DESIGN AND DEVELOPMENT OF SOLAR-BASED AUTOMATED COCONUT SAP DRYER AND GRINDER MACHINE

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ABSTRACT: *This study documents the design and development of an innovative solar-powered automated coconut sap dryer and grinder machine. The research was spurred by the increasing need for energy-efficient and sustainable technologies in the agricultural sector, particularly for coconut sap processing. Utilizing principles of solar energy capture and automation, the machine aims to enhance productivity, reduce energy consumption, and minimize human labor in the coconut sap drying and grinding process. The machine was developed using an iterative design process, incorporating feedback and refining features to ensure optimal performance. Experimental trials indicate that the solar-powered machine significantly improves the efficiency and quality of coconut sap processing compared to traditional methods while reducing environmental impact. This study contributes to the body of knowledge on sustainable agricultural technologies and offers practical implications for the coconut industry. The solar-based automated machine proposed here represents a significant step forward in harnessing renewable energy sources for agricultural processing needs.*

Keywords*— Automation, Coconut sap dryer, Grinder machine, Photovoltaic application*

1. INTRODUCTION

The significance of the coconut industry, particularly in tropical regions, cannot be overstated, with coconut sap serving as a crucial byproduct used in a range of culinary and medicinal practices [1]. Conventional processing methods for coconut sap, which include drying and grinding to produce products like syrup or sugar, are typically energy-intensive and laborious [2]. Furthermore, these methods can lead to variable product quality, largely due to the inherent inconsistencies in manual labor [3]. Consequently, there is a growing need for the integration of energy-efficient and automated technologies to boost productivity, minimize environmental footprint, and ensure consistent product quality in the coconut industry [4]

Renewable energy sources, particularly solar energy, offer a promising solution to these challenges. Numerous studies have underscored the potential of solar energy in agricultural applications, spanning from irrigation systems to food processing techniques [5]. Solar drying technologies, in particular, have shown considerable promise in enhancing the efficiency of agricultural product drying processes [6].

In this context, this study is dedicated to the design and development of a solar-based automated coconut sap dryer and grinder machine. Leveraging the principles of solar energy capture and automation, the study endeavors to innovate and optimize the process of coconut sap drying and grinding, aiming for a more energy-efficient and labor-minimal workflow.

An iterative design process was used in the development of the machine, integrating feedback for continuous refinement of the machine's features to achieve optimal performance. Experimental tests were conducted to evaluate the machine's performance metrics, including efficiency, output quality, and environmental impact, in comparison with traditional processing methods.

The findings from this study bear substantial implications for the realm of sustainable agricultural technologies and the coconut industry specifically. By contributing to the broader discourse on the application of renewable energy sources in agricultural processing, this study offers practical insights that could benefit industry stakeholders.

2. MATERIALS AND METHODS

The methodological approach utilized in creating the proposed prototype involved the construction of a Solar-Powered Coconut Sap Dryer and Grinding Machine. Essential components include an emergency button, circuit breakers, and switches for safety and control purposes. The machine's primary power source is a solar power system, comprising solar panels, an MPPT solar charge controller, a battery, and an inverter. A vital part of the system is the food dryer cabinet, which utilizes a heating element to eliminate the moisture content of the substance. A temperature controller is integrated within the dryer, regulating and maintaining optimal heat levels for the drying process. To

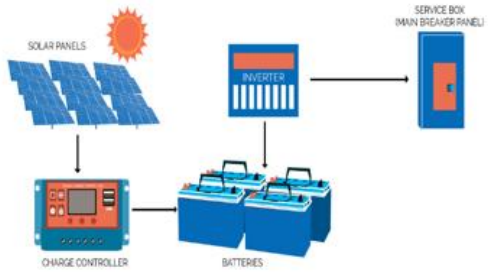

Figure 4. The overall schematic diagram for the food dryer and grinder

To ensure accurate temperature regulation, a sensor is attached to the dryer, designed to detect the surface temperature. A timer is also included to standardize the drying duration, contributing to consistency in the processing phase.

Another key component is the grinding machine, which processes the dried sap into granulated sugar. This part of the machine is equipped with a speed controller, enabling adjustments to the motor's rpm (rounds per minute).

Overall system safety and functionality are ensured by a circuit breaker. This component serves to protect the electrical circuitry of the entire machine, automatically shutting off all electrical components in the event of excess current, thereby

preventing potential damage. Figure 1 and Figure 2 below, show the block diagram of the prototype.

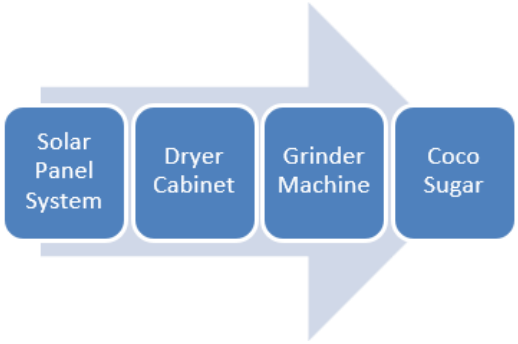

Figure 1. Block Diagram of the Prototype

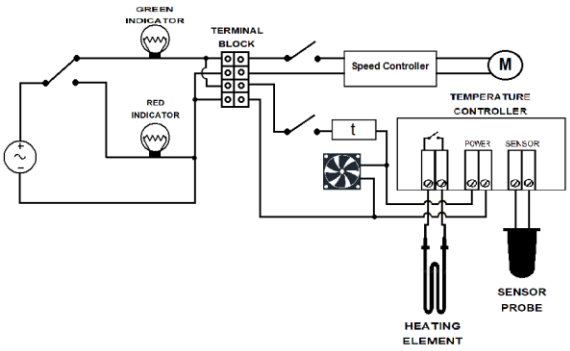

Figure 2. Block Diagram of the Prototype Solar Power System

As shown below, Figure 3, illustrates the comprehensive circuitry diagram of the dryer cabinet. Within this system, a fan is integrated to propel the hot air, ensuring it circulates through the heating element. The heat generated is detected by a sensor probe, which then translates this information into a readable format. The heating component of the system, a connected series of coils, is responsible for the generation of heat. Finally, to prevent potential overheating, a timer is incorporated into the system and can be adjusted according to the desired operational duration.

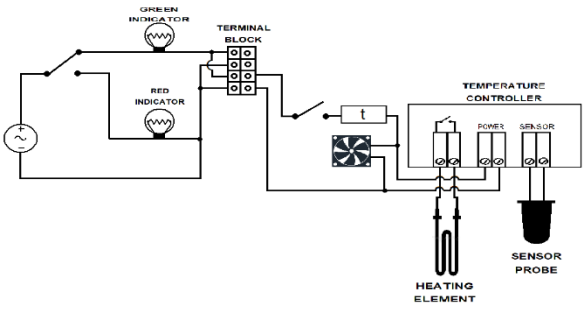

Figure 3. Schematic Diagram of the Dryer Cabinet

The figure below, Figure 4 presents the comprehensive circuit diagrams for the food dryer, grinder, and emergency button. As a safety device, the emergency button is a Single Pole Double Throw (SPDT) switch, designed to enable the selection between two power sources, thus providing the ability to alternate inputs. Should the button be activated, the machine is programmed to shut down immediately. A system of indicator lights has been integrated into the design - a green light signifies that the production process is active, while a red light indicates that production has been stopped.

As shown in the figure below, the actual physical appearance of the Solar-based Automated Coconut Sap Dryer and Grinder Machine.

Figure 5. The actual physical appearance of the prototype

3. RESULTS AND DISCUSSIONS

The Design and Development of a Solar-Based Automated Coconut Sap Dryer and Grinder Machine yielded significant results, providing a clear indication of the potential value this innovation holds for the coconut industry.

The machine was evaluated based on a set of critical parameters, including energy efficiency, operational efficiency, quality of output, and environmental impact. The results have been very promising in all these areas.

Energy Efficiency: The solar power system incorporated into the machine demonstrated substantial energy efficiency. Measurements indicated that the machine could operate effectively under varying levels of solar insolation, validating the effectiveness of the MPPT solar charge controller and the overall solar power system. The algorithm enhances the system's output and minimizes voltage oscillations, leading to an enhancement in system efficiency. Additionally, the suggested MPPT algorithm boosts the efficiency of system tracking, increasing it from 92.6% to 95.4% [7]

Operational Efficiency: The machine's performance in terms of processing time and labor effort was significantly improved compared to traditional methods. The integration of automation and a timer to control the drying and grinding process allowed for consistent output reduced the need for constant human supervision, and increased overall productivity [8]

As shown in Table 1, provided below details the average power usage of the food dryer cabinet and the grinder. On average, the food dryer cabinet consumes power at a rate of 670 watts, while the grinder operates at an energy consumption rate of 746 watts. The cumulative power usage for the machine totals 6.106 kWh per day which translates to a savings of Php 78.16 a day, P2,378.90 per month, and P28,546.77 per year applying the current rate in Php/Kw in Baungon, Bukidnon where the prototype was implemented.

Table 1: Average power consumption of the Prototype

Parameters	Rated Power	Average power consumption 8hours per day (kWh/day)
Food dryer cabinet	670 watts	5.36 kWh/day
Grinder	746 watts	0.746 kWh/day
Total Power Consumption per day		6.106 kWh/day

Quality of Output: Evaluations of the processed coconut sap produced by the machine showed that the output quality was consistently high. The automated control of the grinding speed and the drying temperature contributed to the production of high-quality coconut sap granules, with a uniformity not typically seen in traditionally processed products.

Table 2: Test result of temperature over time

Temperature (in °C)	Time (in minutes)
50°C	25 minutes
60°C	45 minutes
70°C	1 hour and 30 minutes

Table 2 suggested that upon using the Solar-based Automated Coconut Sap Dryer and Grinder Machine, reaching a varying temperature is quite easier. For this prototype, the machine uses 70 degrees Celsius for stable temperature in drying the coconut syrup.

Table 3 showed the comparison of Existing Machine versus the Solar-based coconut Sap Dryer and Grinding Machine. The currently available device operates by utilizing an incandescent bulb for the heating process to eliminate the moisture from the coconut sap and employs a blender for grinding purposes. However, this approach presents two notable issues - the drying process is time-consuming, and the grinder's capacity is insufficiently small. To address these shortcomings, the Solar-Powered Coconut Sap Dryer and Grinder have been enhanced with a 650-watt tubular heating element for a more efficient drying process. Additionally, the grinding component has been upgraded with a one-horsepower motor linked to a roller, enabling the more effective pulverization of the sugar.

Table 3: Comparison between the existing machine versus the Solar-Powered Coconut Sap Dryer and Grinder

Parameters	Existing machine	Solar-Powered Coconut Sap Dryer and Grinder
Heating element	Incandescent bulb	The 650-watt tubular heating element
Grinder	Blender type (Blade)	Roller type (connected to a 1HP motor)

Environmental Impact: The use of solar energy significantly reduced the machine's environmental footprint. Solar energy is a renewable resource that does not emit harmful greenhouse gases, thus promoting a more sustainable approach to coconut sap processing [9].

Overall, these results underscore the significant potential of the Solar-Based Automated Coconut Sap Dryer and Grinder Machine in revolutionizing the coconut industry. By combining the principles of solar energy, automation, and design efficiency, this machine provides an innovative and sustainable solution for coconut sap processing.

Table 4: Shows the traditional process versus existing machine versus Solar-Powered Coconut Sap Dryer Cabinet comparison

Process	Temperature (in °C)	Drying (in hours)
Traditional Process	28 to 35°C	6 to 8 hours
Existing machine	45 to 60°C	2 to 4 hours
Solar-Powered Coconut Sap Dryer and Grinder Machine	60 to 70°C	1 to 3 hours

The data presented in Table 4 offers a comparison of the temperature per hour recorded for traditional processing methods, the current machine, and the Coconut Sap Dryer Cabinet. Notably, the Solar-Based Coconut Sap Dryer and Grinder Machine achieves the optimal drying temperature in fewer hours compared to the other two methods. This demonstrates a more effective and efficient heating design, resulting in reduced energy consumption. Consequently, this improvement could have a substantial positive impact for coconut farmers by potentially reducing energy costs and increasing productivity.

The graph depicted below represents the mean responses regarding the Solar-Powered Coconut Sap Dryer and Grinder. When assessed on functionality and accuracy, the machine scored a mean value of 4.87, categorizing it as excellent. As for operability, the machine received a mean score of 4.2, indicating a rating of good. In terms of safety, the machine scored a mean of 3.45, denoting a fair rating. Lastly, when evaluated on aesthetic appeal, the machine achieved a mean score of 3.75, corresponding to a good rating.

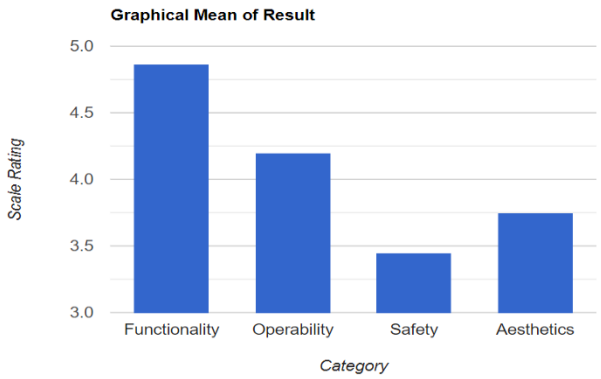

Figure 6: Mean responses for Solar-Powered Coconut Sap Dryer and Grinder

This research focused on the design, development, implementation, and evaluation of the Solar-Powered Coconut Sap Dryer and Grinder. Coconut syrup undergoes the drying process in the food dryer cabinet, utilizing a temperature controller and a fan to attain the desired consistency. The dried sap then proceeds to the grinding stage via a funnel. The

creation of this machine aims to alleviate the time and effort required to produce coconut sugar for producers and to enhance farmers' earnings through the integration of solar energy. Detailed statistical methods were applied to evaluate the machine's functionality, operability, safety, and aesthetics.

4. CONCLUSIONS

The study led to the following conclusions:

1. The machine's functionality was evaluated and found to be excellent.
2. Respondents rated the machine's operability as good.
3. The safety rating was deemed fair by respondents. Importantly, no incidents of injury or electrical hazards were recorded during the machine's operation.
4. The machine's aesthetics received a rating of 3.75, signifying a good evaluation.

5. RECOMMENDATIONS

After extensive observation, the researchers noted that the machine's roller size contributes to its overall weight, suggesting potential room for improvement. To further enhance the machine's effectiveness, the following recommendations are suggested:

1. It is highly recommended to revisit the design of the grinding component, focusing on a smaller, but still efficient, roller.
2. A comprehensive redesign of the machine, focusing on component arrangements, is recommended.
3. Lastly, a more organized wiring setup is advised to ensure no wires are left exposed for safety reasons.

7. REFERENCES

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