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Development and Experimental Studies of a Small-scaled Solar-powered Sago Plant Dehydrator

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***Abstract*— Sago is an important agricultural commodity of the largest state in Malaysia, Sarawak. This paper presents a small-scaled solar-powered sago dehydrator with temperature sensing and monitoring unit. The main focus is to provide a feasible solution for sago farmers or producers who live in isolated remote areas. The dehydrator system is controlled by a microcontroller PIC16F877A. The electrical circuit of the dehydrator allows the user to programmed desired time setting and the controller will interact with the temperature sensor and display unit of the dehydrator for the purpose of temperature monitoring within a specific range for the sago flour drying process. This project has adopted the green technology concept as the system components are powered using the energy produced from the solar panels. A small portion of sample of the sago flour will be dehydrated in the proposed solar powered plant dehydrator. The operation of the dehydrator and the experimental results are presented.**

***Keywords*— solar; dehydrator; temperature control; microcontroller; Sago.**

I. INTRODUCTION

In Malaysia, sago is an important agricultural commodity and the sago palm is widely planted in the nation's largest state, Sarawak. Sarawak is situated at the latitude of 0°50' and 5°N, and longitude 109°36' and 115°20'E. [1]

Local residents harvest the sago by cutting the logs and transport the logs to the nearby factories that are located nearby the river through water route. The reason for the factories to be established nearby the river is due to the convenience for obtaining water resources for the sago flour process.

Sago products that are available in the market appear in the form of pearl or powder. This material continues to proliferate as main ingredient from edible to pharmaceutical products. Sago flour extraction involves a series of process that transforms the sago palm (*Metroxylon)* into the consumable product which has a better commercial value. The increasing demand of sago flour, particularly in the food industry, has driven the sago manufacturing factories that are usually small in size or family-owned. Although the production capacity could be increased by improving the processing level as stated in [2], expanding manufacturing facility is normally cost-prohhibitive.

In a conventional sago mill, wood-fired dryer has been the dominant in the sago production process as this technology is the most economic technique. Also, the mill can utilize the bark-layer peeled from the sago palm as the resource for the dryer. However, heavy use and inefficient consumption of wool-fuel in the burning process of the wood-fired dehydrator is contributing to environmental problems such as the increase in green-house gas emissions.

Other than the factory, there are many family-owned sago processing business exist in the remote area of Sarawak. Due to the geographic isolation and barriers, these communities are encountering challenges to access electricity and also basic daily needs. Majority of the populations are depending on agriculture activities for their livelihoods. Excessive harvested agricultural products are dehydrated and preserved for commercial purposes.

In the hypercompetitive market nowadays, the quality of the product is definitely a main concern of the consumers. Traditional plant drying method under open sun has been the most common method in food preservation. Hygiene remains as the main challenge for open sun drying due to the food are exposed to contaminated conditions. Traditional open sun food drying process, although is still being practiced, it is gradually phased out and replaced by other productive process. Due to relatively little efforts have been found in improving the plant drying technology that is feasible to be employed by rural communities, this paper proposed a small-scaled solar-powered sago dehydrator.

II. CONVENTIONAL SAGO DEHYDRATOR

The most commonly found conventional way of sago drying process at the small-scale sago mills is the wood-fired dehydrator. With the advancement of technology, certain factories have opted the electric powered dehydrators for better efficiency for sago production. The pros and cons for both methods will be discussed in the next sections.

A. Wood-Fired Heater of a Dehydrator

Wood fuel has been a dominant source of energy historically and it is widely adopted for energy production in developing countries. Wood-fired dehydrator plays an essential role in food preservation. A typical wood-fired dehydrator is show in Fig. 2. The combustion chamber is built from materials that are fire resistant, which can provide firm and steady structure and sufficient thermal insulation. The wood-fuel can be the sago bark layer peeled from the sago log as shown in Fig 3 or forest wood.

Fig 1. Wood-fired chamber at a Sago Mill

Fig 2. Sago bark layer that is usually used for wood-fired dehydrator

From the economic point of view, wood-fired dehydrator is feasible for rural applications due to its simplicity in structure and operation. There is no requirement for technical maintenance which is usually inaccessible at remote areas. However, due to the operation of this dehydrator requires a considerable amount of wood as primary resource and no additional equipment to increase the efficiency of the burning process, this method is usually associated with controversial environmental issues such as deforestation and pollution due to inefficient burning process.

B. Electric Powered Dehydrator

Due to the limitation and environmental impacts of the wood-fired dehydrator, some of the sago factories have started implementing the electricity powered dehydrator. This electrical dehydrator use 3-phase power supply from the electricity grid and draws lot of current during operating. The operation of this electric dehydrator has to be monitored and controlled either manually or automatically to maintain the energy consumption at a desirable level. Therefore, the sago mill will only operate during day time for approximately 8 hours of operation time.

The advantage of this kind of electrical dehydrator is the continuity of drying process even during rainy season where outdoor drying of the sago is not possible.

Fig 3. Electric Powered Dehydrator

C. Solar Dehydrator

Solar dehydrator is an alternative to the traditional open-air sun drying method. Solar dehydrator is preferred by farmers in remote areas due to lower investments to sophisticated drying techniques using electric and fossil fuels.

Basically, solar drying can be categorized into natural and forced convection. [3] Various plants dehydrating methods using solar such as the natural convection cabinet type, forced convection indirect type, solar tunnel driers type and green house type have been reviewed in [4]. In the natural convection dryers, there is no assistive component to circulate the air through the dryer. This results in the low air flow rate and therefore long drying time. The drying capacity of this method is low. It is not capable to process a large quantity product for commercial market. On the other hand, forced convection dryers are preferred for higher drying capacity. The forced convection dryers use fan or blower to circulate the hot air in the drying box, cabinet or tunnel. Large-scale plant dehydration method as proposed in [5] has adopted natural convection method with assistive ventilation.

The proposed small-scaled solar powered plant dehydrator is adopting the forced convection solar dryer concept with user interface, temperature sensing and monitoring unit. The operation of this dehydrator will be presented in the next section.

III. THE PROPOSED SMALL-SCALED SOLAR POWERED PLANT DEHYDRATOR

A small-scale solar plant dehydrator with automated control of temperature by PIC16F877A was designed and constructed as shown in Fig 8. The heating chamber is shown in Fig 9. The dimension of the chamber is 45 cm in height, 45 cm in length, and 18.5cm in width. The inner wall of the chamber is constructed from aluminium plate. The aluminium plate is an ideal medium to allow even heat transmission in the heating chamber.

The design requirements of the proposed solar powered plant dehydrator are as follows: Temperature can be adjusted to rise up between $50^{\circ}C$ to $75^{\circ}C$ by turning on the heating element and fan according to the source code of the system implemented in the microcontroller. The switch that is connected to the heating element will receive signal from the microcontroller and will be turned on or off at the programmed temperature. The temperature sensed by the temperature sensor will be display at the LCD display as shown in Fig 7 for monitoring purpose. A timer button is integrated as user interface component to allow the user to set the drying duration.

The power supply of the proposed plant dehydrator consists of a 12V battery and three 12V solar panels. Due to the different power supply requirement between the microcontroller and other direct current (DC) loads, therefore separate power supply will be provided for these components. The microcontroller received 5V DC voltage while the 12V battery is connected to supply the DC loads, i.e. the sensor, heating element and fan. The DC fan is installed to ventilate and provide balance heat in the heating chamber.

During day time, the battery will be charged from the solar panel. The excessive power from the solar panel will be used to operate the loads as mentioned. Since this project is a small-scale dehydrator project for demonstrating the feasible idea for remote communities, therefore only small ratings components are considered.

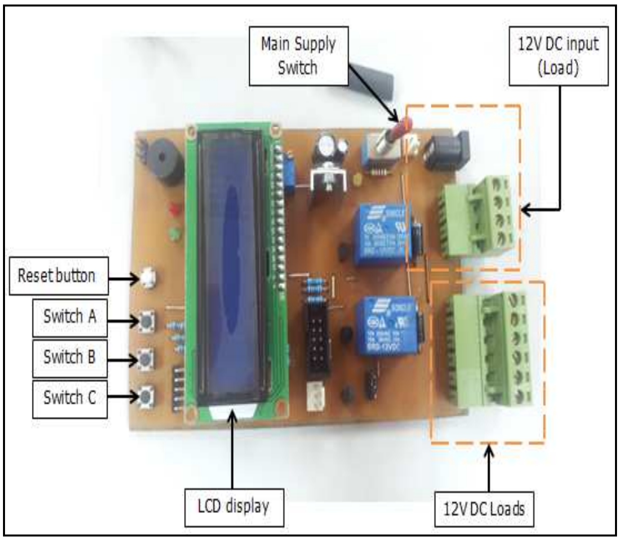


Fig 4. Microcontroller circuit and user interface buttons

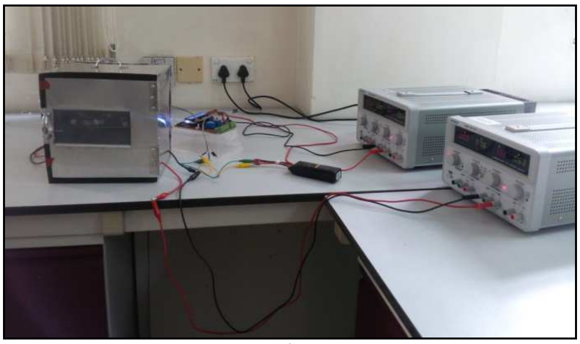


Fig 5. Temperature control testing using DC supply

The heating element is constructed using resistive component to dissipate 20W of power with 1.7A supply current. A 12 V, 7.2 Ah of battery pack is selected. Drying of sago flour need an amount of energy depends on the size of solar panel and amount of sample to be dried. Sufficient supply from solar panels is necessary to provide constant drying and efficient heating.

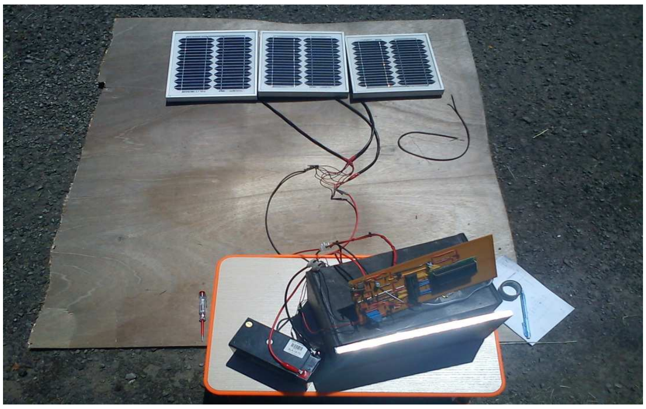
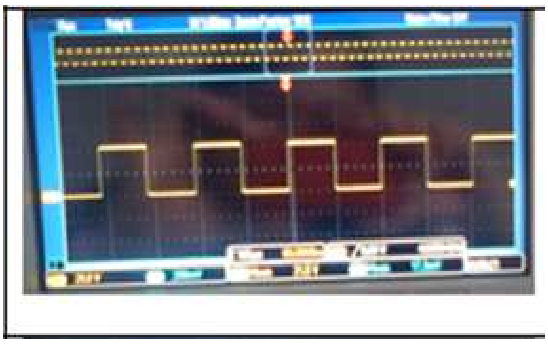
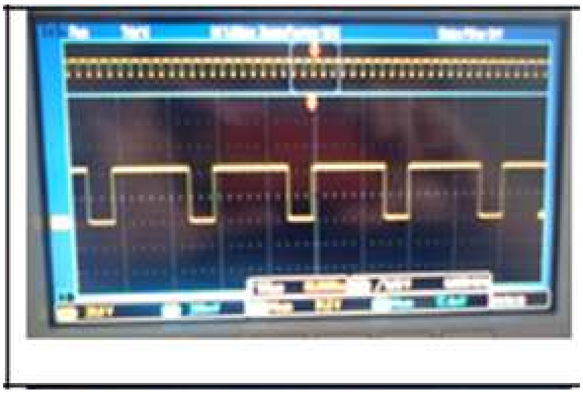


Fig 6: Experiment set-up of the proposed plant dehydrator.

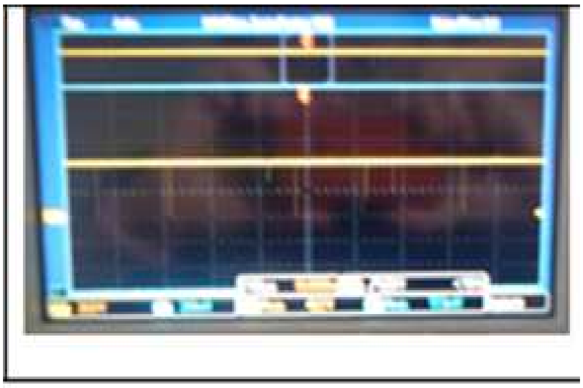
The speed of the fan installed in the heating chamber is controlled using the Pulse Width Modulation (PWM) method. Based on the experiment, it can be observed that the duty cycle is varied according the operating condition in the heating chamber. Fig 9a – c show the duty cycle of the control signals to regulate the fan speed. The wider the duty cycle represents the higher speed of the fan.



(a)



(b)



(c)
Fig 7 (a) – (c) PWM signals for controlling DC fan.

IV. Experimental Results

In order to verify the electric circuit of the system, the voltage signals from the LM35 sensor was verified prior to the beginning of the experiment. The output voltage signal of the LM35 was sent to the microcontroller at a preset interval and the changes of the voltage for a corresponding temperature are recorded and plotted in Fig 8. From the graph, it is shown that the sensor voltage output is increasing accordingly with the temperature. The ideal temperature for drying the sago powder is around 50℃~75℃.

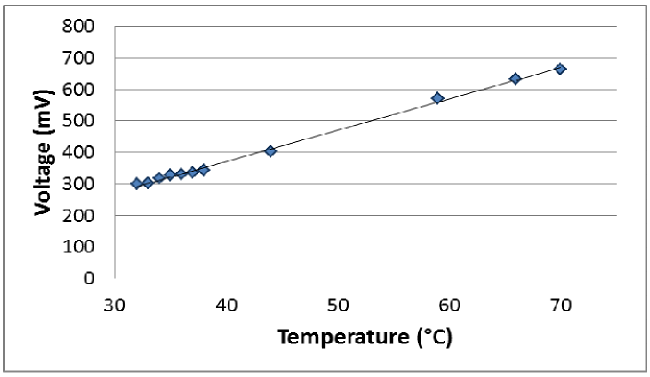


Fig 8 Relationship between sensor voltage output and temperature

Sago powder was moistened with 30~40% of water and the pre-experiment weight measured was 10.2 grams. The experiment was conducted in the duration of 25 minutes. The weight of sago powder after the drying process was 9.34 grams. The water content in removed using the proposed plant dehydrator of the experiment was 9.2%. The relationship of weight versus time (hours) of drying were recorded and plotted as shown in Figure 11.

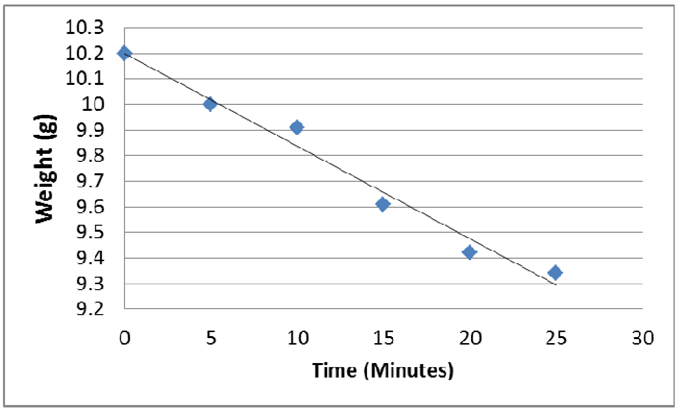


Fig 9 Decreasing weight of the sample in the drying process.

V. Conclusion

From the experimental studies, the proposed small-scaled solar-powered sago dehydrator has demonstrated its capability for plant drying, which suits the needs of the Melanau clan living in the rural areas of Sarawak. This dehydrator can help to improve the sago quality compare to the open sun drying that is usually associated with high percentage of spoilage. Consequently, this will increase the income of the family who has no access to the electricity for drying agricultural products. The green concept integrated in this project using the solar technology also provide a more environmental friendly solution for plant dehydration process compare to the wood-fired dehydrator. Implementation of this technology will enhance and sustain the traditional business of sago flour. High quality of sago flour can be achieved by the family-owned business or small mill entrepreneurs with low cost and easy handling technology. In short, this project has positive impacts not only to the local economic, but it is also beneficial for the environment and society.

Acknowledgment

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