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Automated rice grain dryer with sun-tracking solar panel using Arduino Uno

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Abstract

A developmental evaluative experimental research design was used to develop an automated rice grain dryer and determine its effectiveness. This study constructed an Automated Rice Grain Dryer with Sun Tracking Solar Panel to advance drying technology and enable farmers to save time without jeopardizing the drying process despite bright or rainy days in the Philippines. The researchers employed a frequency and percentage to determine the level of effectiveness of the automated rice grain dryer. In addition, t-test analysis was used to determine if the Solar Rice Grain Dryer using Arduino differs significantly from traditional grain drying methods. The findings revealed that using an automated rice grain dryer with a sun-tracking solar panel reduced moisture content and accelerated the drying process of rice grains. The rice grains dry faster at greater temperatures when used in an automated rice grain dryer with a sun-monitoring solar panel. The findings indicate that the automated rice grain dryer is more efficient than the traditional method of drying rice grains in terms of moisture content, drying speed, and different temperature levels. Researchers suggest using a stronger solar panel for rice drying, improving the solar tracker's accuracy, and constructing a larger tunnel for rice grains. They also advise monitoring temperature and time fluctuations during the experiment to ensure accurate moisture content calculations. This will be a great resource for future researchers looking to improve and enhance the product's usability.

Keywords: automated rice grain dryer, moisture content, drying process, solar panel, traditional method

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1. Introduction

Farming is the Philippines' primary means of subsistence since it has long been one of the most important ways to make a living. In rural areas, people can observe that most of the population depends entirely on farming, mainly rice. As stated by Haefele et al. (2014), in both "upland" rained direct seeded areas and "lowland" flooded transplanted paddies, the Philippines produces about 3% of the world's rice. It is an essential part of consumer baskets because it is the country's staple food, the nation's most significant agricultural produce, and a significant source of revenue for millions of Filipino farmers. A farmer's primary goal is to maintain a crop's freshness because its likelihood of selling in the market increases when it is fresh and at its best quality. After all, it plays an integral role in the country's economy and the people's social livelihoods.

Weather significantly impacts the prevalence of pests and diseases, the availability of water, and the amount of fertilizer needed to grow crops. Farmers rely on climate patterns and weather forecasting to determine which crops to cultivate and when to sow them. Climate change disrupts food availability, access to food, and quality through the increased variability of weather. Located on the equator, the Philippines has a tropical marine climate. Thus, there are two distinct seasons: wet and dry. The wet season is when there is the most rainfall, whereas typhoons are relatively common during this time. Despite the frequency of natural hazards, farmers rely on the consistency of this pattern to know the optimum time to plant to achieve the greatest harvest. As a result of climate change, local weather patterns have changed significantly, making it increasingly more difficult for farmers to know when to plant their crops. Although many crops grown here in the Philippines rely on significant rainfall, typhoons increase the likelihood of flooding, which damages crop yields and causes soil erosion. Regardless of where humans are, climate change is inevitable and cannot be avoided or prevented. Thus, it is impossible to predict the ideal period for planting, harvesting, or drying of crops. It affects the environment and has a big impact on the producers and the farmers. As stated by Arouri et al. (2015), while the effects of extreme climate change on the environment are still being observed, the effects on people are more severe, especially for those who depend on environmental and climatic stability, such as Asian farmers.

Since they had no other option, Filipinos were compelled to adapt to this situation. Adaptation is viewed as the best solution as the effects of climate change on the environment intensify (Shaffril et al., 2018). Researchers' ideal design is to keep rice quality in its optimum state throughout drying and have a location in case of sudden rain or flood because the weather is unpredictable. The rice grain dryer is primarily powered by solar tracking solar panels, which lower electricity costs, save energy, and prepare the dryer for long-term use. According to the United Nations, solar energy is significant and widely available among renewable energy sources. It is preferred because it is a readily available source on Earth and has many advantages over other resources. One of its benefits is that it uses clean, renewable energy that does not deplete when not in use, protecting the environment (Masson et al., 2014).

This study constructed a device where researchers can easily dry rice grains and help them prevent getting wet from the rain. Additionally, with the help of Arduino Uno, researchers can set an exact temperature to help rice maintain its best quality and possibly dry it faster than the average time to help the farming community. Moreover, solar energy is more suitable since it is an endless renewable energy source. It will be fueled all day without concern for a utility bill, considering the sun is an endless energy supply. In addition, compared to any fossil fuel system, it does not harm the environment and has minimized greenhouse gas emissions. It also requires minimal maintenance and features a solar tracking system that moves the solar panel to where the sun is out.

Statement of the Problem - This study constructed an Automated Rice Grain Dryer with Sun Tracking Solar Panel to advance drying technology and enable farmers to save time. Specifically, it responded to the following: (1)

What is the level of effectiveness of the automated rice grain dryer in terms of moisture content and drying speed? (2) What is the difference between using an automated rice grain dryer at a different level of temperature in terms of 45 ℃, 50 ℃; and 55 ℃? (3) Is there a significant difference between automated rice grain dryers and traditional drying techniques in terms of moisture content and drying speed?

Significance of the Study - This research constructed an automated rice grain dryer that employs an Arduino Uno to advance drying technology and allow farmers to save time. The findings of this study provided an efficient device for farmers and assisted the community in promoting more environmentally friendly surroundings. The researchers believe that the study benefited the following: To the farmers, this will supply them with an alternate solution that will speed up the drying process of rice grain while also increasing convenience. To the community, they may utilize this study in their homes to develop and integrate it for their practical use. This can also be beneficial for individuals to provide an efficient, hassle-free, and environmentally friendly device. To the business establishment. They may apply the findings of this study to their agriculture practices. This may increase efficiency and lower the cost of drying rice. This study will aid future researchers in developing their research and improve and broaden this study regarding solar dryers. Future researchers may also use this study as a resource to gain ideas.

Scope and Delimitations of the Study - This study focused on constructing an automated rice grain dryer as an alternative solution for drying rice. The researchers determined how effective the automated rice grain dryer was in the drying process, whether the system could eliminate moisture in grains in a short time, and its effectiveness in sudden weather changes. Moreover, the automated rice grain dryer used solar energy, and the solar panel included a sun tracker to improve energy efficiency. This research focused on using an Arduino Uno R3 microcontroller to control and manage a rice grain dryer system. The system was programmed to the specified temperature, depending on the weather. This ensures that the temperature needed in the drying process is consistent. Additionally, this study was designed specifically for rice grain only, specifically Longping 937 hybrid rice variety, among the top choices of farmers to plant in their succeeding planting operations (6 Hybrid Rice Varieties Named as 'Farmers' Choice' Variety | DA Regional Field Office 1, 2022). Researchers tested ½ cup of rice grain per test. Every afternoon, the tests were conducted in La Curva, San Jose, Occidental Mindoro, from March 20 to March 23, 2024. Any consumer may utilize this for their use, provided it is for agricultural purposes. This investigatory project was conducted in San Jose, Occidental Mindoro, during the School Year 2023-2024 timeframe.

2. Methodology

Research Design - The researchers conducted this study using a developmental evaluative experimental research design to develop an automated rice grain dryer and determine its effectiveness. This research design enabled the researchers to provide innovation in drying rice grains by developing an automated machine that can dry rice grains effectively and environmentally friendly. In addition, experimental research design provides the researchers with a high level of control by enabling them to manipulate the target variables included in the study and test their effectiveness. Lastly, the scientific procedures used in this research design helped to increase the probability of obtaining accurate and trustworthy outcomes. Automated rice grain dryer. The data collected served as a guide for the researchers in determining whether the machine's performance was effective.

Data Gathering Procedure - To assess the product's effectiveness, the researchers conducted a series of tests with the study's statement of the problem after the product's construction. This improves the study's generalizability and validity while also avoiding research biases. The testing lasted for four (4) days to collect vital information and insights for the researchers better to understand the conflicts and the benefits of the device. The researchers conducted the testing with the help of two farmers in La Curva, San Jose, Occidental Mindoro, every afternoon from March 20 to March 23, 2024. Following product testing, researchers collected, organized, and analyzed the results.

Research Process; Stage 1 Preparation and Gathering of Materials - The materials needed to produce the Automated Rice Grain Dryer with Sun Tracking Solar Panel are as follows:

- Solar Tunnel Dryer: PVC Pipe, Plastic cover and Cladding
- Automated Rice Grain Dryer: Arduino Uno, Temperature Sensor LM 35, Relay, Liquid Crystal Display (8-bit), Fan, LED Light, Solar Panel, Charge Controller, Servo motor, LDR, Jumper Wires, Breadboard, Lead-acid battery (Motolite), Switch and 220 Resistor.

All the materials required to build the device were bought through online shopping specifically MakerLab Electronics. The total amount spent on buying the materials was Php 5,870.

Stage 2: Building and Development of the Project - As the prototype design and the final product illustrated in Figure 1, the machine consists of different components that function together to perform the intended output for the experiment. To determine whether the Automated Rice Grain Dryer with Sun Tracking Solar Panel using Arduino Uno is functional, the researchers designed the product in Tinkercad, an online 3D modeling tool for almost 3 weeks that includes the majority of the Arduino package's components.

Figure 1. Automated Rice Grain Dryer with Sun Tracking Solar Panel using Arduino Uno

Stage 3: Experimental Stage, Observation, and Data Recording - The necessary components were purchased from an online store. The researchers then obtained and finalized all materials before assembling the product based on the Tinkercad model. The program the researchers coded will be transferred to Arduino IDE application, which implements the program into the actual product. The application identified the code errors and helped the researchers fix the program for the rice grain dryer to work. To ensure the effectiveness of the Automated Rice Grain Dryer with Sun Tracking Solar Panel, the researchers tested the product first by putting rice grain into the product and putting it outside the establishment wherein there is a sun together with the test rice grain in the traditional method. After putting it, the researchers conducted a series of tests for four (4) days, including the moisture content test in a trusted rice mill, depending on the study's statement of the problem. The researchers used a Grain Moisture Meter Humidity Analyzer to determine the moisture content with the help of the rice mill personnel, who helped and accommodated the researchers. They also observed it and made a timer to measure the drying speed. The researchers coded the drying speed at a specific temperature level in Arduino IDE to determine the drying speed. They limited the temperature based on the study's statement of the problem. The researchers gathered and analyzed the data after testing the product's best features.

The researchers collected all the data before and after the machine was completed in this study. The researchers recorded every step, procedure, preparation of the materials needed, and the machine's construction, whether through photos or videos, to prove that the machine was made by the researchers. When the machine was finished, the researchers tested it to see if it was functional. They also wrote down all the information and ensure that the data gathered is accurate and honest.

Statistical Treatment of the Data - In this study, researchers employed a frequency and percentage to determine the level of effectiveness of the automated rice grain dryer. Moreover, a t-test, Two-Sample Assuming Unequal Variances, was used to determine if the Solar Rice Grain Dryer using Arduino differs significantly from traditional grain drying methods. The t-test: Two-Sample Assuming Unequal Variances assessed the level of effectiveness and efficiency of the product regarding its moisture content and drying speed. The results of this statistical treatment provided insights into the performance of the Solar Rice Grain Dryer and useful information for community stakeholders. By demonstrating its efficiency, highlighting environmental considerations, and suggesting areas for improvement, the statistical findings contribute to the overall assessment of how helpful this product can be to the community.

3. Results and Discussions

Table 1

Level of the effectiveness of the automated rice grain dryer in terms of moisture content of ½ cup of rice grain in 25 mL, 50mL, and 75mL of water after 45 minutes of drying

Number of Trials	**Moisture Content of Rice Grain in Automated Rice Grain Dryer with Solar Tracking Panel**			**Moisture Content of Rice Grain in Traditional Method**		
	25mL	**50mL**	**75mL**	**25mL**	**50mL**	**75mL**
1st trial	12.2 %	20.4 %	34.0 %	15.0 %	30.1 %	48.1 %
2nd trial	11.9 %	20.9%	36.3 %	15.2 %	29.8%	48.9 %
3rd trial	11.8 %	19.0 %	32.7 %	14.7 %	33.0%	49.5 %
4th trial	12.5 %	19.5 %	33.1 %	14.1 %	32.6%	49.9 %
5th trial	13.1 %	19.7 %	32.1 %	15.3 %	28.9%	50.2 %
Average	**12.3 %**	**19.9 %**	**33.46 %**	**14.86 %**	**30.88 %**	**49.32 %**

Legend*: * Ideal moisture content (Dry)- 14% and below*

15% and above moisture content- needs to be dried to reach a target (Ideal Moisture)

Source: Palacious-Cabrera et al. (2022)

The data provided in Table 1 delineates the outcomes of a meticulously designed experiment comprising five trials, each spanning 45-minute intervals. The experiment juxtaposes the efficacy of a prototype drying method against the conventional approach for drying rice grains. Researchers systematically immersed rice grains in varying volumes of water (25 mL, 50 mL, and 75 mL) before subjecting them to the respective drying techniques. Subsequently, they meticulously measured and analyzed the resultant moisture content, discerning notable disparities between the prototype and traditional methodologies using a Grain Moisture Meter Humidity Analyzer. For instance, when employing 25 mL of water, the prototype yielded an average moisture content of 12.3%, while the traditional method yielded 14.86%. Similarly, with 50 mL of water, the prototype recorded an average moisture content of 19.9%, whereas the traditional method exhibited 30.88%. Utilizing 75 mL of water led to an average moisture content of 33.46% in the prototype, contrasting with 49.32% in the traditional method. These discernible differences underscore the superior moisture preservation capabilities of the prototype across all experimental conditions. Such findings align with the assertions of Fu et al. (2017), who advocate maintaining a moisture content of 11–14% to uphold the quality and storability of rice grains over prolonged durations. Consequently, the observed moisture content of 1/2 cup of rice grains immersed in 25 mL of water following a 45-minute drying period with the prototype aligns harmoniously with the optimal moisture range recommended for sustaining rice quality and facilitating long-term storage.

Table 2

Level of effectiveness of the automated rice grain dryer in terms of drying speed of ½ cup of rice grain in 50 mL of water

Number of Trials	Drying Speed of Rice Grain in Automated Rice Grain Dryer with Solar Tracking Panel	Drying Speed of Rice Grain in Traditional Method
1st trial	1 hour, 7 minutes and 21 seconds	1 hour, 25 minutes and 22 seconds
2nd trial	1 hour, 29 minutes and 6 seconds	1 hour, 21 minutes and 36 seconds
3rd trial	1 hour, 2 minutes and 51 seconds	1 hour, 30 minutes and 4 seconds
4th trial	1 hour and 24 seconds	1 hour, 30 minutes and 27 seconds
5th trial	1 hour, 3 minutes and 43 seconds	1 hour, 34 minutes and 21 seconds
Average	**1 hour, 8 minutes and 41 seconds**	**1 hour, 28 minutes and 22 seconds**

Table 2 displays the various rice grain drying rates using traditional and prototype methods. Researchers used an automated rice grain dryer with a solar tracking panel and the traditional rice grain drying method to compare the drying speeds to ascertain the difference. The researchers ran five trials to determine if the drying time was consistent. The results indicate differences in the amount of time needed to dry. Researchers recorded one hour, twenty-five minutes, and twenty-two seconds during the first trial. Subsequent trials revealed notable variations in the drying time. This variation was also seen in the prototype trials; however, the prototype was more time-saving as it consumed less time than the traditional method. Based on the experiment's findings, the product differs from the traditional method in terms of drying speed, with an average drying speed of 1 hour, 8 minutes, and 41 seconds for the prototype and 1 hour, 28 minutes, and 22 seconds for the traditional method. According to Patil et al. (2022), developing a solar-powered automatic grain dryer system improves grain storage by removing excess moisture content from harvested grains. It's also time-saving because of the energy storage that saves from natural resources like the sun.

Table 3

Data of Drying Speed of 1/2 cup of rice grain in 50 mL of water at different levels of temperature

Number of Trials	Temperature	Drying Speed
Trial 1	45 °C	1 hour and 17 minutes
Trial 2	50 °C	53 minutes and 5 seconds
Trial 3	55 °C	43 minutes and 8 seconds

Table 3 presents the different temperature levels observed while drying rice grains using the automated machine. The researchers determined the temperature level during the process by utilizing the Temperature Sensor LM 35 and Liquid Crystal Display (8-bit). In addition, the temperature inside the solar tunnel was controlled using a fan that increased and maintained the temperature level. In the first trial, there was a temperature of 45°C inside the solar tunnel. The rice grains were dried inside the automated machine for 1 hour and 17 minutes. During the second trial, the temperature inside the solar tunnel was 50°C, resulting in 53 minutes and 5 seconds for drying rice grains. In the third trial, the solar tunnel temperature increased to 55°C. This eventually dried the rice grains for 43 minutes and 8 seconds. With the help of some farmers residing in the area, the researchers examined the rice grains frequently during the drying process. To identify the dryness of rice grains, the researchers used the rice grains in the first experiment, which contained only 11% moisture content, as a basis to compare the rice grains dried inside the solar tunnel with the rice grains dried using the traditional method. The data shown in the table above indicates that the temperature level inside the solar tunnel influences the speed of drying rice grains. Moreover, different levels of temperature result in different rates of drying time. The data collected during the experiment imply that a higher temperature inside the solar tunnel results in faster drying of rice grains. As stated in the study of Müller et al. (2022), elevated temperatures lead to an extreme decrease in rice grains' water content, impacting their protein, lipid, and ash composition. Controlling the temperature of the drying process has a significant impact on the duration of drying rice grains.

Table 4

Difference between the Automated rice grain dryer and the traditional method in terms of moisture content of 1/2 cup of rice grain in 25 mL, 50ml, and 75ml of water after 45 minutes of drying.

	25ml		**50ml**		**75ml**	
	Variable 1	Variable 2	Variable 1	Variable 2	Variable 1	Variable 2
Mean	0.123	0.1486	0.199	0.3088	0.3364	0.4932
Variance	2.75E-05	0.0000233	5.65E-05	0.0003287	0.0002688	7.02E-05
Observations	5	5	5	5	5	5
Hypothesized Mean Difference	0		0		0	
Df	8		5		6	
t Stat	-8.03143430		-12.5096224		-19.04281777	
P(T<=t) one-tail	2.12262E-05		2.8958E-05		6.77914E-07	
t Critical one-tail	1.859548038		2.015048373		1.943180281	
P(T<=t) two-tail	4.24523E-05		5.79161E-05		1.35583E-06	
t Critical two-tail	2.306004135		2.570581836		2.446911851	

Legend: P-value ≤ 0.05 Significant; reject H_0.

Table 4 contains the t-Test Two-Sample Assuming Unequal Variances of the moisture content of 1/2 cup of rice grain in 25 mL,50ml, and 75ml of water after 45 minutes of drying. The data analysis consists of two variables: Variable 1 for the moisture content of rice grains in an Automated Rice Grain Dryer with Solar Tracking Panel and Variable 2 for the moisture content of rice grains in the traditional method. In 25ml, 5he absolute computed value (t_{comp}) is 8.03 and the critical value (t_{crit}) is 2.31. Since the t_{comp} is higher than the t_{crit}, the researchers rejected the null hypothesis. Therefore, there is a significant difference between the automated rice grain dryer and the traditional drying technique regarding moisture content in 25 mL of water in 45 minutes of drying. In terms of 50ml, the absolute computed value (t_{comp}) is 12.51, and the critical value (t_{crit}) is 2.57. Since the t_{comp} is higher than the t_{crit}, the researchers rejected the null hypothesis. Therefore, there is a significant difference between the automated rice grain dryer and the traditional drying technique in terms of moisture content in 50 mL of water in 45 minutes of drying.

In terms of 75ml, the absolute computed value (t_{comp}) is 19.04 and the critical value (t_{crit}) is 2.45. Since the t_{comp} is higher than the t_{crit}, the researchers rejected the null hypothesis. Therefore, there is a significant difference between the automated rice grain dryer and the traditional drying technique regarding moisture content in 75 mL of water in 45 minutes of drying. The findings of this study are supported by Jain et al. (2019), who state that the moisture content of post-harvest grains typically falls within the range of 25-30%, which is less than ideal for storage. However, using a dryer reduces this moisture content to an ideal range of 12-14%, making it suitable for storing grains for 6-12 months.

Table 5 contains the t-test Two-Sample Assuming Unequal Variances of the drying speed of 1/2 cup of rice grain in 50 mL of water. The data analysis consists of two variables: Variable 1 for the drying speed of rice grains in an Automated Rice Grain Dryer with a Solar Tracking Panel and Variable 2 for the drying speed of rice grains in the traditional method. The absolute computed value (t_{comp}) is 3.42 and the critical value (t_{crit}) is 2.57. Since the t_{comp} is higher than the t_{crit}, the researchers rejected the null hypothesis. Therefore, there is a significant difference between automated rice grain dryers and traditional drying techniques in terms of drying speed. Product drying in a solar tunnel drier is faster than product drying in the sun, as discoverd by Tesfaye and Habtu (2022).

Table 5

Difference between automated rice grain dryer and traditional method in terms of drying speed of 1/2 cup of rice grain in 50 mL of water

	Variable 1	**Variable 2**
Mean	68.2	88
Variance	141.7	25.5
Observations	5	5
Hypothesized Mean Difference	0	
df	5	
t Stat	-3.423986596	
P(T<=t) one-tail	0.009378556	
t Critical one-tail	2.015048373	
P(T<=t) two-tail	0.018757112	
t Critical two-tail	2.570581836	

Legend: P-value ≤ 0.05 Significant; reject H_0.

4. Conclusions

After a summary of findings, the following conclusions were drawn, which also correspond to the order previously presented: The use of an automated rice grain dryer with a sun-tracking solar panel reduced moisture content and accelerated the drying process of rice grains. Rice grains dry faster at greater temperatures when used in an automated rice grain dryer with a sun-monitoring solar panel. There is a significant difference between automated rice grain dryers and traditional drying techniques in terms of moisture content and drying speed.

4.1 Recommendation

The recommendations stated below serve as a great resource for future researchers looking to improve and enhance the product's usability. The researchers recommend using a more powerful solar panel because the battery might run out before the rice is thoroughly dried, even if it is charging through solar. The researchers recommend improving the solar tracker since it may infrequently be accurate when tracking the sun. The researchers recommend a significantly larger tunnel for the rice grains since it requires a lot of rice grains to calculate their moisture content. It is recommended to keep an eye out for changes to the temperature and time of the experiment, as these variables can fluctuate while the experiment is being conducted. The researchers recommend placing the fan above the tunnel's base rather than at the entrance to allow for easy drying and simultaneous mixing of the rice grains. Researchers recommend mixing the rice grains at intervals during traditional experiments for better data accuracy.

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