On-Site Testing A Prototype Solar Drying Cabinet Utilising Calcium Chloride as Dehumidifier

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Abstract. Solar drying is a sustainable and eco-friendly method that generates no greenhouse gas emissions or air pollutants. It contributes to reducing the carbon footprint of the drying process. By using solar power as the main energy source, the prototype solar dryer can help reduce electricity costs and reduce the negative impact on the environment. Solar drying is also an alternative solution to dryers that use fossil fuels. However, due to the irregularity of the solar power source, the solar dryer suffers from irregular drying and long drying times. Drying agricultural produce directly during the day is a conventional method that has been used by farmers in Bali. Tropical climate conditions and high levels of rainfall cause frequent failures and damage to agricultural materials in the drying process. In this work, a prototype solar drying cabinet had been designed to improve the traditional method which has been uses in Bali. This cabinet dryer employs a flat plate collector as thermal energy source and calcium chloride as dehumidifier. Calcium chloride is a drying material used to remove moisture from the air. It functions as a desiccant because it has the ability to bind water molecules and maintains a dry state. Calcium chloride is a type of solid desiccant which has the ability to bind water molecules and maintain low humidity conditions. This work aims to build and test a prototype solar dryer to ensure optimal efficiency and performance in drying agricultural products. The performance has been indicated by the increase of the temperature of cabinet and also the rate of moisture content which adsorbed by solid desiccant. Measuring the performance of a solar dryer is essential to ensure its effectiveness and efficiency in drying various materials while utilizing solar energy

Keywords*:* Solar Drying, Plat-flate Collector; Calcium Chloride; Dehumidifier

1. Introduction

Indonesia is an agrarian country. Most of the population make a living as farmers, the people consume rice as the main staple and agricultural products are the commodities most relied on by farmers as agricultural products that have selling value to support their daily life. One of the most common stages of the processing of agricultural products is the drying process, drying aims to reduce the water content in the product so that the product can be stored or processed but because it is Indonesia has two seasons, namely the dry season and the rainy season, so the drying process in the rainy season often causes many problems. In addition, the

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hot and humid tropical climate affects the drying rate of agricultural commodities. High temperature will speed up the drying process whereas high humidity will reduce the speed of the drying process. [1]

Drying of agricultural products is one of the important processes in the agricultural industry. This process aims to extend the shelf life of the product and ensure good product quality. However, the use of electric dryers usually has several problems, such as high electricity costs and negative impacts on the environment. A solar dryer is one solution that can help solve this problem [2]. By using solar power as the main energy source, the prototype solar dryer can help reduce electricity costs and reduce the negative impact on the environment. Solar drying is also an alternative solution to dryers that use fossil fuels. [3][4] However, due to the irregularity of the solar power source, the solar dryer suffers from irregular drying and long drying times. Drying agricultural produce directly during the day is a conventional method that has been used by farmers in Bali. Tropical climate conditions and high levels of rainfall cause frequent failures and damage to agricultural materials in the drying process.[5][6]

A solar dryer is a drying system that uses solar energy as its energy source to remove moisture from the material to be dried. This aims to speed up the drying process and reduce the electricity costs needed in the drying process. The basic concept of solar drying is to direct sunlight into the drying chamber to heat the air and make moisture evaporate from the material being dried. The hottest air is then expelled through a ventilation system, which makes the dried material dry faster and maintains good quality of the material. Drying also serves as a traditional preservative used to dry various agricultural products. The drying process reduces the moisture content in agricultural products and provides a longer shelf life. It prevents spoilage of the crop by preventing the growth of bacteria, yeast and mold. Various types of grains, nuts and other ingredients.[7][2]

A solar collector is a device designed to capture solar energy and convert it into usable heat energy for various applications. .[8] One common application of solar collectors is in drying equipment, where solar collectors are used to generate the heat energy needed to dry clothes. In drying equipment with a solar collector, the solar collector is usually installed above or around the drying equipment. A solar collector consists of a material that absorbs heat from sunlight, such as a metal plate covered with a heat-absorbing material such as black metal or plastic. When sunlight hits a heat-absorbing material, heat energy is generated and stored in water or other cooling fluid that flows through the solar collector. The heat energy stored in the cooling fluid is then pumped to the drying equipment, where the heat energy is used to dry clothes. In drying equipment that uses solar collectors, the source of heat energy comes from the sun, which is clean, inexpensive, and renewable, thereby reducing operational costs and the environmental impact generated by conventional drying equipment that uses fossil fuels.

Adsorbent materials play a pivotal role in solar drying technology, especially in the context of solar desiccant drying systems. Solar drying is a method used to remove moisture from various products such as agricultural crops, fruits, vegetables, and industrial materials using solar energy. The primary role of adsorbent materials in solar drying technology is to enhance the drying process by reducing humidity and improving the overall efficiency of the system. These materials have a high affinity for water vapor. They can adsorb moisture from the air inside the drying chamber, lowering the humidity level. This is particularly beneficial when drying processes require low humidity conditions, as it accelerates the moisture removal from the product being dried.[9][10]

This project aims to design a prototype of solar desiccant drying which can employ to dry agricultural product for small and wet farming type. This prototype will be tested on site

village that has farm field with the specific agricultural product. A type of design solar cabinet drying will be chosen to simply the process of drying due to utilization of solar thermal energy.

2. Literature Review

2.1 Solar Driying In The Application Domestically

Solar drying is gaining great attention as an alternative solution to drying using fossil fuels. A group of researchers submitted a published paper on the use of sorption materials to improve the performance of solar dryers. Key aspects regarding their use as a thermal energy storage or dehumidification material are highlighted. This paper shows that solid adsorbents, especially silica gel, are the most widely used materials. [7] The use of composite materials, for example a mixture of bentonite, $CaCl_2$, vermiculite, and cement has proven promising. The inclusion of a sorption dehumidifier in a solar dryer, usually at the inlet of a solar collector, generally results in a reduction of drying time of 15-30%, although values of up to 50% and even 64% have been obtained in their tests. On the other hand, introducing sorption materials as thermal energy storage in solar dryers, usually integrated at the top in the drying chamber, leads to a reduction in drying time of about 30-45%. However, many aspects need to be investigated prior to the large-scale use of this technique in solar drying technology. [9]

Drying of agricultural products is a method of preserving food which is quite popular and effective. In drying agricultural products, water contained in foodstuffs is removed naturally or with the help of equipment, thereby reducing the activity of microorganisms and enzymes that can damage foodstuffs. Here are some of the functions of drying agricultural products in preserving materials:[4][11]

2.2 Cabin Dehumidifier by Solid Dessicant

Solid desiccant is a drying material used to remove moisture from the air. It functions as a desiccant because it has the ability to bind water molecules and maintains a dry state. Solid desiccant is commonly used in applications such as humidity control, gas drying, air quality control, and material storage systems. There are several types of solid desiccant available, such as silica gel, alumina, calcium chloride, and magnesium chloride. Each of them has certain specific humidity and different physical properties. Calcium chloride ($CaCl_2$) is a type of solid desiccant which has the ability to bind water molecules and maintain dry conditions. Calcium chloride is one of the most commonly used solid desiccant types. It is a chemical compound with the formula $CaCl_2$. Calcium chloride is highly hygroscopic, meaning it has a strong affinity for water and is able to absorb moisture from the air. This makes it very effective at reducing moisture and helps prevent damage caused by excess moisture.[12][13]

3. Material and Methods

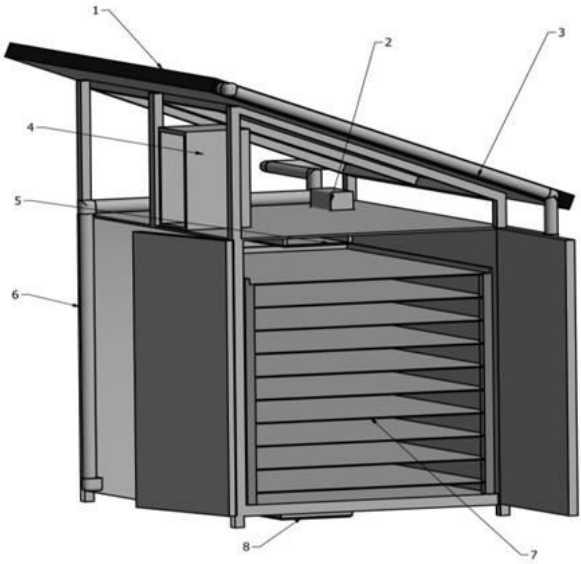
Agricultural product dryers are tools used to dry various kinds of agricultural products produced by farmers. The conventional drying system uses solar heat directly in the drying area which will be very difficult during the rainy season. The influence of weather can also cause damage and crop failure of various agricultural products that require drying processes. Among the various types of agricultural products include rice, peanuts, green beans, soybeans, and various types of grains and other crops that require drying processes. In conventional systems, farmers do not use any equipment to carry out the drying process, but these

agricultural products are dried directly in the sun. This is what causes the drying process to be less effective, the influence of weather and environmental conditions on the drying speed is very high.[14]

In this work, a prototype solar drying cabinet had been tested in Gelgel village. This village is one of the sites of farming in Bali. Due to utilization of solar thermal energy, it can be realized its performance which have been affected by several ambient condition in that site. This cabinet dryer had been designed by employing a flat plate collector and sodium chloride as dehumidifier. This prototype is one of type of indirect solar dryer technology. A solar collector which is used to collect solar thermal energy then it will flow into the cabin by the convection of heat transfer fluid (water).[6]

3.1 Cabin and cabinetry construction and its manufacturing

A solar drying cabinet is a type of drying equipment that utilizes solar energy to dry various materials, typically agricultural products such as fruits, vegetables, grains, herbs, or clothes. The basic principle behind a solar drying cabinet is to harness the heat and energy from the sun to facilitate the drying process, which helps preserve the quality and shelf life of the materials being dried.[15]



Legend:
1 flat plate Solar Collector
2 DC Brushless Pump
3 Header of output channel box wall
4 Adsorbent box on the top cabinet
5 Controller Box
6 Heat transfer fluid piping
7 Drying material cabinetry
8 Adsorbent box on the bottom cabinet

Fig. 1. Prototyping of Solar Cabinet Drier.

This cabinet was designed with a box or cabinet-like structure that has one or more trays or racks inside to hold the materials to be dried. The cabinet is usually insulated to minimize heat loss and maximize efficiency. the volume of this cabinet is 2 m^2 which is equal to 1-2 tons grain. It is considered by the production of paddy's grain in every rice field in Gelgel Klungkung. On the roof of the cabinet, there are one or more solar collectors, which are made of galvanize aluminum plat. These collectors absorb solar radiation and convert it into heat energy. The box has been insulated by the multiplex wood plat and coated by resin.

In an indirect solar dryer, a heat transfer fluid (water) circulates through the solar collector. This fluid absorbs the heat from the sun and transfers it to the drying chamber. A DC brushless pump had been installed to circulated the water as heat transfer fluid. In the wall of the box, mini channel constructs inside the wall by utilizing galvanize aluminum sheet. The heat by solar collector will be transferred inside the chamber from the cabinet wall.

The prototype of solar dryer will be tested for the changes in relative humidity due to the addition of calcium chloride as an adsorbent from the moisture content that is released by the dried material. This drying cabinet system causes water vapor to not be released directly into the environment. The role of the adsorber in absorbing the moisture content will decrease the relative humidity of the air in the drying room. In this case, the adsorber material used is calcium chloride. Calcium chloride is a type of salt which has the property of absorbing water content in the air (hygroscopic).

In this study, the effect of using adsorber material (calcium chloride/$CaCl_2$) on decreasing the humidity of the drying chamber will be known in the drying process carried out. Reducing the relative humidity of the air in the drying chamber is expected to speed up the process of releasing the water content in the dried material. Air conditioning in the drying cabinet is

expected that the air does not become saturated in receiving the mass of water released by the material being dried because the drying cabinet system is isolated from its environment.

3.2 The performance testing the prototype of solar drier

The test to be carried out is to place the drying equipment in direct sunlight and use a cloth that has been moistened with a certain volume of water (10-40% by weight of the cloth). During the drying process the data will be retrieved using a datalogger. Test data includes: temperature, relative humidity, flow rate of heat transfer fluids, and differential pressure of heat transfer fluids. The equipment and instruments needed in testing this drying equipment: Digital manometer, Flow meter K24, Thermocouple type K, Digital humidity meter GSP6.

In this research, in situ testing (Gelgel Vilage) had been carry out for three days, under sunny days and six hours every day. Data had been collected for relative humidity of the cabin, the rate of energy thermally from solar collector into the cabin and also moisture content which has been adsorbed by the calcium chloride.

4. Result and Discussion

4.1 Cabin conditions and drying performance

This paper studied a type of indirect solar dryer, its design, development and performance for utilization of solid dessicant. This paper focuses on influence of different number of mass calcium chloride as adsorbent and their effect drying cabin environmentally. The solar radiation intensity, relative humidity, ambient temperature, initial moisture content and drying rate are the factors need to consider while designing the solar dryer. Forced convective dryer is suitable than natural convection dryer for high moisture content product, because it has higher drying rate. [3]

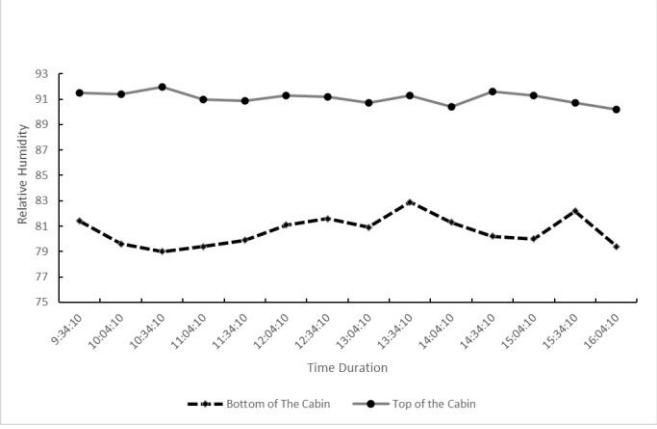


Fig. 2. The different of relative humidity between the top and the bottom of cabin.

From the tests that have been carried out, it can be seen that there is a difference between the relative humidity at the bottom of the cabin and the top. The relative humidity of the cabin at the bottom will always be higher than that is at the top. This is caused by the specific gravity of air with higher humidity has a higher specific gravity as well. Likewise, absorption by absorbent calcium chloride is always higher when placed at the bottom of the cabinet. Although the adsorbent used already has good water vapor absorption characteristics, the

water vapor that can be absorbed is still quite low. This requires a mechanism that can circulate air to the adsorbent so that the contact surface of the air is higher and the absorption of water vapor becomes higher. Increasing of weight by adsorbed the moisture content in the cabin lead to the rise of solid desiccant weight. Sodium chloride in the bottom of the cabin rises about 500 grams and on the top of cabinetry (inside cabin) about 300 grams.

In indirect-type solar dryers, flat plate solar collectors are integrated into the system to provide the heat required for the drying process. These collectors are responsible for capturing and harnessing solar energy, which is then used to heat air in the cabin or another heat transfer fluid. This heated air or fluid is subsequently used to facilitate the drying process within the solar dryer. The absorber plate is covered with a galvanize aluminum sheet without glazing cover. Even the glazing cover that allows sunlight to pass through while minimizing heat loss but this cover will be increasing the cost of this solar dryer. The back sides of the collector are insulated to prevent heat from escaping to the surroundings. Insulation helps maintain a higher temperature on the absorber plate. Beneath the absorber plate, there is a passage through which a heat transfer fluid circulates. As these medium flows through the collector, it absorbs the heat from the absorber plate.

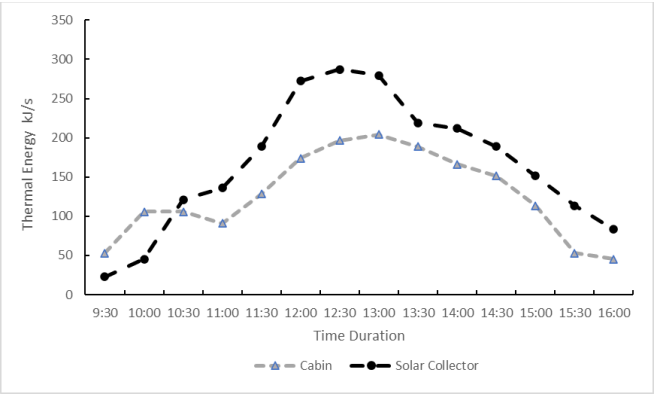


Fig. 3. The rate of energy thermally from solar collector into cabin

The rate of thermal energy into the cabin caused by the flat plate collector that generates the solar energy radiation in the galvanize aluminum sheet. Thermal energy increase by duration of time goes in the day when tested been carry out. Then, it will decrease after middle of the day tested. Energy rate in the cabin is commonly below the energy which adsorbed by solar collector. Flat plate solar collectors are installed on the exterior of the solar dryer, facing the sun. They absorb incoming solar radiation, converting it into thermal energy. In this drying equipment, this is cause of the efficiency of utilizations of solar thermal energy and induce the thermal energy in the cabin below thermal energy that had been adsorbed by solar collector.

4.2 Conclusions and suggestions

The utilization of solid desiccants in indirect-type solar dryers can be highly beneficial, especially for applications where precise control over drying conditions and moisture removal is essential. While there are challenges, such as system complexity and maintenance requirements, these can be mitigated with proper design, monitoring, and maintenance practices. Overall, solid desiccants can enhance the efficiency and effectiveness of indirect solar drying systems, particularly when drying moisture-sensitive products. Improving the performance of indirect-type solar dryers involves optimizing various aspects of the system to enhance drying efficiency, reduce energy consumption, and maintain product quality.

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