Design and Development of a Greenhouse Solar Energy-based Corn Dryer: A Case Study

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ABSTRACT

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| **Aims:** The study aimed to design and develop a greenhouse solar corn dryer that provides an efficient, sustainable, and cost-effective drying solution.The consistent use of traditional and conventional open sun drying (OSD) for agricultural products and yield necessitates the development of an innovation that can maintain quality, expedite the drying process, and potentially replace these techniques by utilizing renewable energy.**Study design:** The study employed a Research and Development Design and an experimental quantitative approach to analyze variables and data.**Place and Duration of Study:** Situated in Brgy. Anlugan, Cabanglasan, Bukidnon and lasted from January 28, 2025, to March 26, 2025.**Methodology:** First, the sketch and construction of the greenhouse solar dryer (GSD) were done in the locale of the study. Then, to commence the corn drying process, 2 sacks were bought for each method and repeated to conduct 2 trials, totaling up to 8 sacks of corn kernels with high moisture content. Necessary research instruments were used to measure the following parameters: moisture content, temperature, relative humidity, cost, and time. Lastly, samples of corn were randomly taken and filled into bags for testing of aflatoxin levels.**Results:** There was a significant difference between the performance of the GSD compared to the OSD in terms of moisture content, as *P =* 0.001. for both trials. Furthermore, there was no significant difference in the relative humidity measured from both methods, yet the GSD managed to store more heat compared to the OSD. Furthermore, aflatoxin levels measured through the ELISA test showed that the former contained samples that were food-grade compared to the traditional method. Lastly, through calculated costs and efficient hours of drying, the GSD was cheaper and took less time compared to the latter.**Conclusion:** The developed design has the potential to replace the traditional practice of open sun drying, yet it requires more enhancements and further trials to evaluate and potentially replace this method for the benefit of local farmers. |

*Keywords: Corn, Drying Process, Greenhouse Solar Dryer, Open Sun Drying, moisture content, performance, renewable energy, innovation*

1. INTRODUCTION

Corn (*Zea mays*) is recognized as one of the staple foods of the Philippines, second only to rice (*Oryza sativa*). It is required for corn and other agricultural products to undergo the drying process to prolong their quality and minimize damage from contaminants (Alit et al., 2020, Babar et al., 2020). This process also encourages proper storage as lowering the moisture content present in the grains helps prolong shelf-life, slow the process of bacterial and fungal growth, and maintain the quality of corn (Hnin et al., 2018; Mohana et al., 2020). The need for eco-friendly and affordable ways to perform this is heavy demand, as conventional methods require more energy and use large amounts of fossil fuels to power and execute the drying process (Chauhan et al., 2018). Thus, solar energy can be utilized in exchange for nonrenewable energies that damage our environment as it is abundant and easy to harness through photovoltaic panels (López-Vidaña et al., 2020). Solar PV is a renewable and mature technology widely used for decentralized energy conversion worldwide and suitable to meet the SSA water, energy, and food needs (Favi et al. 2024). With the introduction of renewable energy sources, distributed generation has grown into a significant portion as compared to fixed generation. In the present situation, the solar distributed generation has become a considerable amount and its uncertainty in production poses a serious challenge to load prediction (Sasidharan et al. 2023).

Although the Philippines is a tropical country with lush and diverse terrains that aid in agriculture, it still lags in terms of technology (Digal et al., 2018; Soriano et al., 2019). Though slowly developing, the agricultural sector of the country still suffers from many factors such as the persistent use of traditional techniques for producing crops and solving ongoing issues (Pulhin et al., 2016; Guro, 2019). Furthermore, much of the corn drying process still seems to involve the simple, energy-efficient, yet tedious process of sun-drying and other setups that involve fossil fuel use (Silva et al., 2021; Yahya et al., 2022).

Dryers can be classified according to their operating modes. In the case of direct solar dryers, the product is exposed directly to the sun’s rays inside a glass enclosure, the inside of which is painted black. Indirect solar dryers generally consist of a solar collector and a drying chamber containing the products to be dried. The solar collector converts the sun's rays into heat and this heat is sent into the drying chamber either by forced convection (using a fan) or by natural convection (using a solar chimney) (Tera et al., 2024; Amer et al., 2010). Mixed solar dryers combine the two solar drying methods (direct and indirect). Hybrid solar dryers use solar energy with other energy sources, the most commonly used of which are: electricity, gas, biomass and diesel (Fudholi et al., 2010).

The drive to create dryer designs was pursued due to the cons of traditional drying methods such as excessive manpower, contamination, lesser yield, and agricultural and economical losses (Moses et al., 2014; Gong et al., 2019). The presence of contaminants such as mycotoxins produces millions of losses in money, human population, and livestock (Luo et al., 2017). Thus, with the development of an efficient solar dryer, people and livestock that belong in the agricultural and economic sectors benefited from this.

Several local and international studies highlight the creation of solar dryers to increase productivity and the effectiveness of these setups in drying grains like rice and corn. An example can be seen in the study of Ntwali, et al. (2021), which employs an inflatable design and compares the difference between the effects of this with the samples that have undergone direct sun drying. Results here showed that the former performed better, reduced spoilage, and had lesser aflatoxins and impurities compared to the latter. Additionally, executing the drying process at dawn maximized the amount of solar energy and decreased the moisture content significantly before sunset.

There were also numerous solar dryer designs done within the local areas of the Philippines. First, one study pointed out more components that farmers can incorporate to upgrade their dryers while still being cost-effective. The review further promoted the advantages of solar energy and mentioned that more studies need to be conducted to provide and support more details on designs that can dry samples quickly and operate throughout the night (Oria, 2022). Lastly, another solar dryer was created in a cabinet-like shape consisting of heaters and trays. Banana was the dependent variable here, and the design managed to dry more than 40% of the moisture content. Other factors recorded were the average temperature of 42 degrees Celsius, 10 hours of drying time, and an efficiency evaluated at 18%. This design was lastly evaluated to have a decent performance and possessed the potential to replace other drying methods (Genobiagon et al., 2019).

It was for these reasons that the researcher has been striving to design solar dryer setups. These innovations possessed outstanding potential and opportunities for farmers from not only Bukidnon but possibly nationwide and internationally. Moreover, these handed environmental and economic benefits to not only the local community but also the country. The research was directed at creating a greenhouse solar dryer (GSD) that features a 30 sq. meter area, a greenhouse heating system, and axial exhaust fans for proper air circulation. To add, the developed design was created to be functional and cost-effective, ensuring that it will be accessible and simple to replicate. This design was tested through two (2) trials and has each data compared to the (OSD) and output performance of the mechanical dryer (MD). Lastly, the drying process of corn was done through several trials with the parameters including moisture content, aflatoxin levels, temperature, relative humidity, cost, and time of drying process.

2. METHODOLOGY

**2.1 Study Design**

This study utilized the Research and Development (R&D) design. This type of design encompassed a gathering of literature and analysis, formulation of objectives, development and testing of the product, and collection of data for revisions (Gustiani, 2019). Moreover, this applied an experimental quantitative approach to examine the performance of the developed greenhouse solar corn dryer for the farmers in Anlogan, Cabanglasan, Bukidnon. The researcher conducted experiments to test the efficiency of the device compared to other drying methods (independent variables) and the results of the corn prior to and after drying (dependent variable) (Creswell et al., 2017).

**2.2 Location of the Study**

The study site was in Anlogan, Cabanglasan, Bukidnon, a rural area recognized for its rich agricultural landscape and verdant surroundings. It has the coordinates 8.0531340, 125.3047321. This region features rolling hills at an elevation of 400 to 700 meters above sea level, offering a cooler climate favorable for various crops. In Anlugan, temperatures typically range between 22°C and 28°C, with an average outdoor humidity of 90%. The GSD design was situated here as it was perfect for testing a device that can dry corn in an underdeveloped area with limited access to good technology and electricity.

Moreover, sites for purchasing and gathering the necessary materials were made within the area of Malaybalay City, Bukidnon. Most importantly, the researcher prepared the funds by soliciting and withdrawing from Pitac-MPC, which is in the Chamen Building, San Victores St., Barangay 9, Malaybalay City. Moreover, the researcher, along with the construction workers, bought the materials from local construction supply markets and Citi Hardware. Lastly, in collecting samples to compare aflatoxin levels and dryer features, a mechanical dryer (MD) from Mantibugao, Manolo Fortich, Bukidnon, was included to present industrial dryer features to compare with the collected data.

**2.3 Sample Collection and Preparation**

To test the drying process, two (2) trials were conducted with close monitoring of two (2) drying methods: the GSD and OSD. To ensure quality and observable characteristics of the drying process, two (2) sacks weighing about 100 kg of freshly purchased shelled corn were purchased from sellers around the local area of Cabanglasan. Moreover, to prevent external factors with the potential to interfere with the data-gathering procedure, the drying surfaces of both methods were swept and cleaned well. Lastly, this process was replicated again for the second trial.

**2.4 Sampling Procedure**

For the extent of this study, the researcher utilized random sampling and took 10 samples of final moisture content values from around the area of the GSD and OSD. In the case of the MD, because of the expensive service, only other parameters were measured and compared to provide more context. Such was the aflatoxin level, where one (1) bag worth 300 g of corn kernels was sampled per trial and method in preparation for the Enzyme-Linked Immunosorbent Assay method (Oplatowska et al., 2016). Another was the relative humidity, wherein values were measured based on various periods of the drying process, and five (5) values were only taken from each trial and method for statistical analysis.

**2.5 Data Gathering Procedure**

To specify the first two drying methods two drying methods, which were the focus of the study, the initial and final moisture content, temperature, relative humidity, and cost were highlighted. In the case of moisture content values, 10 recorded values were used in preparation for statistical analysis. In obtaining the temperature, values were recorded but only the minimum and maximum values were presented since the observation period did not involve a thorough 24-hour span, especially during overnight drying hours of the GSD in comparison to the OSD samples that were stored after sunset.

Additionally, 5 values were recorded on the relative humidity of both drying periods. These were prepared to undergo statistical analysis to determine any significant difference in values. In obtaining essential data on aflatoxin levels present, the bagged samples, including those from the MD, were sent to Pilmico Corporation, where their facility was utilized in identifying if these were food-grade or not.

Furthermore, the cost was computed through the price of materials and receipts kept. This parameter included not only the expenses but also the estimated and calculated unit price of drying corn. This was done to assess the cost-effectiveness of the drying methods further. The following were the formulas used to compute the unit cost of drying from the GSD and OSD.

 Total Expenses or Capital

**GSD** = --------------------------------------------------------------------------------------------------------------

 (Depreciation)(Number of dryer uses in a month)(Total weight of corn for drying)

(Minimum Wage of Agricultural Workers)(Number of Workers)(Days of Work)

**OSD** = -----------------------------------------------------------------------------------------------------------------

 Total weight of corn for drying

Lastly, the time was recorded from the beginning of fresh purchase and properly setting up the corn kernels to dry until the moisture percentage drops to about or less than 14%. It is important to note that during special cases of rainy weather, the time of the GSD continued to tick to count its efficiency hours, while the OSD drying time also continued ticking, with only a difference in efficiency and active drying hours.

**2.6 Research Instruments**

Throughout the study, the researcher utilized the Grain Moisture Meter SHEGA III for measuring moisture content values, a cellphone to document the progress of the study, receipts, and Microsoft Excel to calculate the total cost of expenses, and the SketchUp App to create, enhance, and design the GSD. To add, two (2) units of 3-in-1 clocks featuring temperature and relative humidity sensors were used to mark the start and end of each drying period, the hotness of the GSD compared to the OSD, and the amount of water vapor present from the former and latter. Most importantly, close monitoring of weather forecasting websites such as PAG-ASA and AccuWeather was done to maximize the drying process of each method.



**Figure 1.** *GSD Front Side View*

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**Figure 2.** *GSD Back Side View*



**Figure 3.** *GSD Heating System Concept*

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**Figure 4.** *GSD Heating System with Axial Fan (Blower)*

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**Figure 5.** *GSD Exhaust System*

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**Figure 6.** *GSD Roof Side View*

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To add, only two (2) drying methods were closely monitored in this study. The OSD only utilized an open cemented area within Brgy. Anlugan, with no other equipment such as tarpaulins. On the other hand, the GSD used one (1) roll of UV plastic, square steel tubes, steel pipes, steel elbows and nipples, welding sets, disc grinder, cutting discs, black epoxy primer paint sets, door hinges, plain sheets, PPR tubes and elbows, Teflon tape, thin wood moldings, black screws, and other essential tools that were used to make the structure rigid. The concept also involved a solar setup to accommodate the power needed for essential mechanisms to function.

**2.7 Statistical Treatment**

Since the study involved two (2) trials for only two drying methods, the independent t-test was utilized. This was only specifically applied to the following parameters: moisture content percentages and relative humidity. In the case of the temperature, a bar graph depicting minimum and maximum numbers was used to present data from the first and second trials. Additionally, the aflatoxin levels, cost, and time were presented in tables to depict the significant values recorded.

**2.8 Ethical Considerations**

During the conduct of this study, the researcher practiced proper ethics by protecting the privacy of the participants involved, such as the personal data of the local farmers, workers, and the expert. The Data Privacy Act was adhered to, which is a law designed to ensure the protection of individuals' personal information from unauthorized access and misuse. The researcher followed proper conduct so that there was no leaked information on those individuals who helped in setting up the dryers.

3. results and discussion

This section presents the actual setups of the GSD and OSD. Furthermore, the resulting data and essential parameters are presented and discussed based on the trials conducted.

**3.1 Greenhouse Dryer Design**

The Greenhouse Dryer Design consists of many significant features that aid in creating a sealed environment for corn to dry evenly. These include a 6 m by 5 m cement floor (30 sq. m), a 4 m height, ventilation screens on the roof and sides of the dryer, and areas that shelter the axial fans used for air circulation. Unfortunately, the solar water heater was not functional enough to be used for longer periods, as it easily overheats after 10 minutes of use. Thus, the whole drying mechanism relied on sunlight, air circulation, stored heat, and proper ventilation.

**3.2 Parameters Used in Determining Performance**

To present the resulting data obtained from the drying processes, the moisture content must be investigated first, as this is the primary factor in determining the drying method's efficiency. For this, initial and final moisture content values were measured from the first and second trials. The Independent T-Test Analysis was applied to analyze the difference between the GSD and OSD performance based on this important parameter.

**Table 1. Initial and Final Moisture Contents (%)**

**Initial 1 OSD Final 1 GSD Final 1 Initial 2 OSD Final 2 GSD Final 2**

23.6 14.1 12.9 26.5 13.3 12.4

22.5 14.2 13.0 24.5 13.7 12.8

21.4 14.1 12.5 26.1 13.6 12.7 23.1 13.8 12.3 24.5 14.0 12.6 22.9 14.1 12.9 27.1 13.5 12.8 23.3 13.7 12.6 27.4 13.6 12.9 23.2 13.7 12.8 26.2 13.8 12.5 21.9 13.6 13.0 26.0 13.5 12.4 24.2 14.3 12.9 25.4 13.9 12.7 25.2 13.6 12.0 25.0 13.4 12.9

It is important to note that each number arranged on rows based on trials does not correspond to a specific category but is arranged randomly. Nevertheless, a major observation from here is that the GSD has dried more moisture compared to the OSD. Within a drying time of 2-3 days, the former managed to reduce the amount of water present in the corn to below 13%, which is ideal for proper storage and prevention of fungal and bacterial growth (Li et al., 2014; Li et al., 2020; Valle et al., 2021). Although the OSD managed to also dry the kernels to around 14% and below, there is a significant observable difference between the final moisture contents.

**Table 2. Moisture Content t-Test Analysis**

**Dryer n mean SD t df p Decision**

OSD 1 10 13.63 0.221

 7.41 18 0.001 Reject

GSD 1 10 12.69 0.335

OSD 2 10 13.92 0.266

 12.12 18 0.001 Reject

GSD 2 10 12.67 0.189

As depicted in the table above, the means of GSD from both trials are less than the OSD and the p-value resulted to be0.001. This proves to be promising for determining the performance of the dryer since the data was interpreted to have a significant difference between the efficiency of the design compared to the traditional method. In other words, the null hypothesis is rejected, and GSD can compete against the OSD based on the amount of moisture content removed from the corn kernels.

Moving on, the next table demonstrates the hours taken to dry the corn kernels from both trials. Time is significant in determining the speed and rate of drying. Thus, the following data is presented:

**Table 3. Time of Drying Process**

**Dryer Trial Start Trial End Time**

GSD 1 ` March 6, 9:30 AM March 7, 5:00 PM

 31 hrs, 30 mins

OSD 1 March 6, 9:30 PM March 7, 5:00 PM

GSD 2 March 10, 11:30 AM March 11, 5:00 PM 30 hrs, 30 mins

OSD 2 March 11, 5:00 PM March 12, 4:00 PM 52 hrs, 30 mins

MD - - 8 hours

During the process of conducting the drying process on the first trial, these were arranged and done on the same date, under the same weather conditions, and at the same time to produce fair and comparable data. In the span of 31 hours and 30 minutes, GSD managed to dry corn from an initial moisture content of 23.13% down to 12.69%, while OSD dried it to only 13.63%. Based on these insights, the dryer design performed well in the first trial with a significant difference in moisture in this uniform amount of time.

The same can be said for the second trial, only that there was a difference in active drying hours and weather conditions. During the drying process of the OSD, the weather was unfavorable on the first day, March 10, due to rain and cloudy weather. The sun was not present for this method to continue; thus, it was set back up on the next day, March 11, in the morning. For the GSD, even during rainy weather, it managed to dry the kernels from an initial moisture mean of 25.87% down to 12.67%. Due to the presence of the axial fans, UV plastic covering, and proper ventilation screens. These were also analyzed to be like the first trial, having a significant difference in efficiency.

As seen also, the time and opportunity it took for OSD to dry the corn kernels as fast as it could after harvest and purchase provides key information about its disadvantages. Mainly, this conventional method lags others due to its dependence on sunlight (El Hage et al., 2018; Hempattarasuwan et al., 2019).

Concisely put, the GSD continues to have the upper hand in drying corn effectively, time-wise. Because the covering and structure prevented water leakage, the corn kernels were allowed to continue laying on the surface until dried to the desired standard. Yet, the design requires further modifications to compete with the drying time achieved by the MD, which could dry corn within a few hours of a day. Unfortunately, due to the limitations of the study, including finances, no trials were conducted on the MD, and only specifications were obtained.

Moreover, there are 2 other primary factors that influence the time and decrease in moisture content. These are the relative humidity and temperature. The data presented are displayed below:

**Table 4. Relative Humidity (%)**

**OSD Final 1 GSD Final 1 OSD Final 2 GSD Final 2**

 35 35 38 37

 36 37 39 40 39 38 43 42

 42 41 44 43

 43 42 47 47

**Table 5. Relative Humidity t-Test Analysis**

**Dryer n mean SD t df p Decision**

OSD 1 5 39 3.536

 0.2 8 0.423 Accept

GSD 1 5 38.6 2.881

OSD 2 5 42.2 3.701

 0.17 8 0.435 Accept

GSD 2 5 41.8 3.701



**Figure 7.** *Minimum and Maximum Temperatures (Celsius)*

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In the context of drying, relative humidity and temperature are inseparable as these parameters determine the heat input and the movement of water vapour during drying. Furthermore, the relationship of these two is inversely proportional, as a faster drying system is achieved with a higher temperature and lower relative humidity (Depiver et al., 2023; Kumar et al., 2016).

Based on the t-test analysis, there is no significant difference between the recorded relative humidity values from both drying methods. Even by the means of these and the minimum and maximum values of the temperature recorded from both trials, there is only a little difference. Although the GSD was noticeably able to store heat better than the OSD, the device requires further enhancements to compete with industrial methods. At least, the GSD was able to maintain around the same or even less relative humidity values due to the utilization of the two (2) axial fans. These fans feature 250 W power, 2800 rpm output, and a maximum air pressure of 215 Pa. Through these, the evaporated moisture from the corn undergoing the drying process was able to escape through the ventilation screens.

Besides identifying the performance of the drying mechanisms, it is important to explore the quality of the corn, especially after drying. This is because, during the period of drying, the moisture levels are still above 14% during the earlier periods, which risks the presence and growth of fungi such as the notable *Aspergillus flavus* (Bhandari et al., 2015; Gündüz et al., 2021).

**Table 6. Aflatoxin Level (ppb)**

 Dryer Sample 1 Sample 2

 OSD 0.4 0

 GSD 0 0

 MD 0 0

Aflatoxins are remarked as one of the most well-known and well-researched toxins due to how problematic it is for the agricultural and food sectors (Gomiero, 2018). They are known to decrease the yield of corn and cause fatal digestive illness and physiological damage when consumed by animals and humans (Munkvold et al., 2019; Eraslan et al., 2017; Fetaih et al., 2014; Da Silva et al., 2021). Therefore, it is required for corn outputs to undergo careful inspection prior to food and feed production.

In relation to Table 6, OSD was the only one with the presence of aflatoxins. The second trial of the OSD and the test results of GSD and MD demonstrated zero levels of the toxin present in the samples. Although these zero levels indicate that it is food-grade quality, this is solely based on one (1) sample of each trial and drying method submitted to Pilmico Corporation for testing. Furthermore, a small sample size of 300 g compared to the whole initial drying weight of around 100 kg, or 2 sacks of corn, seems to be too small to achieve a solid verdict. For more comprehensive results on this parameter, it is recommended to test at least 3 sample bags of corn weighing about 500g or more.

**Table 7. GSD and OSD Cost**

 Dryer Expenses Unit Cost (Theory)

 GSD Php 43, 915.00 Php 0.50 / kg

 OSD No Cost Php 2.84 / kg

Lastly, replicability is important when creating an innovation with the potential to aid the community. Thus, in determining so, the expenses of the dryer setups were computed. As seen above, the whole structure of the GSD cost a total of Php 43,915.00, while the OSD setup for the extent of the study amounted to none.

Though theoretical, calculating the unit cost is significant in determining how cost-effective the drying method is. Since the current GSD design lacks the presence of solar panels as an alternative to electricity power lines, the total capital can be inferred to be around Php 60,000. This is the estimated value because the true objective of this design will be to have a functional solar water heating system and have each mechanism such as the axial fans powered through solar panels, batteries, and solar inverters. Thus, the expenses of these additional modifications are accounted for future purposes. Additionally, the current setup has undergone trials of corn kernels weighing approximately 100kg. The whole setup can be multiplied by 10 on both corn weight and total expense to identify the unit cost of a functional device with the following features:

* Php 600,000.00 capital
* 1,000 kg capacity
* 10 years of useful life x 12 months (depreciation)
* 30 days in a month divided by 3 days work time (2 days drying, 1 day rest) = 10 uses per month

 Php 600,000.00 capital

**GSD** = --------------------------------------------------------------------------------------------------------------

 (10 years x 12 months depreciation) (10 uses per month) (1,000 kg capacity)

 = **Php 0.50 per kg of corn kernel**

Thus, the unit cost can be estimated at a value of 50 centavos per kg of corn.

Now, for accounting for the important factors in the OSD method:

* Minimum Wage for Agricultural Farmers from Cabanglasan = Php 446.00 per day (Notshe, 2025)
* 3 days drying time
* 2 workers
* 1,000 kg of shelled corn
* Rental area per day (Rate in Cabanglasan is Php 8.00 per sack or 50 kg multiplied by days of drying)

(Php 446.00)(3 days work time) (2 workers) + (Php 8.00) (1000kg / 50 kg rental)

**OSD** = -----------------------------------------------------------------------------------------------------------------

 1,000 kg of corn

 Php 2,676.00 + Php Php 160.00

=--------------------------------------------------------

 1,000 kg of corn

= **Php 2.84 / kg of corn**

In comparing the cost of the GSD and the OSD, it is essential to consider that the latter relies on labour and minimum wage compared to the former, which focuses on the depreciation of the product with consideration that it is functional enough to disregard electrical fees and requires little to no labour for observation. Though prices may vary for different products and services, the OSD still proves to be more costly compared to a fully functional GSD. A sustainable product like this possesses the potential to replace conventional methods of drying, while also ensuring quality, faster drying rates, and much better efficiency hours.

**3.3 Scope and Limitations of the Study**

The scope of this study covered the sketching, designing, gathering of materials, and construction of the GSD. Alongside this was the OSD, which shall be situated in Brgy. Anlugan, Cabanglasan, Bukidnon. Corn was the only agricultural product that would be dried and tested. Furthermore, parameters of the study included the moisture content, aflatoxin levels, temperature, relative humidity, depth of corn samples, cost, and time of drying process. After measuring these parameters through four (4) trials of the drying process for each method, the data were compared through ANOVA format.

The study was limited to utilizing three drying methods, namely the GSD and OSD. The agricultural product limited to the drying process was corn. Moreover, the GSD involved a unique design featuring a base of 30 sq. m, a height of 4 m, a greenhouse heating system, two (2) axial fans, ventilation screens, square steel tubes, and UV plastic. In the case of the OSD setups, these were limited to areas within Brgy. Anlugan. This other drying method was set up on a cemented floor near the GSD setup.

**4. CONCLUSION**

In the pursuit of creating innovations that utilize renewable energy, a greenhouse solar dryer was developed to compete with open sun drying. Since the traditional method included cons such as lesser quality of corn due to contamination and fungi, the developed design aimed to counter this by creating a sealed environment with better heat circulation and storage. Furthermore, the study was focused on creating an efficient drying environment using powerful fans and proper ventilation to compare its performance with other drying methods. Once a functional drying mechanism is achieved, it will transition from the use of electricity from power lines to a full solar setup for cost-effectiveness.

Based on the data collected and analyzed, the performance of the GSD was better compared to the OSD in terms of moisture content, efficient hours used, aflatoxin level, cost, and temperature. In relatively the same amount of time and weather conditions, the design was able to store slightly more heat and reduce moisture to less than 13% on average, while the traditional method dried to equal to and less than 14%. There were also no aflatoxin levels from both samples of the GSD and MD, while the OSD had one sample containing 0.4 ppb of the toxin. Additionally, in theoretically computing the cost of setting up a functional GSD in comparison to the OSD, the former would only cost Php 0.50 per kg of corn compared to the latter, which would approximately cost farmers Php 2.84 per kg of corn.

Since the device was not fully functional, especially with the solar water heater, there is a need to further modify and improve the device until it becomes a sustainable and effective model. Once this is achieved, a transition to solar energy and electricity production can be pursued to accommodate the total amount of power required by the system and decrease the expenses of farmers in electrical fees. Moreover, a high-capacity design can also be replicated in the future to lead farmers to clean and green agricultural practices, and better economic development. All in all, though flawed in many aspects, the GSD as of this study already paves the way for eco-friendly, productive, and cost-effective opportunities in the agriculture and corn production business. Further studies on an efficient dryer design, especially ones conducted in the Philippines, are necessary to address and assist production in agriculture sectors.

**Recommendations**

For rich statistical data, more samples and trials are needed. This is essential especially for the aflatoxin levels to ensure that the whole batch that is being dried is at least good for consumption. In measuring the temperature and relative humidity, this must be done with, at best, a 24-hour observation to determine the drying properties of the GSD with its potential to utilize more work hours compared to the OSD. Once these two factors are also measured, a line graph demonstrating the proportional decrease of moisture in relation to these will effectively present the data. Lastly, the dryer design must be developed further, with emphasis on its solar water heater, to utilize the heat exchanging property well. Once completed, the power source can be transitioned into a full solar setup to reduce costs in the long run.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Authors’ Contributions

Dash Constantine S. Chamen is the study's student researcher. His contributions mainly focused on paper writing, data gathering, performance assessment, and statistical analysis.

Dr. Ian Jay P. Saldo is Dash Constantine S. Chamen's research adviser. His contributions involve providing suggestions, guidance, and assistance in data collection and statistical analysis.

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 **Table 8.** *Aflatoxin Test Results from Pilmico Corporation*

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