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Clove (Syzygium aromaticum) Drying Using Hybrid Rack-Type Drying House

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Abstract. *The objective of this research is to analyze the drying time of cloves using a hybrid rack-type drying house. The study was conducted for 60 days in Harapan Jaya Village, Wayratai Subdistrict, Pesawaran Regency, Lampung. The tools used include a rack-type drying house, Lux meter UT383, digital scale, grain moisture meter AR991, analog thermometer, hygrometer, and a gas stove. The tested material in this research was fresh cloves, amounting to 12.5 kg. The experimental method with two different treatments was employed in this study. Firstly, testing without additional energy was divided into drying using a drying house (using natural energy or sunlight) and sun drying without a drying house. Secondly, testing with additional energy included drying using a drying house with additional energy from sunlight and gas-fired heaters. Based on the research results, it can be concluded that the time required to dry 22.5 kg of cloves to a moisture content of 12.5% is as follows (1) drying with a drying house using solar energy takes 180 hours (8 days), (2) drying with a hybrid drying house using solar energy and gas takes 132 hours (6 days), (3) sun drying using traditional methods (without a drying house) takes 162 hours (7 days). The hybrid drying house is suitable for the drying process in high-altitude areas or during cloudy or rainy weather, as it can continuously carry out the drying process, whether there is sunlight or not.*

Keywords: *Cloves, Drying, Drying Time, Hybrid, Post-Harvest.*

1. Introduction

Cloves are one of the seasonal plantation commodities that play a crucial role in both food and non-food sectors. The majority of clove production is utilized in the kretek cigarette industry, pharmaceuticals, cosmetics, and perfumes (Nurdjannah, 2004). To maintain the quality of cloves, drying efforts are employed to enhance their durability for storage and add value. Post-harvest handling of cloves at the farmer level is traditionally carried out, starting from manually threshing the flowers, a time-consuming process (Jannah *et al*., 2020). Drying must be promptly conducted after harvesting because delayed drying can negatively impact the quality of cloves.

Drying is a critical post-harvest process. It involves the separation of a small amount of liquid from a substance, reducing its moisture content (Ridhatullah & Hasibuan, 2019). The drying process requires the movement of hot air to extract moisture from the surroundings through evaporation. The drying rate or the rate of water evaporation in the drying process is significantly influenced by the temperature of the drying air. Elevating the drying air temperature reduces the heat needed for the evaporation process. Thus, the role of air temperature in drying is crucial (Risdianti *et al*., 2016), and it can be accomplished in two ways: natural drying and artificial drying. Natural drying or conventional drying involves spreading the dried product on the floor, whether it is made of cement or soil, followed by sun drying. It is resistant to heat and requires a fast drying time.

The traditional drying process employed by clove farmers using sunlight takes 4-6 days, with a daily drying time of 8-9 hours (Alfitri *et al*., 2019). In reality, this drying process is highly influenced by environmental conditions, especially temperature. Sometimes, the drying process coincides with the rainy season, posing a challenge for traditional drying methods.

The rack-type hybrid drying house is a design used for product drying, offering advantages such as independence from weather conditions, minimal space requirements, measurable temperature changes, and adjustable drying capacity based on needs. The rack-type hybrid drying house harnesses solar and gas energy. The aim of this research is to analyze the drying time of cloves using a rack-type hybrid drying house.

2. Research Methods

The research was conducted over a period of 60 days in Harapan Jaya Village, Wayratai Subdistrict, Pesawaran Regency, Lampung. The equipment used included a rack-type drying house with dimensions of 20m in length, 4m in width, and 2m in height (Figure 1). Additionally, other equipment utilized comprised a Lux meter UT383, a digital scale with a capacity of 5 kg, a grain moisture meter AR991, an analog thermometer, a hygrometer, and a gas stove. The material tested in this study was fresh cloves, amounting to 12.5 kg.

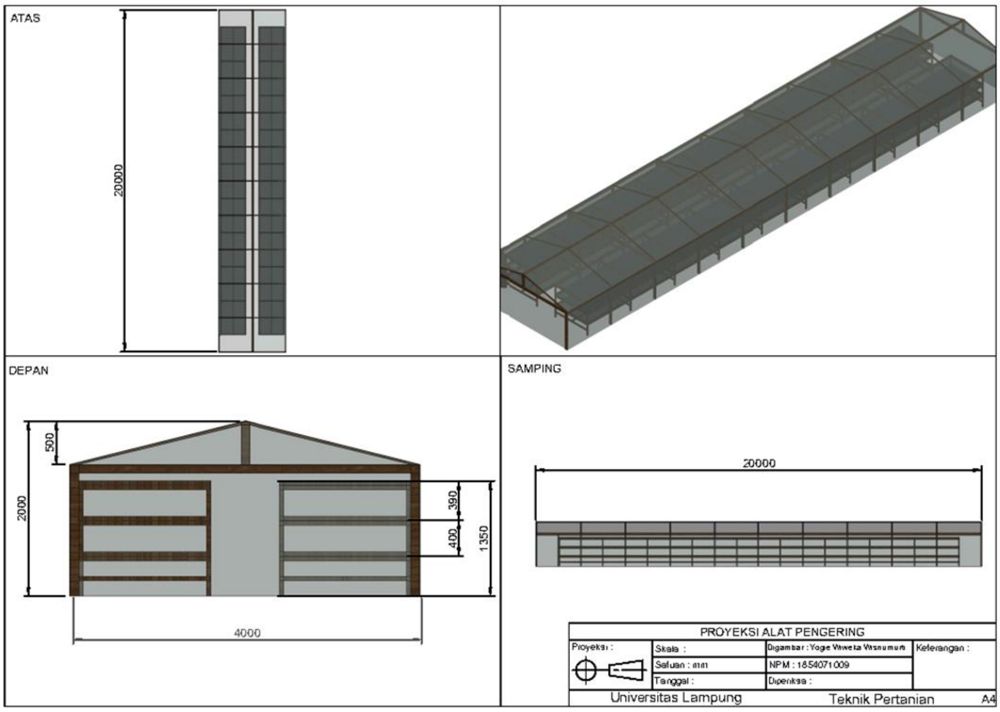

Figure 1. Rack-type hybrid drying house design

The rack-type hybrid drying house is covered with UV plastic, serving to absorb solar heat as an energy source during the drying process. In addition to UV plastic, the rack-type hybrid drying house is equipped with a gas-fired stove. The stove aids in the drying process during nighttime when sunlight is unavailable, enabling the drying house to operate continuously for 24 hours with available heat. The rack-type hybrid drying house has two sections (right and left racks) inside the drying space. Each section contains three layers of drying racks, with only two racks used in each section: two racks on the right side (top and middle racks) and two racks on the left side (top and middle racks).

This research employs an experimental method with two different treatments. Firstly, testing without additional energy is divided into drying using the drying house (using natural energy or sunlight) and sun drying without a drying house. Secondly, testing with additional energy includes using a drying house with additional energy from sunlight and gas heaters.

The initial step in this research involves testing without additional energy using two methods: drying with a drying house using solar energy. Data collection was performed every hour for 8 hours. Testing without additional energy involved 5 kg of cloves. Testing with additional energy used sunlight and gas for 5 kg of cloves, and conventional sun drying for 2.5 kg, resulting in a total of 12.5 kg of material used in this testing.

Observations were made on drying temperature, drying time, and moisture content measurements during the drying process. These calculations were necessary to determine the efficiency level of the drying house when used for clove drying. Data collection for the testing without a load was carried out for 8 hours, with data collected every 30 minutes for the first 5 hours and then every hour afterward. Testing without a load aims to determine the temperature inside the drying house when there is no material drying.

1. Drying Temperature
   Air temperature in the drying house was measured using an analog thermometer placed on the rack inside the drying house and outside to determine the ambient temperature, observed every hour.

2. Drying Time
   Drying time is the duration needed to dry clove flowers, starting from sunlight exposure or when the gas stove is ignited until the desired moisture content of the cloves is achieved, i.e., at least ±12% (Amelia *et al*., 2019).
3. Moisture Content
   Moisture content in this study was calculated from the beginning when cloves started drying until the desired moisture content was reached. Moisture content measurement was performed using a grain moisture meter. The moisture content would be visible on the grain moisture meter during the measurement process. One sample was taken from each rack, and the sample was then placed in the grain moisture meter to obtain the moisture content value by inserting the dried cloves into the checking compartment of the grain moisture meter. The cloves were pressed with the device, and the moisture content data would appear as a numerical value. Moisture content measurement was calculated based on the equation for moisture content calculation (wet basis).

$$KA\ (\%\ bb) = \frac{W_{awal} - W_{akhir}}{W_{awal}} - 100\ \% \tag{1}$$

   Whereas, KA represents the moisture content of the material on a wet basis (%), Wawal is the weight of the sample material before drying (grams), and Wakhir is the weight of the dried sample materian (grams).

3. Results and Discussion

3.1. Testing of Drying House Without Load

Testing of the drying house without a load was conducted using two methods: testing with solar energy and testing with solar energy and gas (hybrid). The aim of testing the drying house without a load was to determine the temperature inside the drying house when there is no material drying.

3.1.1 Testing using solar energy

The room temperature during the testing without a load using sunlight in the drying house ranged from 26°C to 43°C. The highest temperature was recorded on the top rack (rack no. 1), both on the right and left sides, while the lowest temperature was observed on the middle rack (rack no. 2), both on the right and left sides. This variation is due to the fact that the only source of heat energy is sunlight. Consequently, the top rack receives direct sunlight without any obstruction from other racks. Changes in room temperature during the testing of the drying house using solar energy are shown in Figure 2.

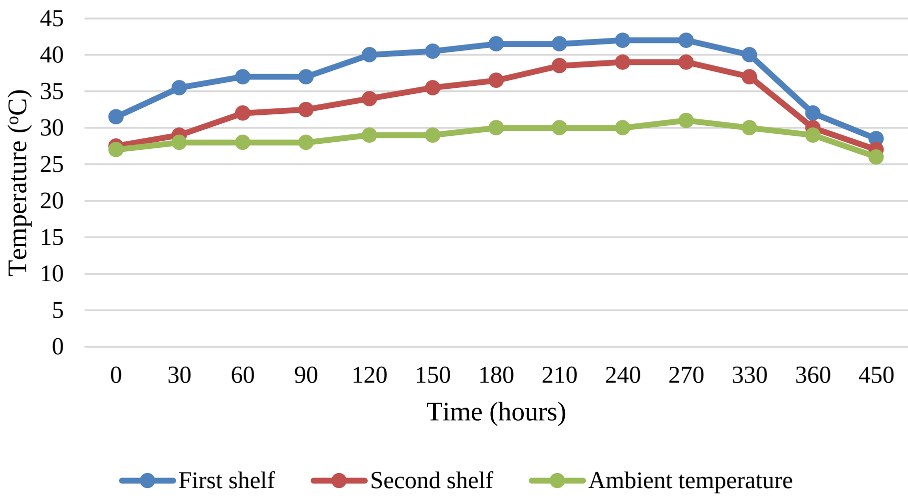

Figure 2. Temperature changes in the drying house without load using solar energy

The room temperature during the testing of the drying house without a load using solar energy tends to rise continuously, although there are decreases at minutes 180, 300, 360, and 420, influenced by uncertain weather conditions, which also affect the changes in ambient temperature. Temperature changes can impact the drying duration and the quality of the material (Putra & Kuncoro, 2021). The average ambient temperature in this testing was 28 ºC. The maximum temperature recorded during the testing using solar energy was 43 ºC. The difference in the maximum temperature on the top rack, both on the right and left sides (first shelf), and the middle rack, both on the right and left sides (second shelf), is due to sunlight exposure.

3.1.2 Testing using solar energy and gas (hybrid)

Based on the observation results shown in Figure 3, the temperature generated from the load-free hybrid testing ranged from 27 ºC to 34 ºC. The temperature during hybrid testing is relatively more stable. This is due to the presence of heat energy from the gas used in the testing, making the heat generated inside the drying space more stable during the nighttime compared to testing using solar energy. The following are the testing data obtained.

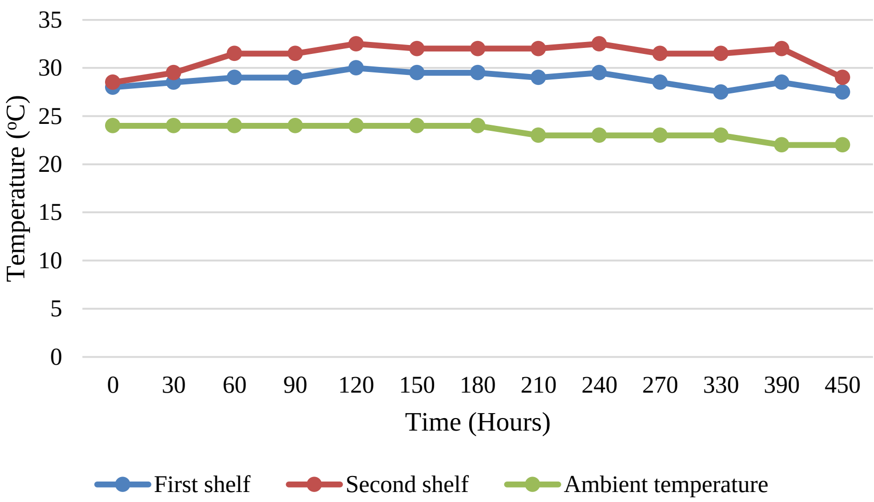

Figure 3. Temperature changes in the testing of the apparatus with material using solar and gas (hybrid) energy

The room temperature during the testing of the drying house without a load using solar and gas (hybrid) energy tends to be stable. The average ambient temperature in this testing was 23.25 ºC. The highest temperature during the testing of the drying house using solar and gas (hybrid) energy was on the bottom rack (rack 2). The load-free testing using solar and gas (hybrid) energy had a lower temperature compared to the first testing. This is because this testing was conducted during the night when there was no sunlight, driven by the lower ambient temperature compared to the first testing. This testing was carried out by turning on the gas stove placed on the floor of the drying house, causing the bottom rack to receive heat first, followed by the top rack, resulting in different temperatures for the top and bottom racks.

3.2. Testing with Load

Each rack was provided with a base consisting of dense wire (wire mesh) and a net containing 2.5 kg of evenly spread cloves. During the testing using solar and gas energy as the heat source in the drying space, temperature changes with a load were recorded every hour.

3.2.1 Testing Using Solar Energy

Testing the drying house with a load using solar energy took 8 days or a total drying time of 180 hours to achieve the specified moisture content. During the testing, the temperature inside the racks ranged from 20 ºC to 44 ºC (Figure 4). The highest temperature was only on the top rack (first shelf) because in this testing, the heat source for drying the cloves was only from the sunlight. The temperature difference between the top rack and the one below it ranged from 2 ºC to 6 ºC. This significant difference was due to the sunlight being obstructed by the spread of cloves on the top rack, preventing direct sunlight for the rack below it. Therefore, the heat energy from the sunlight affected the top rack more (first shelf).

The temperature distribution between the right rack (KA) and the left rack (KI) in this testing was relatively even when viewed based on the average temperature data. However, when considering the location of the racks, the temperature had a significant difference. Some challenges that occurred during testing using solar energy included weather conditions, which were sometimes unfavorable (cloudy), resulting in suboptimal and unstable heat generated in the drying space. The sunlight intensity greatly affected the temperature; the higher the sunlight intensity, the higher the temperature inside the drying space.

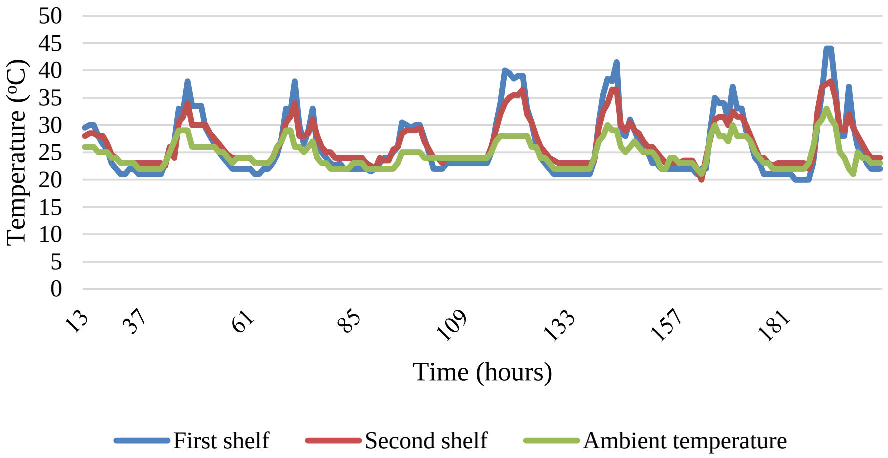

Figure 4. Temperature changes in the testing of the apparatus with load using solar energy

3.2.2 Testing using solar energy and gas (hybrid)

Testing the drying house with material using solar and gas (hybrid) energy took 6 days or 130 hours (Figure 5) and consumed 78,268 J of gas to achieve the desired moisture content. The heat source in this drying process utilized two heat sources: solar heat and gas heat. As a result, the air temperature inside the drying space was higher compared to using only one source of solar energy. During the testing, the temperature ranged from 20 ºC to 51 ºC. The highest temperature occurred on the top rack near the sunlight (first shelf) during the day, and at night, the highest temperature was on the rack below it (second shelf). This was because this testing used the energy source from the gas stove to dry the cloves.

The temperature generated in the drying process using solar and gas energy (hybrid) was higher compared to drying using only one energy source. One advantage of drying using gas and solar energy (hybrid) is that it can still be carried out when it rains or the weather does not support drying. The average ambient temperature obtained in this testing was 24.88 ºC.

In this testing, the drying house was directly exposed to sunlight during clear weather. If the weather is not clear (cloudy), the drying process can still be carried out using gas energy. This process is referred to as hybrid drying, utilizing two heat sources simultaneously. If one heat source encounters issues, the drying process can still be continued with the other heat source.

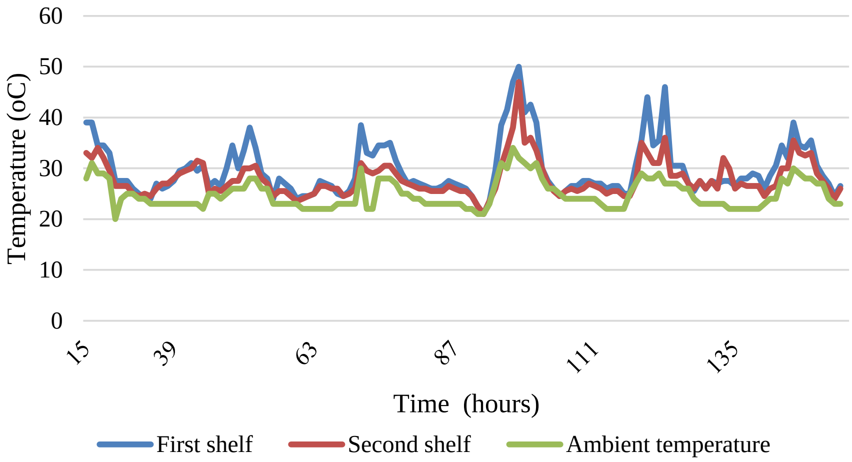

Figure 5. Temperature changes in the testing of the apparatus with load using solar and gas (hybrid) energy

3.2.3 Traditional drying testing

Traditional drying was performed using a base made of a bamboo-woven tray. This testing was conducted as a control against the testing of the hybrid rack-type drying apparatus. This traditional method relies on weather conditions, requiring a longer time (Yultrisna *et al*., 2017). The material used for drying was the same as in the apparatus testing, which was 2.5 kg of cloves. The control drying was carried out for 10 days with 8 hours of effective drying each day, totaling 79 hours of drying time. Cloves were dried directly under sunlight exposure, making traditional drying highly dependent on the weather. Temperature measurements in this drying were taken based on the ambient temperature. The highest temperature recorded was 34 ºC, and the lowest temperature was 23 ºC. The average ambient temperature was 27.54 ºC. The graph of temperature changes in this testing can be seen in Figure 6.

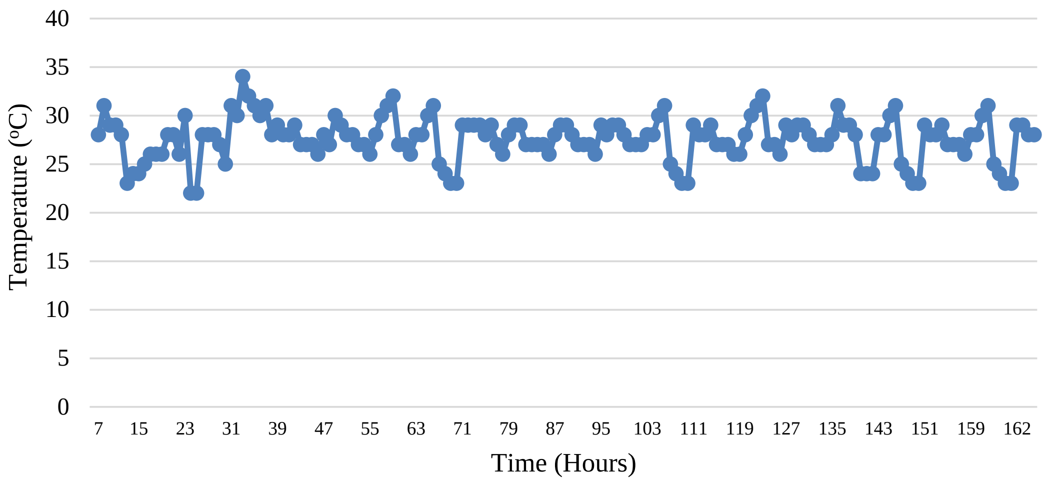

Figure 6. Temperature changes in sun drying with tray

3.3. Moisture Content

3.3.1 Moisture content decrease with solar energy

The average initial moisture content in the testing using solar energy was 40.3%, while the average final moisture content after drying for 8 days, with effective drying time of 8 hours each day, totaling 180 hours of drying time, was 12.5%. The decrease in moisture content after drying varied for each rack (Figure 7). The average final moisture content on both racks was the same, namely 12.5%. The decrease in moisture content during drying was 27.8%. The average daily decrease in moisture content for solar energy drying was 3.38%.

3.3.2 Moisture content decrease with solar and gas (hybrid) energy

The average initial moisture content in the testing using hybrid energy (Figure 7) was 40.2%, while the average final moisture content after drying for 6 days, with effective drying time of 24 hours each day, totaling 132 hours of drying time, was 15.52%. The decrease in moisture content after drying varied for each rack. The average final moisture content on both racks was the same, namely 12.5%. The decrease in moisture content during drying was 27.7%. The average daily decrease in moisture content for solar and gas energy drying was 4.94%.

3.3.3 Moisture Content Decrease with Traditional Method

This drying was performed only as a comparison with drying using trays (conventional). Traditional drying took 10 days with effective drying time of 8 hours each day, totaling 270 hours of drying time to achieve a moisture content of 12.5%. The initial moisture content in traditional drying was 40.2%, and the final moisture content obtained after drying was 12.5% (Figure 7).

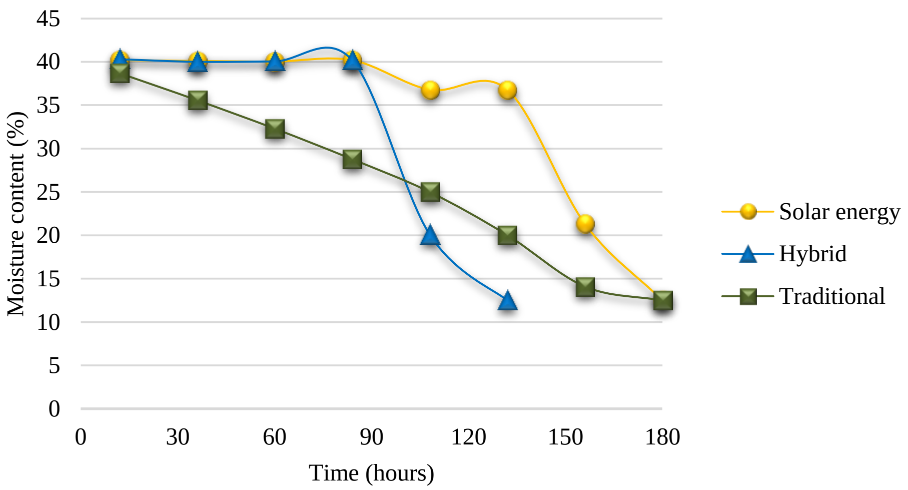

Figure 7. Changes in moisture content in the three drying methods

Based on the presented test results, it can be observed that the fastest decrease in moisture content occurred in the testing using solar and gas energy (hybrid), which required 132 hours or 6 days. This is reinforced by research conducted by Sari *et al*. (2014) and Munandarsyah *et al*. (2018) proving that drying with a hybrid system results in a shorter drying duration. This is followed by testing using trays, which required 270 hours or 10 days, and solar energy drying, which required 180 hours or 8 days. This is because in the drying process using solar and gas hybrid energy, the gas stove is turned on during the night, allowing the drying process to be continuous, leading to a faster drying process compared to solar heat drying and conventional sun drying.

Another constraint that causes drying using solar energy and conventional sun drying to take a long time is because the clove drying process is highly dependent on the weather during the drying process (Prayuda *et al*., 2022). Additionally, indirectly, traditional drying can affect the quality of the material in terms of cleanliness.

4. Conclusion

Based on the conducted research, it can be concluded that the duration for drying 22.5 kg of cloves to achieve a moisture content of 12.5% is as follows: drying with a solar dryer requires 180 hours or 8 days, drying with a solar and gas hybrid dryer requires 132 hours (6 days), and sun drying using trays (conventional) requires 162 hours (7 days). The hybrid drying house is suitable for the drying process in highland areas or during cloudy or rainy weather, as it can perform the drying process continuously, whether there is sunlight or not.

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