passes through the evaporator and its humidity level is the lowest at point (4), as the air is condensed into liquid form.

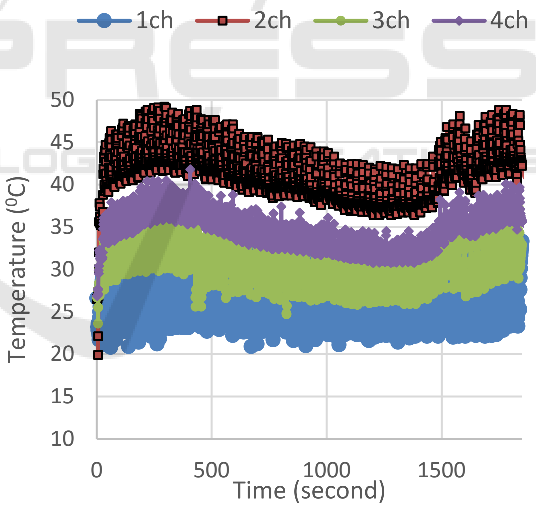

Figure 4: Graph of measurement points on the refrigeration system.

Figure 4 shows the measurements obtained from the refrigeration system. Channel 1 records the lowest temperature, as it is located at the point where the R32 refrigerant enters the compressor in its gaseous form. Channel 2 records the temperature of the refrigerant as it exits the compressor, having been pressurized and heated. Channel 3 records the temperature of the refrigerant as it passes through the condenser and its heat is removed, causing the refrigerant to condense into a liquid form. Finally, channel 4 records the temperature of the refrigerant as it passes through the expansion valve, causing its pressure to decrease and its temperature to remain relatively constant.

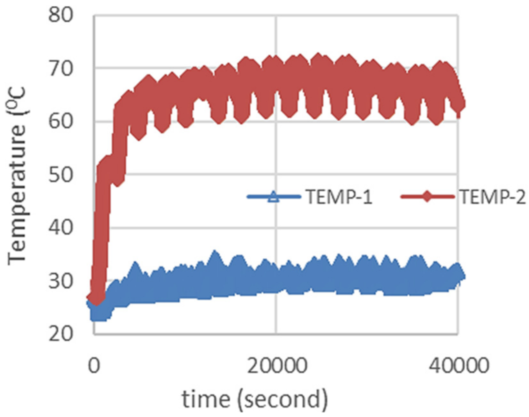

Figure 5: Graph of compressor casing temperature while operating. (1.lower casing, 2.upper casing).

To ensure the safety of the refrigeration system, it is important to monitor the temperature of the compressor, which is the heart of the system. Figure 5 shows the graph of the compressor casing temperature while the system is operating.

Figure 6: Gemitir flowers that have been dried for 24 hours in a dehumidification system dryer.

The temperature of the compressor casing is a good indicator of whether the system is operating safely or not. If the temperature of the casing is close to 100ºC, it indicates that the compressor is operating in unsafe conditions and its coils may burn.

However, if the temperature is far below 100ºC, then the system can be considered safe. In this particular system, the compressor operating temperature is around 70ºC, indicating that the system is operating within safe parameters and the compressor motor is not at risk of burning out. Monitoring the compressor temperature is an important part of ensuring the safe and efficient operation of the refrigeration system.

After 24 hours the dryer is turned on, the results of the dried gemitir flowers are as follows:

Table 1: Yield of dried gemitir flowers.

Shelf	Initial Weight (Grams)	Final Weight (Grams)	Weight Loss (%)	Moisture content (%)
1	150	25	83%	10,5
2	150	25	83%	9
3	150	25	83%	8,3
4	150	25	83%	8
5	150	25	83%	7,8
6	150	20	87%	7,5
7	150	15	90%	5
Total Energi			14,63 kWh	

The drying process resulted in an average weight loss of 85% for the gemitir flowers after 24 hours. The largest weight loss was observed on rack number 7, which is positioned directly above the electric heater and receives the most heat. The average moisture content of the dried gemitir flowers was measured at 8%.

To calculate the energy required to convert fresh gemitir flowers into dried gemitir flowers, we divided the total energy spent (14.63 kWh) by the total weight of the dried flowers (3.5 kg). The resulting energy consumption was 4.18 kWh/kg of gemitir flowers.

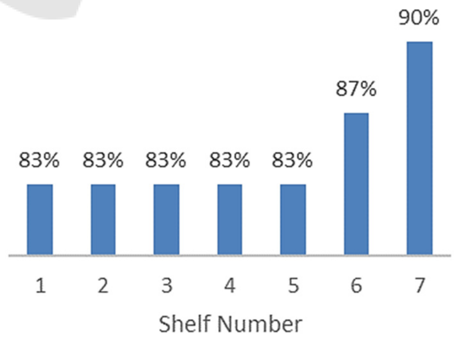

Figure 7: Loss of weight after drying.

This energy consumption value can be used to optimize the drying process and minimize energy waste. Additionally, the information about the weight loss and moisture content of the dried flowers can help determine the appropriate storage conditions and shelf life of the product.

Overall, the results of the drying process indicate that the system is effective at removing moisture from the gemitir flowers, with the largest weight loss occurring on the rack positioned closest to the heat source. The calculated energy consumption value can be used to improve the efficiency of the process and ensure optimal product quality.

4 CONCLUSIONS

In conclusion, the dehumidification system using a refrigeration system was successful in drying gemitir flowers, resulting in a weight loss of 85% and an energy consumption of 4.18 kWh/kg. The system can be optimized by monitoring weight loss and energy consumption, allowing for adjustments to be made to improve efficiency and reduce energy waste.

The results of this study can be used to improve the overall effectiveness and cost-efficiency of the drying process for gemitir flowers. With further optimization, this system could potentially be used on a larger scale for commercial drying applications.

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