GALAXY INTERNATIONAL INTERDISCIPLINARY RESEARCH JOURNAL (GIIRJ)
ISSN (E): 2347-6915
Vol. 11, Issue 06, June (2023)

MULTI-FUNCTIONAL SOLAR-BASED GRAIN STORAGE DRYER: AN EQUIPMENT FOR EFFICIENT DRYING OF RICE GRAINS

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ABSTRACT

PURPOSE

This study focused on determining the effectiveness of Multi-Functional Solar-Based Grain Storage Dryer in reducing and eliminating post-harvest risks that are present in sun drying. The researchers also aim to help the local farmers of Mauban, Quezon in increasing agricultural productivity through the use of modern technologies and renewable energy.

DESIGN/METHOD/APPROACH

The study used quantitative research method and true-experimental approach. Also, the study used observation method in determining the quality of the variables being studied. The study used One-Way ANOVA, T-test, and WAM (Weighted Arithmetic Mean) in interpreting the data gathered.

FINDINGS

The study revealed that the average weight that is being reduced in level 1 of blower is 1.45 kg, 1.55 kg for level 2, and for level 3, it is 1.90 kg. Using One-Way ANOVA test, the study revealed that there is a significant difference on the average amount of weight reduced using different levels of blower. Furthermore, the study indicates that there is no significant difference in the quality of rice grains dried using Traditional Sun Drying and Multi-Functional Solar-Based Grain Storage Dryer in terms of color, taste, and texture. Lastly, using WAM analysis, the data indicates that the respondents strongly agreed to the Specifications and Functionality of the product.

RESEARCH LIMITATIONS/IMPLICATIONS

While the study focuses on helping local farmers in reducing the post-harvest risks present in Traditional Sun Drying, the study does not cover any problems experienced by the local farmers that are not part or related to post-harvest risks.

ORIGINALITY/VALUE

This study has proven its usefulness in assessing the posts-harvest risks that are present in Traditional Sun Drying by maximizing modern technologies and renewable energy. This study can be useful for the school and future researchers, but most importantly, it can help local farmers especially in Mauban, Quezon.

Keywords: Rice grains, Solar-Based Grain Storage Dryer, Traditional Sun Drying, Solar energy

INTRODUCTION

In the past 25 years, most rice-producing countries of the developing world have had active programs geared to increasing rice production to meet the demands of their growing populations. But the problems with paddy production are followed by what are often termed second-generation problems particularly, those associated with postharvest (Wimberly, 1983).

Traditionally in Nigeria, rice is commonly dried on bear grown; along the high way on mats etc. most of these drying facilities expose the grains to contamination, quality and quantity losses due to spillage, animal consumption and wind. Currently, no mechanical paddy drier are available for farmers, except at the large mills for parboiled rice, even though some drying equipment (rotary dryer) have been developed by NCRI, it has not been tested and validated on industrial scale (Danbaba et al., 2014).

In the Philippines, the most prevalent drying practice up to the present is sun drying on concrete pavements, either on the 47 highways or basketball courts. Before the advent of GPEP (Grains Production Enhancement Program) it is estimated that only about 12% of the grain harvest was dried using mechanical dryers. Of the total mechanical dryers then in the country, 90% are in the government sector (NAPHIRE,1990).

One of the main reasons is that Cooperatives are not ready to adopt modern postharvest technologies. The cooperative movement in the Philippines was initiated by government as early as the 1930s. At present, both government and nongovernment organizations (NGOs) support and encourage the formation of farmer cooperatives. The goal is to organize the Filipino farmers with small landholdings to combine their resources so as to have a collective undertaking that can afford to acquire costly but efficient machinery and facilities that are beyond the reach of individual farmers. Unfortunately, the development of cooperatives has been, in general, very slow. Evidently the operating principle of cooperativism and the socioeconomic and moral values required of members are, for the most part, lacking. Thus, in spite of government and NGO assistance programs cooperatives remain at a primitive state of development (NAPHIRE, 1990).

With the underlying problems being experienced by different countries including the Philippines related to post-harvest drying, the researchers wanted to conduct a study on the effectiveness of Multi-Functional Solar-Based Grain Storage Dryer in reducing post-harvest risks and improving drying efficiency of grains. The researchers also aim to improve the agricultural productivity through the use of modern technology.

REVIEW OF RELATED LITERATURE

According to the study of Ban et al., 2000, Temperature, relative humidity, air speed are important factors in drying different agricultural crops. Improper drying processes can be a major cause of degradation in quality of. The proportion of fissured kernels and grains increases with the temperature and the evaporating capacity of the air.

According to the study of Mehdizadeh Z. et al., 2009, Solar drying process was conducted in a passive, mixed mode type solar dryer at about 50ºC for 90 minutes. In sun drying method this process took 8-10 hours at a mean temperature of about 26ºC. Samples were milled and polished. Quality factors including trade quality (head rice yield percent and whiteness), cooking quality (amylose content, gelatinization temperature, gel consistency, aroma and flavor) as well as nutritional quality (thiamine and lysine contents) were evaluated. Results indicated that under the conditions prevailing in solar dryer, quality factors weren't affected except for whiteness of rice that too was better than that for sun dried samples. All other quality characteristics of the final product were acceptable in comparison with those in sun drying method.

According to the study of Rahman et al., 2022, Renewable energy (RE) is gaining momentum in agricultural applications due to its lower risk than fossil fuels, reduced costs of solar modules, wind, and battery-related technologies.

Factors such as the height and flow of the grain mass, temperature and relative humidity of the drying and storage air, temperature of the grain mass, and type of drying process need to be addressed to ensure operational efficiency and grain quality in a dryer. For example, the increase in the height of rice mass causes drying in the upper layers to remain incomplete, which results in low drying efficiency and poor rice grain quality (Coradi et al., 2020).

RESEARCH QUESTIONS

This study is conducted to determine the effectiveness of multi-functional solar-based grain storage dryer in improving drying efficiency and improving grain security.

Specifically, it sought to answer the following questions:

1. What is the average weight reduced of rice grains using multi-functional solar based grain storage dryer at different levels of blower?

1.1 level 1;

1.2 level 2; and

1.3 level 3?

2. Is there a significant difference among the average weight reduced using different levels of blower?

3. Is there a significant difference between the quality of grains dried in sun drying and using the multi-functional solar-based grain storage dryer in terms of color, texture and taste?

4. What is the level of assessment of multi-functional solar based grain storage dryer in terms of:

4.1 Specification; and

4.2 Functionality?

METHODOLOGY

This chapter presents the methods and procedure for the study, such as research design, respondents of the study, research instrument, gathering procedure, and statistical treatment of data.

Research Project

Figure 2: Multi-Functional Solar-Based Grain Storage Dryer

Figure 3: Multi-Functional Solar-Based Grain Storage Dryer

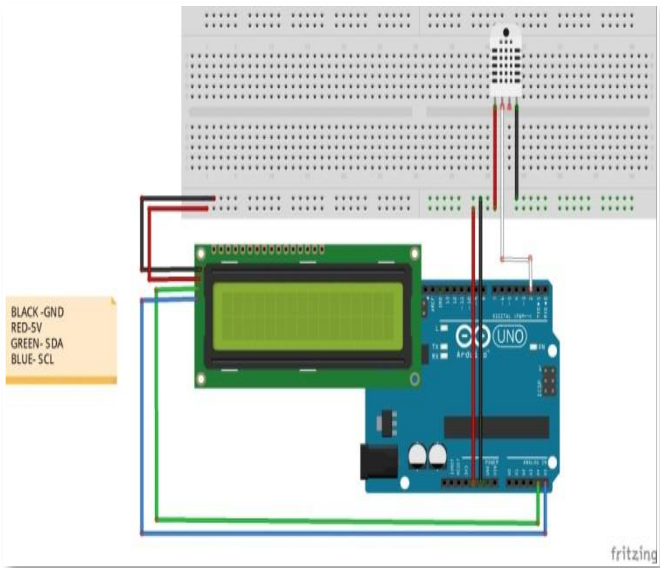

Figure 4: Schematic Diagram of Temperature and Humidity Sensor with LCD display

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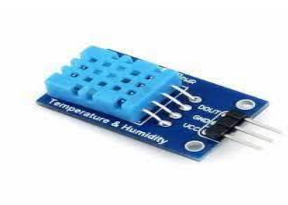
Table 1. Materials used by the researchers in making the Multi-Functional Solar Based Grain Storage Dryer:

MATERIALS	NAME	FUNCTION
	20 Watts Solar Panel	Serves as the main source of energy by absorbing the solar energy from the Sun.
	12 Volts Battery	Stores the energy and power up the blower.
	12 Volts Blower	Helps in drying the rice grains by distributing the heat inside the equipment
	Wires	Transports electricity which enables the other materials to dry the rice grains.
	Glass Sheets	Covers the main storage. Its purpose is to make the transportation of rice grains easier. It also protects the grains from different animals.
	Aluminum Sheets	Cover the sides of the storage and attracts heat which makes the inside of the storage hotter.
	Arduino Uno	The Arduino Uno contains a set of analog and digital pins that are input and output pins which are used to connect the board to other components.
	DHT 11 Temperature and Humidity Sensor	Detects the level of temperature and helps the researchers to find the ideal amount of temperature in terms of drying the rice grains.

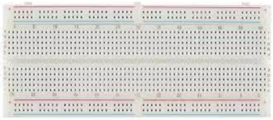
	Bread Board	Creates electrical connection between the LCD Display and DHT 11 Temperature
	Jumper Wires	Connects the LCD Display and DHT 11 Temperature and Humidity Sensor.
	LCD Display	Shows the amount of temperature and humidity inside the equipment.
	Speed Regulator	Regulates the speed of the blower.

Table 1 shows the necessary materials in making the Multifunctional Solar-Based Grain Storage Dryer.

Research Design

The study used Quantitative research method. By applying Experimental approach, the researchers will measure the amount of weight that is being reduced to the rice grains using different levels of blower. This can be done through series of trials. It also tests the difference in quality of rice grains dried using Traditional Sun Drying and Multifunctional Solar-Based Grain Storage Dryer in terms of color, taste, and texture after cooking. The comparison was done through observations using checklist. The researchers use online survey-questionnaires in finding the level of assessment of the Multifunctional Solar-Based Grain Storage Dryer.

Research Locale

The study was conducted to test the effectiveness of Multi-Functional Solar-Based Grain Storage Dryer in drying the rice grains as compared to traditional Sun Drying. The study was conducted in areas of Mauban, Quezon where the use of sun drying is mostly prevalent specifically, in Barangay Bagong Bayan, Mauban Quezon. The respondents were taken from national agriculturist and 4th year agriculture students which has much knowledge about agriculture. The researchers voluntarily served as the respondents in observing the trials.

Subject and Respondents of the Study.

The subject of the study is the rice grains and the product itself. The researchers will observe the behavior of the rice grains using when dried using the Multi-Functional Solar-Based Grain Storage Dryer.

In testing the level of assessment of the Multi-Functional Solar-Based Grain Storage Dryer, the researchers chose 80 respondents in which fourty (40) are professional agriculturist and another fourty (40) 4th year agriculturist students from different regions in the Philippines.

Sampling Techniques

The researchers employed purposive sampling technique in selecting the respondents. The researcher used non-probability sampling to allocate the respondents of the study. The researchers chose forty (40) professional agriculturist and forty (40) fourth-year agriculture students from different regions in the Philippines.

Research Procedure

The researchers gathered and plan about the flow of the study. First, the researchers gathered the necessary materials. After gathering the materials, the researchers created a diagram of different features that will be add Solar-Based Grain Storage Dryer. After creating the model and diagram, the researchers, with the help of welder then assembled the materials to make it a whole. After the product was finished, the researchers made a series of trials and observations to collect the necessary data. The researchers conducted survey-questionnaires through Google form to test the level of assessment of the designed project. The researchers explained the function of the product to the chosen respondents to be able to give them an idea about the survey-questionnaires. The researchers asked for consent to the chosen respondents before answering the survey-questionnaires. In addition, the researchers first asked for validation of Agriculturist. Before conducting the survey-questionnaires. The researchers explained the procedure and purpose of the survey. The result will use the method of elimination. The results will also be tabulated, analyzed, and interpreted.

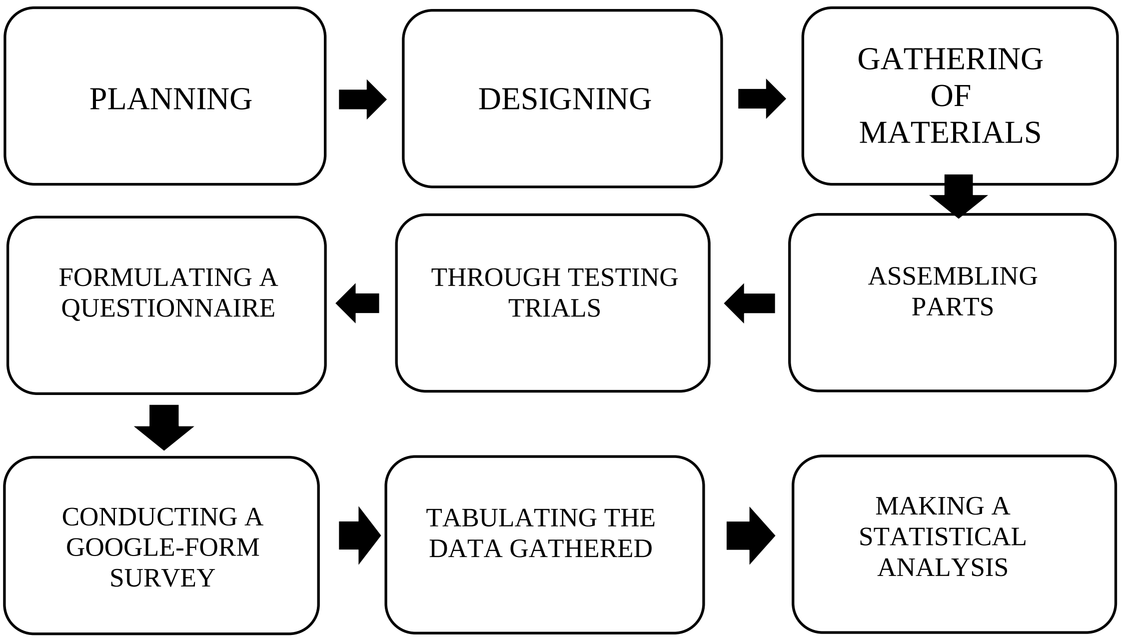


Figure 5 shows the flow chart diagram of the research procedure

Research Instrument

The primary data gathering tools are: series of trials, observations, and self-made Google form Survey-Questionnaires. The trials were validated by Chairman of Agriculture in SLSU Tayabas. The researchers asked for the permission of the SLSU Tayabas' Chairman of Agriculture before conducting the survey-questionnaires.

The validated research instrument will be submitted to the adviser for review and to the panel of experts for their approval.

Statistical Treatment of Data

1. To find out the significant difference to the amount of weight reduced using different level of blower, the researchers employed One-Way ANOVA Test.
2. To find out the significant difference in terms of color, taste, and texture, the researchers employed Checklist and computed the weighted mean of each scores.

Formula for the Mean:

$$\bar{x} = \frac{\sum X}{N}$$

3. After finding the mean of each scores, the researchers employed T-test.
4. To find the level of assessment of Multi-Functional Solar-Based Grain Storage Dryer in terms of Features and Functionality, the researchers employed Weighted Mean,

To compute the weighted mean, the following formula was used:

Formula: $WM = \frac{4f+3f+2f+1f}{N}$

WM: weighted mean

F: number of respondents' answer

N: number of respondents

Point Value	Continum	Qualitative Index	Code
4	3.25-4.00	Strongly Agree	SA
3	2.50-3.24	Agree	A
2	1.75-2.49	Disagree	D
1	1.00-1.74	Strongly Disagree	SD

Qualitative Index Interpretation:

SA- Highly Effective

A- Effective

D- Low level of Effectivity

SD- Not effective

RESULTS AND DISCUSSIONS

Part 1. The amount of weight reduced using different level of Blower.

Table 1.1. Using level 1 of Blower.

Trial	Level of Blower	Time (hr)	Weight before drying (kg)	Weight after drying (kg)	Total amount of weight reduced (kg)
1	1	3	5	3.32	1.68
2	1	3	5	3.37	1.63
3	1	3	5	3.35	1.66
4	1	3	5	3.63	1.37
5	1	3	5	4.07	0.93
		Mean			= 1.45

Table 1.2. Using level 2 of Blower.

Trial	Level of Blower	Time (hr)	Weight before drying (kg)	Weight after drying (kg)	Total amount of weight reduced (kg)
1	2	3	5	3.12	1.88
2	2	3	5	3.13	1.87
3	2	3	5	3.60	1.40
4	2	3	5	3.63	1.40
5	2	3	5	3.80	1.20
		Mean			= 1.55

Table 1.3. Using level 3 of Blower.

Trial	Level of Blower	Time (hr)	Weight before drying (kg)	Weight after drying (kg)	Total amount of weight reduced (kg)
1	3	3	5	2.96	2.04
2	3	3	5	3.10	1.90
3	3	3	5	3.11	1.89
4	3	3	5	3.11	1.89
5	3	3	5	3.22	1.78
		Mean			= 1.90

Table 1 shows the amount of weight reduced after drying a 5 kilogram of rice grains using different level of Blower. In table 1.1 , the average weight reduced using level 1 of blower was 1.45 kg. On the other hand, table 1.2 shows that the average weight reduced using level 2 of blower were 1.55 kg. Lastly, table 1.3 shows that the average weight reduced was 1.90 kg
According to the study of Ban et al., 2000, Temperature, relative humidity, air speed are important factors in drying different agricultural crops. Improper drying processes can be a major cause of degradation in quality of. The proportion of fissured kernels and grains increases with the temperature and the evaporating capacity of the air.

Table 2. One-Way ANOVA Test in testing the significant difference to the amount of weight reduced on different level of Blower.

Groups	Count	Sum	Average	Variance
Level 1	5	7.27	1.45	0.10153
Level 2	5	7.75	1.55	0.0947
Level 3	5	9.50	1.90	0.00855

Source of Variation	SS	df	MS	F	p-value	F crit
Between Groups	0.551053	2	0.275527	4.036429	0.045649	3.885294
Within Groups	0.81912	12	0.06826			
Total	1.370173	14				

The researchers used the data in table 1 in order to get the significant difference between samples.
Table 2 shows that the p-value is 0.04 and the F value is higher than F crit value which indicates that there is a significant difference between the three samples. Therefore, the null hypothesis is rejected
Part 3. The difference in quality of rice grains dried using Traditional Sun Drying and Multi-Functional Grain Storage Dryer.

Table 3.1. Traditional Sun Drying.

Indicators		Scores
1. Grains aren't mixed with dirt and rocks after milling.		2.00
2. Rice is white and polished.		3.00
3. The rice is dry and not fluffy after cooking.		2.00
4. Rice don't get easily break when pressed		3.00
5. The rice doesn't contain any unusual taste.		3.00
Mean	=	2.60

Table 3.1 shows the mean score of the trials made by the researchers in testing the significant difference in quality of the grains. Using the Traditional Sun Drying Method, the mean score is 3.00.

Table 3.2. Multi-Functional Solar-Based Grain Storage Dryer

Indicators		Scores
1. Grains aren't mixed with dirt and rocks after milling.		3.00
2. Rice is white and polished.		3.00
3. The rice is dry and not fluffy after cooking.		3.00
4. Rice don't get easily break when pressed		3.00
5. The rice doesn't contain any unusual taste.		3.00
Mean	=	3.00

Table 3.2 shows the computed scores of the trials made by the researchers using Multi-Functional Solar-Based Grain Storage Dryer. The data indicates that the mean score is 3.00. According to the study of Mehdizadeh Z. et al., 2009, Solar drying process was conducted in a passive, mixed mode type solar dryer at about 50℃ for 90 minutes. In sun drying method this process took 8-10 hours at a mean temperature of about 26℃. Samples were milled and polished. Quality factors including trade quality (head rice yield percent and whiteness), cooking quality (amylose content, gelatinization temperature, gel consistency, aroma and flavor) as well as nutritional quality (thiamine and lysine contents) were evaluated. Results indicated that under the conditions prevailing in solar dryer, quality factors weren't affected except for whiteness of rice that too was better than that for sun dried samples. All other quality characteristics of the final product were acceptable in comparison with those in sun drying method.

Table 3.3.T-test results for the difference of quality of rice grains dried using Traditional Sun Drying and Multi-Functional Solar-Based Grain Storage Dryer.

Groups	N	Mean	SDEV	SEM
Traditional	5	2.60	0.55	0.24
Multi-Functional	5	3.00	0.00	0.00

Standard Error of Difference: 0.245
Tabular: 0.1411
Critical Value: 1.6330
Level of Significance: 0.05
Decision: Accept the Null Hypothesis

Table 3.3 discussed the significant difference between the quality of rice grains dried using traditional sun drying and multi-functional solar based grain storage dryer. The computed value is lower than the tabular which indicates that there is no significant difference between the qualities of two groups.

Part 4. Level of assessment of Multi-Functional Solar-Based Grain Storage Dryer.

Table 4.1. Level of assessment of Multi-Functional Solar-Based Grain Storage Dryer in terms of specification.

Indicators	**Weighted Mean**	**Qualitative Index**
1. The materials used in the equipment are all useful and contributed to the overall performance of the product.	3.65	Strongly Agree
2. The addition of arduino makes the equipment more complex and functional.	3.46	Strongly Agree
3. The position of the sensor, blower, and other features are all properly placed.	3.56	Strongly Agree
4. The blower, arduino, and other features are all well designed and structured.	3.51	Strongly Agree
Average WM	3.54	Strongly Agree

Legend:
3.26 – 4.00 – Strongly Agree (SA) 1.76 – 2.50 – Disagree (D)
2.51 – 3.25 – Agree (A) 1.00 – 1.75 – Strongly Disagree (SD)

Table 4.1 shows the assessment of Multi-Functional Solar-Based Grain Storage dryer in terms of Specification. The data revealed that the respondents strongly agreed and was indicated by the average weighted arithmetic mean of 3.54.The highest mean that was on top were the "The materials used in the equipment are all useful and contributed to the overall performance of the product." It indicates that the respondents believe and strongly agreed that the specifications of Multi-Functional Solar-Based Grain Storage provides a significant contribution in terms of drying the rice grains.

According to the study of Rahman et al., 2022, Renewable energy (RE) is gaining momentum in agricultural applications due to its lower risk than fossil fuels, reduced costs of solar modules, wind, and battery-related technologies. For example, 100% renewable energy is becoming technically feasible and economically viable with decreasing costs every year, and achieving 100% renewable energy by 2050 is possible across all sectors. The agriculture sector is driven by various renewable and non-renewable energy sources. According to the Food and Agriculture Organization (FAO), the agri-food chain systems currently consume 30% of one-third of the world's energy production, with about 70% percent of the energy consumed by transportation, processing, packaging, shipping, storage, and marketing. However, the energy demand from the production stage to processing mainly comes from non-renewable energy.

Table 4.2. Level of assessment of Multi-Functional Solar-Based Grain Storage Dryer in terms of functionality.

Indicators	**Weighted Mean**	**Qualitative Index**
1. The equipment can be used in drying the rice grains even on rainy or cloudy day.	3.53	Strongly Agree
2. The specification of Multi-Functional Solar-Based Grain Storage Dryer has a significant role in its overall functionality.	3.67	Strongly Agree
3. The equipment makes the drying process easier and safer.	3.64	Strongly Agree
4. The functions of the equipment make the drying process more effective as compared to Traditional Sun Drying.	3.63	Strongly Agree
Average WM	3.62	Strongly Agree

Legend:
3.26 – 4.00 – Strongly Agree (SA) 1.76 – 2.50 – Disagree (D)
2.51 – 3.25 – Agree (A) 1.00 – 1.75 – Strongly Disagree (SD)

Table 4.2 shows the assessment of Multi-Functional Solar-Based Grain Storage dryer in terms of Functionality. The data revealed that the respondents strongly Agreed and was indicated by the average weighted arithmetic mean of 3.62. The highest mean that was on top were the "The specification of Multi-Functional Solar-Based Grain Storage Dryer has a significant role in its overall functionality." It indicates that the respondents believe and strongly agreed that the Functionality of Multi-Functional Solar-Based Grain Storage provides efficiency in terms of drying and protecting the rice grains.

According to the study of Mehran 2019, during drying process of paddy grains, as one of the major operations of rice milling process, a considerable amount of fossil fuel is consumed. The air pollutants emitted by combustion of fossil fuels are great threat to human health which strongly contributes to environmental problems. In the present study, to reduce the share of fossil fuels in drying process of paddy grains, a new type solar-assisted fluidized-bed dryer was used with the ability of thermal energy recovery. Two general conditions were considered for conducting the experiments: At two levels of the applied drying temperatures (35 °C and 45 °C), the required thermal energy during the drying process was completely supplied only by solar energy and without the need for fossil fuel.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The following findings are summarized based on the data and other multifarious information obtained in the study:

Summary of Findings

The following findings are summarized based on the data obtained in the study:

1. Base on the trials made by the researchers, the data shows that using level 1 of blower, the average weight reduced was 1.45 kg. In level 2 of blower, the average weight reduced was 1.55 kg. Using level 3, the average weight reduced was 1.90 kg. Shows the trials made by the researcher using the level 2 of the blower. Given the data, it was observed that there is a direct relationship on the level of blower and the average weight reduced of the rice grains.
2. The researchers used the data in table 1 in order to get the significant difference between samples. It shows that there is a significant difference between different level of blowers and the amount of weight being reduced in the rice grains. The data shows that the p-value is 0.03 which is lower than the alpha value that is 0.05 which indicates that there is a significant difference between the four samples. Therefore, the null hypothesis is rejected.
3. Base on the trials made the researchers in determining the difference in quality of the rice grains using Traditional Sun Drying and Multi-Functional Solar-Based Grain Storage Dryer, the data revealed that the mean score in Traditional Sun Drying was 2.60. While in Multi-Functional Solar-Based Grain Storage Dryer, the mean score was 3.00. Using T-test, the data revealed that there is no significant difference in terms of color, taste, and texture of rice grains using the Traditional Sun Drying and Multi-Functional Solar-Based Grain Storage Dryer.
4. After conducting the Google-Form Survey-Questionnaire, the data revealed that the level of assessment of Multi-Functional Solar-Based Grain Storage Dryer in terms of Specification was Strongly Agreed and was indicated with the Average Arithmetic Mean of 3.54. In terms of Functionality, the respondents Strongly Agreed to the statements and was indicated by an Average Weighted Mean of 3.62

CONCLUSION

Based on the findings, the following conclusions were made by the researchers:

1. Based on the finding, the average weight reduced in 5 kg of rice grains using the level 1 of the blower is 1.45 kg.While1.55 kg is being reduced in 5 kg of rice grains using the level 2 of the

blower. The finding also shows that using the level 3 of the blower, a 5 kg of rice grains will reduce 1.90 kg moisture content.

2. The data revealed that there is a difference on the amount of weight using different level of blower. Using statistical test, the study revealed that there is a significant difference between the levels of blower and the amount of weight being reduced in rice grains.

3. There is no significant difference in terms of color, taste, and texture of rice grains using the Traditional Sun Drying and Multi-Functional Solar-Based Grain Storage Dryer.

4. The assessment of Multi-Functional Solar-Based Grain Storage Dryer in terms of Specification and Functionality was Strongly Agree. The respondents believe that the Multi-Functional Solar-Based Grain Storage Dryer is Highly Effective and will benefit them more compared to traditional method of sun drying.

IMPLICATIONS AND RECOMMENDATIONS

In view of the forgoing findings and conclusions, the following points were hereby recommended:

1. Allow the farmers to use the product in drying their harvested rice grains.
2. Promote the product to higher Department of Agriculture.
3. Modify the product into a larger size.
4. For the farmers: Use locally available materials or recyclable materials if necessary to lessen the expenses if you want to make your own.
5. The researchers recommend to modify the product by making the features properly positioned and organize.
6. Maximize the equipment by understanding different concepts related to solar energy and electricity. That way, the user would be able to use the product on its maximum potential.

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