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Temperature control system on greenhouse effect gaplek dryer

Bandiyah Sri Aprillia[1*], Brahmantya Aji Pramudita[2], Prisma Megantoro[3]
[1,2] Telkom University
[3] Universitas Airlangga
[1,2]Bandung, Indonesia
[3]Surabaya, Indonesia
*Corresponding email: bandiyah@telkomuniversity.ac.id

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Abstract — Gaplek is a processed product of cassava that requires a drying process to remove the water content in cassava. Solar thermal energy can be used for the drying process of gaplek by using a greenhouse effect drying system. However, the greenhouse effect drying system using solar thermal energy is very dependent on weather conditions and temperature that is difficult to control. Therefore, a temperature control system is proposed in this study by utilizing Pulse Width Modulation (PWM) to control the exhaust fan speed. Thus, the temperature can be maintained according to the drying standard of processed cassava products. In this study, a temperature control system has been successfully created that is able to maintain the temperature in the drying room according to the drying standard, namely at a temperature of 50℃ to 60℃ when tested in three different locations, namely, Sukamaju Village, Kaligunting Village, and Sumberejo Village which have shown optimal drying temperature.

Keywords – Greenhouse effect drying system, PWM, temperature, control, exhaust fan

I. INTRODUCTION

Cassava (Manihot esculenta Crantz) is an herbaceous plant that stores food reserves in tree roots. Food reserves produced by cassava can be used as an alternative food source and staple foods in many areas that contain lots of carbohydrates [1]–[3]. Various processed products are produced from the basic ingredients of cassava. Gaplek is one of the processed cassava tubers. It has a high nutritional content and has many uses for processed foods, such as cassava flour which can be used in the process of making food such as bread, cakes, and other food products [4], [5]. However, when cassava is processed, several processes are needed before being processed, namely the process of stripping and drying. The drying process is very important because it removes the moisture content in the cassava and also makes cassava can be stored for a longer time [6]. So that, it produces gaplek with good quality.

Various drying systems have been designed for use in the drying of various agricultural or plantation preparations. In addition, drying systems have been developed to maximize the function of the dryer. Thus, improving drying performance to save production costs. Furnace design engineering is a viable way to improve drying performance and can be done in a number of ways.

In the study of the cocoa bean dryer [7], the conventional furnace was modified by changing the structure of the oven floor slope to 45℃. The structure is designed to let hot air out quickly through the rack. For making seaweed drying furnaces mild steel is used as raw material [8]. Mild steel is used because of its advantage in holding heat well, strong, and affordable. Based on these studies, the structure and types of materials used in the manufacture of drying furnaces can be used to maximize drying and minimize the production costs of dryers.

The way a dryer works is to use the hot air that is exhaled to be spread throughout the drying room. Various systems are used to blow the hot air such as centrifugal fan [8], pneumatic [9], flash dryer [10], cabinet dryer [11], thermoelectric [12], [13], etc. Each system is designed based on needs. In addition, the characteristics provided by the system are different. The furnace type batch drying system has good performance because it can provide a short drying process. These results are influenced by the performance characteristics of the system which can increase the rate of evaporation of water by producing high temperatures [14].

The heat energy generated by the sun can be used for the drying process. Various advantages can be obtained from the use of sunlight, such as ease of application, and require a very low cost. However, the disadvantages obtained from the drying system with sunlight are that it depends on weather conditions, is difficult to control, is large, easily contaminated, and takes a long time [15]. One way to overcome this problem is to absorb heat energy from the sun and then reuse it by dispersing the heat in an enclosed space. Thus, heat energy can be collected, confined, and activities such as the greenhouse effect occur. The drying system using this method is called the greenhouse effect solar dryer.

The greenhouse effect drying system in the previous study was used to dry mocaf flour (modified cassava flour). The system was proven to be able to increase the temperature at a temperature of 40-50℃ even without additional heating [16]. However, without additional heating, the system was very dependent on the intensity of sunlight and temperatures which cannot be controlled because of uncontrollable weather conditions. The design of the greenhouse effect dryer system has been developed in combination with a biomass furnace called the hybrid type dryer [17]. Hybrid systems have the advantage of solar and biomass energy sources being abundant so that operating costs can be reduced. In addition, the hybrid system is designed to overcome problems related to weather and solar energy dependence [17]. However, the temperature generated by the greenhouse effect drying system cannot be controlled. The temperature needs to be controlled to obtain the optimal temperature of the object being dried so that drying can be done to the maximum effect.

The greenhouse effect drying system has great potential to maximize its performance for drying gaplek. Therefore, in this study, the electronic system was designed to maximize the drying performance of the greenhouse effect dryer system. This electronic system is used to control the temperature. Moreover, the proposed system is examined at three different places to evaluate the control performance, so it is optimal when drying automatically takes place. This way, the gaplek can be dried effectively.

II. RESEARCH METHODS

A. *Greenhouse Effect Dryer System Design*

Fig.1. Base of the dryer room

The construction of the solar drying system consists of the base and the walls of the building. The pedestal is made using river stone and arranged according to the size of the outdoor space, which is 28m^2 as shown in Fig. 1.

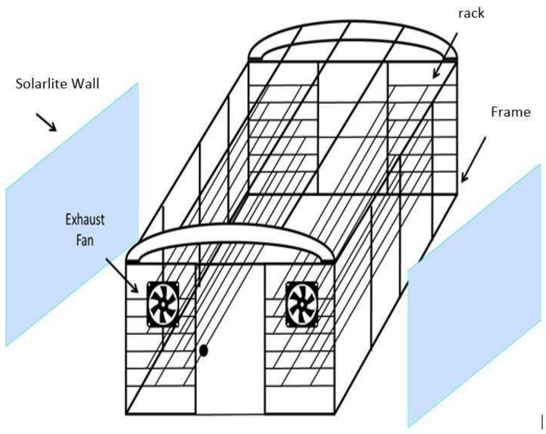

Fig.2. Framework and wall illustration of building

The design of the walls of the building is made of iron frame material and covered with solarlite material as shown in Fig. 2. The iron frame is made with 24 support posts that can support loads, including rack loads. The choice of solarlite as a wall-making material is due to the ability of solarlite to absorb sunlight well.

B. *Electronic System Design*

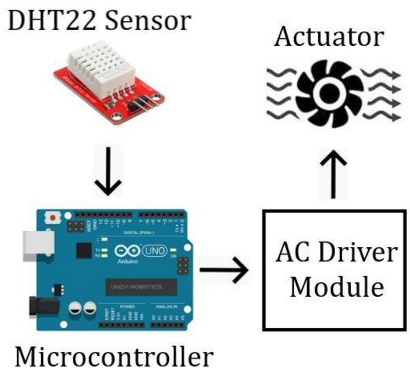

Fig.3. Temperature and humidity controller electronic system design

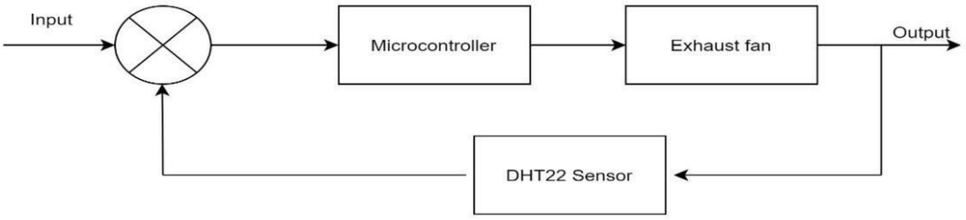

Fig.5. System block diagram of greenhouse effect gaplek dryer.

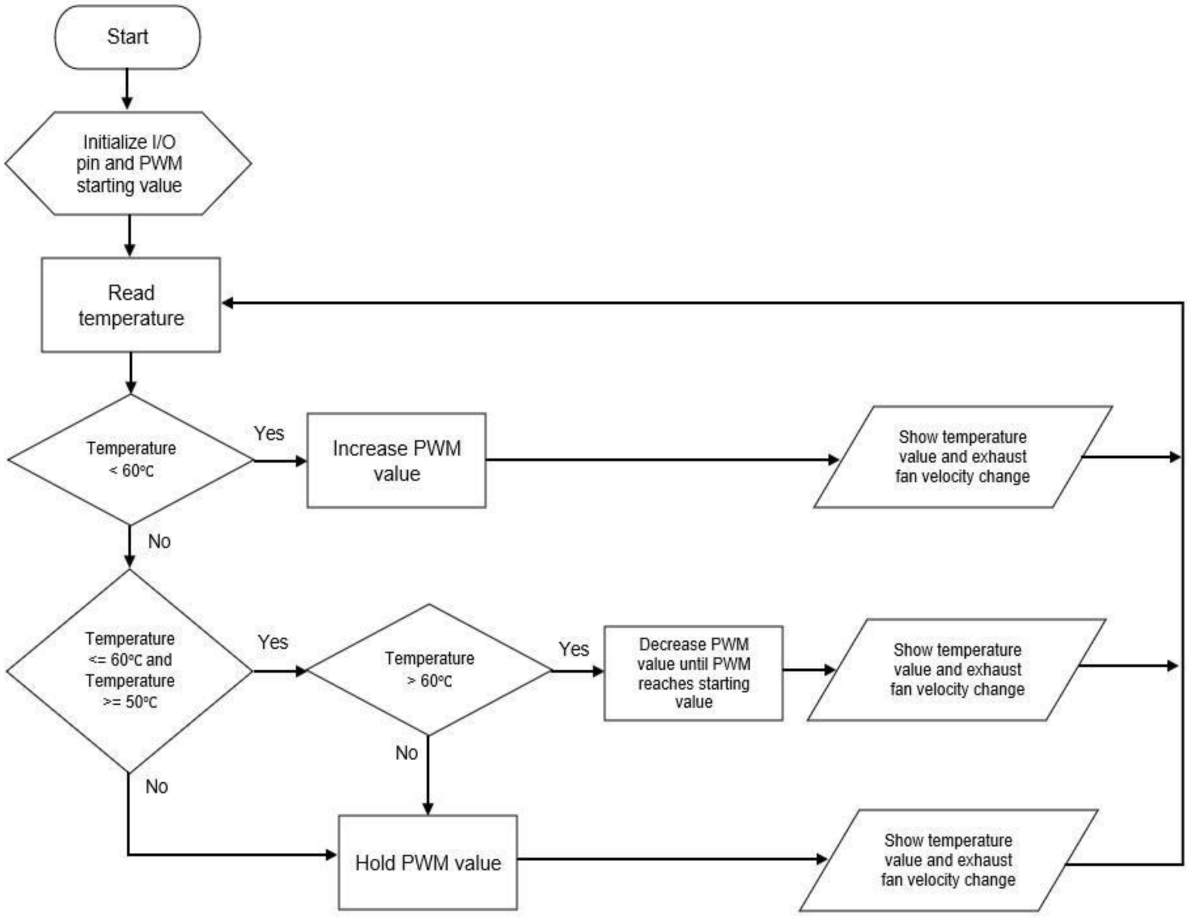

Fig.4. System flowchart of greenhouse effect gaplek dryer controller.

The electronic system is designed to be able to control the temperature and humidity to maintain it at the optimal drying temperature and humidity. The system consists of DHT22 sensors, microcontrollers, and actuators as shown in Fig. 3. The DHT 22 sensor is used to measure temperature and humidity in the room. The microcontroller is used to receive measurement data and use the data as actuator control parameters as shown in Fig. 4. The type of microcontroller used is Arduino Uno, while the actuators used are two exhaust fans. This electronic system also designed a driver module for the exhaust fan. This driver module is used to control the exhaust fan rotation speed according to the drying room temperature conditions.

The total energy required to run all electronic devices is only 13.4 W. The detailed energy consumption of electronic devices consists of one DHT22 sensor (5V DC x 200mA) and 2 exhaust fans (2 x 6.2 W).

C. Control System Implementation

The system design is tested to see the performance of the system to control the temperature in the drying room. In this study, the system was tested directly in several gaplek producing areas, namely, Kaligunting village in Madiun district, Sukamaju village in North Lampung district, and Sumberjo village in Gunung Kidul district. The test was carried out in several areas to determine the performance characteristics of the system with different ambient temperatures. The testing was carried out from 06.00-21.00.

Pulse Width Modulation (PWM) is a method to manipulate the square wave pulse width in one period to control the output voltage [18]. PWM is used to control the exhaust fan speed according to the measured temperature in the drying chamber. The control design as shown in Fig. 4 shows that the control system made is a close loop control system. This system will detect the temperature of the input parameters of the microcontroller. Then, the microcontroller will give a command to the actuator, namely the exhaust fan to work. When the actuator is working the temperature will be detected by the DHT22 sensor. The results of measuring the DHT22 sensor are used for microcontroller control parameters. Then, command the actuator again according to the temperature that has been measured and the system works repeatedly.

Fig. 5 shows the design flow of the drying room temperature control algorithm. The temperature is detected first by the DHT22 sensor. The readable temperature value is used as a control parameter because the greenhouse effect type dryer is able to increase the temperature of the dryer by 40-50℃ [16]. The control rule of the system is that if the temperature reads more than 60℃ then the PWM value will be maximized. Then, the exhaust fan module driver provides maximum voltage so that the exhaust fan speed is maximized. When the temperature detected by the system is between 50℃-60℃. Then, the system will detect the initial temperature conditions. If the initial temperature is above 60℃ then the PWM value will be lowered until it reaches the initial PWM. However, if the initial temperature is below 50℃ then the PWM value will be maintained. In addition, the system will work continuously and stop if there is no voltage source.

III. RESULT

Fig. 6, 7, and 8, respectively, show intermittent solar radiation in the Kaligunting, Sukamaju, and Sumberjo areas based on forecasting potential solar power from the global solar atlas. Based on Fig. 6, 7, and 8, the villages of Kaligunting, Sukamaju and Sumberjo have the potential to utilize solar radiation for the drying process of plantation products.

Fig.6. Monthly Irradiance averages in Kaligunting Village, Madiun District.

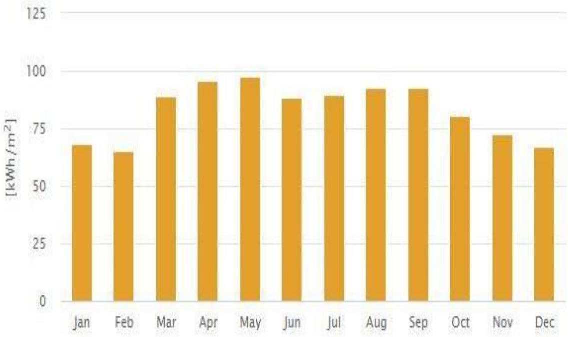

Fig.7. Monthly Irradiance averages in Sukamaju Village, North Lampung District.

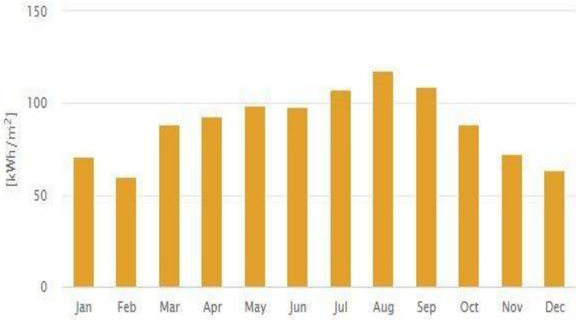

Fig.8. Monthly Irradiance averages in Sumberjo Village, Gunung Kidul District.

Control of temperature and humidity in the greenhouse effect dryer is done by adjusting the speed of the exhaust fan by utilizing Pulse Width Modulation (PWM). In this study, the temperature of the solar gaplek drying chamber with the greenhouse effect was controlled to keep it below 60℃. If the dryer exceeds 60 ℃ it will not meet the quality standard. The temperature is maintained between 50℃-60℃ to meet the standard [19].

The results of controlling the air temperature in the greenhouse effect (GE) dryer in the four gaplek production areas are shown in Fig. 9, 10, and 11. Fig. 9 shows that the temperature control system can work optimally, with a maximum temperature of 60°C from 09.00 to 15.00. Kaligunting village is a lowland area and has a temperature range of 20°C to 35°C. Fig. 10 shows the results of the temperature control test in Sukamaju Village with the maximum temperature reaching 57°C at 12.00 to 15.00. Based on the geographical location, Sukamaju Village is a lowland area and has a temperature range of 22°C to 32°C. Fig. 11 shows the results of the temperature control test in Sumberjo Village, which is not much different from Sukamaju Village, with a maximum temperature of 57°C. Based on the geographical location, Sumberjo Village is the same as Sukamaju Village and has an identical temperature range, which is 23°C to 32°C.

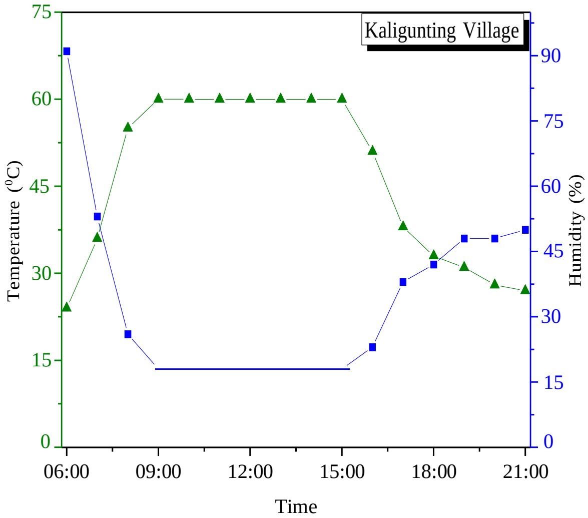

Fig.9. Temperature and humidity reading in Kaligunting Village, Madiun District.

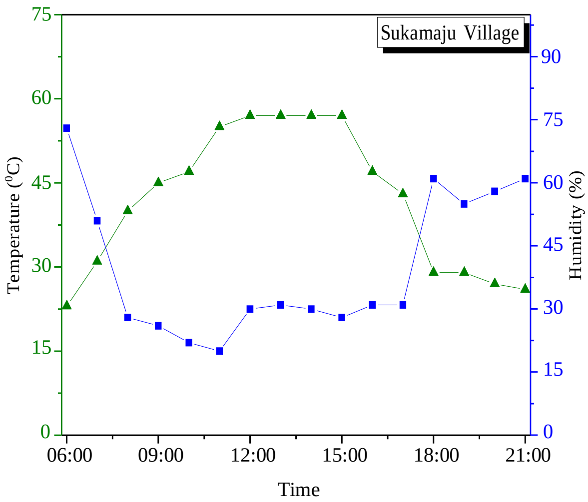

Fig.10. Temperature and humidity reading in Sukamaju Village, North Lampung District

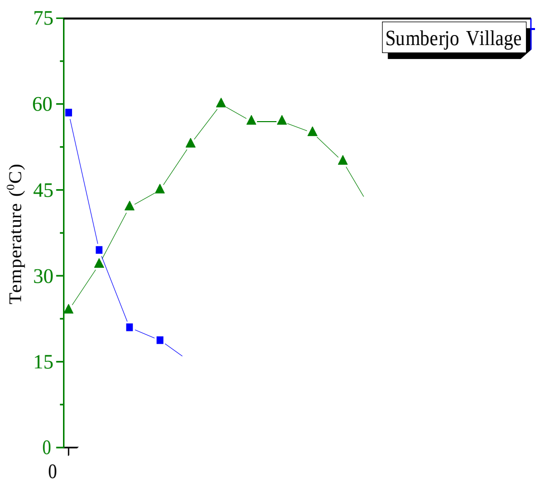

Fig.11. Temperature and humidity reading in Sumberjo Village, Gunung Kidul District

Fig. 9, 10, and 11 show that the temperature is inversely proportional to the humidity of the air in the GE [20]. To carry out a deeper investigation related to variations in temperature and humidity, descriptive statistical analysis was carried out in the form of a boxplot as presented in Fig. 12 and 13.

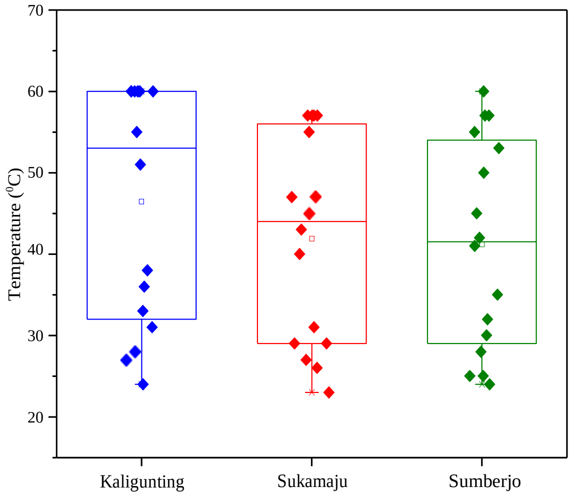

Fig.12. Descriptive statistics in boxplot form for temperature measurements in three regions

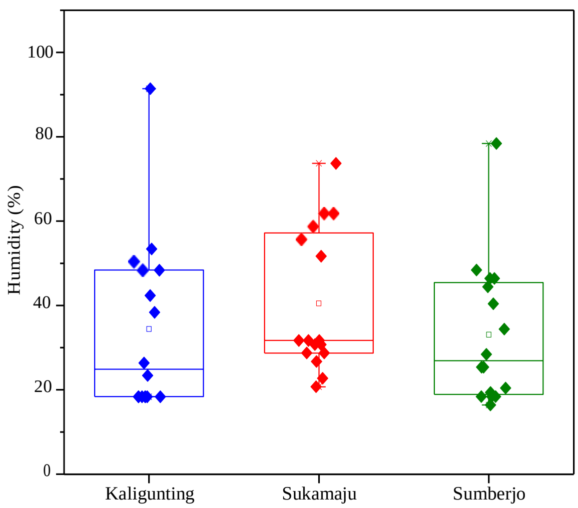

Fig.13. Descriptive statistics in boxplot form for humidity measurements in three regions

In Fig. 12 the diameter of the Kaligunting Village box is higher than that of Sukamaju Village and Sumberjo Village. This indicates the median value (Q2) of temperature in Kaligunting Village is much higher, namely 53℃ while for Sukamaju Village and Sumberjo Village it reaches 44℃ and 41.5℃ respectively. The high median temperature value of Kaligunting Village compared to other areas is consistent with (geographical location and exposure to solar radiation intensity) higher than the other three areas. The size of the boxplot which is not much different for the three regions shows that the standard deviation of temperature in the three regions is not much different. Small perforated square marks in the boxplot indicate the average temperature value of the measurement results. The average temperature for Kaligunting Village, Sukamaju Village, and Sumberjo Village respectively reached 46.44 ℃ ± 14.61; 41.87 ℃ ± 12.74, and 41.19℃ ± 12.96.

In Fig. 13 the diameter of the Kaligunting Village box is lower than that of Sukamaju Village and Sumberjo Village. This indicates that the humidity in Kaligunting Village is much lower, namely 24.4%, while for Sukamaju Village and Sumberjo Village, it reaches 31% and 26.5% respectively. The low median humidity value of Kaligunting Village compared to other areas indicates that the process of taking water from gaplek will take place more quickly or it can be said that the drying process of gaplek is shorter than the other three villages. Meanwhile, in Sukamaju Village and Sumberjo Village, the exhaust fan will turn on with a higher intensity in order to create airflow in the GE thereby increasing the amount of dry air passing through the cassava per unit time.

Testing the performance of the temperature control system on the cassava dryer aims to maintain the quality standard of cassava. Based on the results of interviews with cassava farmers, cassava with the best quality is achieved when the temperature in the dryer is maintained in the range of 50℃-60℃. This is consistent with the results of research on the drying process of cassava slices using a cabinet dryer machine [19]. In this study, the system was tested directly in Jatipuro Village, Karanganyar Regency, which is a cassava production village. The test was carried out from 06.00-21.00 WIB to determine the characteristics of the drying system in Jatipuro Village.

In this study, the influence of the environment is very influential on the measurement results. Kaligunting village has the highest temperature because the location is in a low land area so that it produces high temperatures and is supported by minimal interference from sunlight. In addition, Kaligunting Village has exposure to radiation intensity higher than the radiation intensity exposure in Sukamaju and Sumberjo Villages, as shown in Fig. 6, 7, and 8. The potential of this drying system is very large and can be developed to produce an optimal system. Dependence on sunlight results in suboptimal temperatures. In addition, weather factors affect the capacity of sunlight to illuminate the location of the dryer. Therefore, an additional heating system is needed to overcome these problems, and the way the heating system works can be controlled automatically.

IV. Conclusion

In this study, we have succeeded in making a temperature control system in the greenhouse effect dryer system drying room by controlling the temperature below 60℃. Based on the experimental results in three areas, Kaligunting village shows the most optimal drying temperature. The PWM method can be used to control the rotation speed of the exhaust fan. Thus, the drying room temperature can be controlled according to the control parameters. This system can be optimized by adding additional heating systems and heating operation control. This additional heating system is used when the weather does not allow sunlight to escape.

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