Surigao City Campus

SURIGAO STATE COLLEGE OF TECHNOLOGY

SSCT

"For Nation's Greater Heights"

Bachelor of Science in Electrical Engineering

I.1.7. group/individual study;

# APPROVAL SHEET

This Project Study entitled **"THE IMPLEMENTATION OF THERMOELECTRIC SYSTEM"** prepared by **Delf Enriq Aloyon, Lord John Kevin Bangcoyo, Reiolvi Orcullo, Lowie Pejer, Hannie Bert Quinalagan** in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical Engineering** has been examined and is recommended for acceptance and approval for ORAL EXAMINATION.

**ENGR. JERRY I. TELERON PhD. PCpE**
Co-Author

==============================================================

**PANEL OF EXAMINERS**

Approved by the committee of ORAL EXAMINATION with a Passing Grade on June 07, 2022.

**ENGR. ROBERT R. BACARRO, MECE, MBA**
Chairman

**ENGR. VICENTE Z. DELANTE, M.ENG'G**
Member

**ENGR. FEDERICO A. AVES, Jr., MST, M.ENG'G**
Member

==============================================================

Accepted and approved in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical Engineering.

**ENGR. ROBERT R. BACARRO, MECE, MBA**
Dean, College of Engineering and Information Technology

Date: June 10, 2022

# Renewable Energy: Thermoelectric Power Generating Device

**Delf Enriq Aloyon[1], LordJohn Kevin Bangcoyo[2], Reoilvie Orcullo[3], Lowie Pejer[4], and Hannie Bert Quinalagan[5]**

**Surigao State College of Technology, Surigao City, Philippines**

***Abstract***

Countless households and business establishments are longing to find an alternative source of energy due to the increasing of electricity rates. Nowadays, the most popular solution for this problem are power generating devices that relies only on renewable energy. Specifically, the researchers create a study of how the waste heat from the roast chicken machine turned to be an independent source of energy for the power supply of the machinery itself. Thus, the purpose of this study is to develop a device that can generate electricity using heat energy. Additionally, experimental research is used in this study to develop the device and its scientific design, and to collect data to support the hypothesis. Also, to fully understand the device, the researchers create a project development plan which consists planning, gathering, designing, creating the system, testing, and evaluation.

***Index Terms***

Electricity, Heat Energy, Power Generating Devices, Renewable Energy, Solar Panels

---

**Corresponding author: Engr. Jerry Teleron**

- Manuscript received: January 20, 2022
- Revised:
- Accepted:
- Date of publication:

## I. INTRODUCTION

In the study of *Renewable Energy Resources* by Ellaban et al., renewable energies are sources of energy that are always being replenished by nature. They can come directly from the sun (like thermal, photo-chemical, and photo-electric energy), indirectly from the sun (like wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment, like wind, water, and plants.

Today's modern world is evolving and powered by technologies which lead into a massive production, those it requires enormous source of energy. According to P.K. Haldar et al. (2015), in 2013, global energy consumption was 12,730.4 million tons' oil equivalent (Mtoe), nearly double the 1980 level of 6629.8 Mtoe.

Non-renewable resources cannot be used indefinitely since they cannot be replicated or regenerated with the same capability once exhausted. Global energy demand is expected to climb to 5 times current levels by 2100, according to projections (Sadia Ali et al., 2017). Hence, the rate of electricity is also rising. Base on *Reducing Energy Poverty* (2020) by Son and Yoon, low-income countries undergo economic development like Philippines, electricity usage is continuously increasing in both the industrial and household sectors.

What's the good news? As the renewable energy sector increases and advances, a clean energy revolution is happening. The researchers chose thermoelectricity as the source of power. So how is thermoelectric power generated? According to WatElectrical (2021), it is based on the Seebeck effect, which is a type of thermoelectric effect. A temperature gradient or temperature difference is formed between two endpoints in the Seebeck effect. The electrons flow from one end to the other when a temperature gradient is produced. The electrons at the high-temperature end of the spectrum would have a lot of energy. As a result, they begin to move in the opposite direction.

The application of research output can span in different areas and industries. It puts an advantage especially for those industries that uses coals or any kind of combustion process that provides heat to generate the thermoelectric generator. They can look forward to a device that can generate renewable energy using thermoelectric because it will definitely aid the problem in power interruption for the industrial machinery like for roast chicken machine, this will allow you to make an independent source of energy for the said machinery. Furthermore, it'll also minimize the total estimated bill every month for the household or the industrial itself.

### A. PROBLEM STATEMENT OBJECTIVES

The researchers will develop a thermoelectric device that can generate a renewable energy from waste heat energy. To finish this study, the researchers desired to answer the following problems after developing the said device:

1. What amount of wasted heat energy is required to make a device generate a renewable energy?

2. What is the effect of the device on the production in a certain business?

3. What is the reduction in terms on the electric bill of the user?

### B. SPECIFIC OBJECTIVES

The general objective of this study is to develop a thermoelectric generating device; the specific objectives are the following:

1. To design a secure alternate source of energy for continuous and efficient production.
2. To identify the amount of waste heat energy and its corresponding output voltage.
3. To evaluate the owner's insight and the reduction in their electric bill.

## C. Conceptual Framework

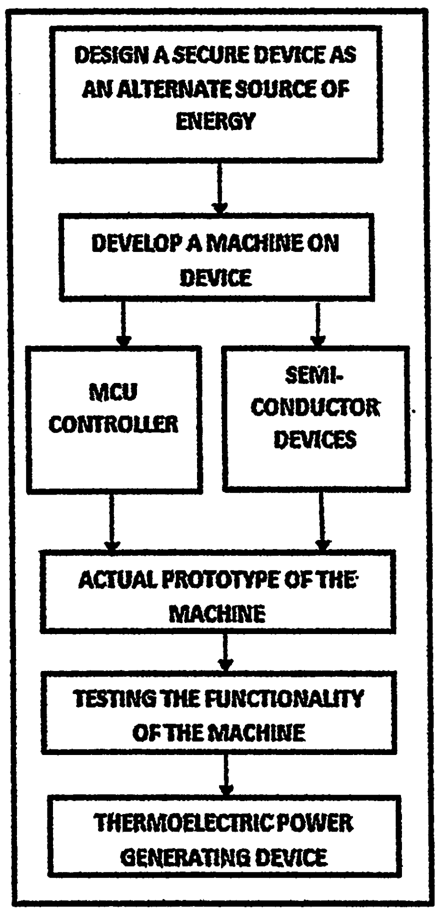



**Fig. 1.1 Conceptual Framework of the Study**

In designing a device, the researchers used an 11-plate battery as an alternative source of energy. They also used a 6000 Watts power inverter which takes on the role of inverting the power supply to provide sufficient power for the device. However, the researchers used a p-type

and n-type semiconductor which is connected in series and covered by a ceramic material which can hold a higher temperature because of its property of having a high melting point. For observing the heat index of the device, the researchers used a digital thermometer.

The current prototype of the machine uses a 0.3 HP motor and a speed controller to control the speed of the rotation of the roast chicken machine. The motor will be directly connected to the 6kW power inverter, which will provide the required power output for the 0.3 HP motor. Additionally, the researchers used p-type and n-type semiconductors for completing the design of the thermoelectric generating device, which further gives enough output power to make renewable energy that'll be stored in an 11-plate battery. Moreover, after the design of the said machinery, the researchers will directly test the functionality of the actual prototype and evaluate the level of success for the actual prototype of the Thermoelectric Generating Device.

## D. Review of Related Literature

This section presents the REVIEW LITERATURE about Renewable Energy: Thermoelectric Power Generating Device.

### 1.1 Concept of Thermoelectric Device

Based on the reaction effect, thermoelectric device materials provide a technique to transform low-quality heating energy into electrical energy. The German scientist Thomas Johann Seebeck discovered this effect in 1821, and it can be employed in a wide range of energy conversion applications. When a thermal gradient is introduced to a material, the charge carriers spread from the hot side to the cold side. An electrostatic voltage is induced as a result. A mono-electrostatic stalk's potential is very low. As a result, thermal generators often consist of tens, if not hundreds, of thermal pairs to obtain high voltage output and energy. Because their output power ranges from several watts to kilowatts, thermoelectric devices can be utilized in a wide range of energy conversion applications, from wristwatches to cars. Electrons leap from a low energy level to a higher energy level, absorbing heat from the environment and vice versa. Low to medium power and size applications benefit, whereas other conversion systems (including power plants) become less efficient when their size and power are reduced. As a result, they're interesting for low to medium power applications, particularly those that are utilized in huge numbers. The human body, for example, is a thermal source that loses heat by convection, conduction, and radiation. That's still plenty to power low-power personal devices, which typically require a power source in the W to mW range. (Fahd, Saud & Khalifa, 2016).

### 1.2 Thermoelectric Power Generator

According to (Delightus Peter et al, 2013), TEG stands for Thermoelectric Power Generator, and it is a solid-state device that converts heat energy into electrical energy. All intriguing traditional power generators transform Thermal Energy into Mechanical Energy, which is ultimately converted into Electrical Energy. As a result, there is no mechanical work here. When compared to traditional power generators, it produces less noise and no pollutants. Thermoelectric Effect (seebeck) is how TEG works. TEG produces a voltage when it is held between temperature gradients (Hot end, Cold end). This voltage is known as seebeck voltage. Modules, which are semiconductors, are available from TEG (p,n). Electrons are used as a thermoelectric power fluid here (working medium). A Module is made up of a pair of p-type and n-type semiconductors. To boost electric conductivity, these semiconductors are heavily doped with contaminants. TEG has a cover that protects modules from being damaged by high temperatures. TEG's efficiency and voltage generated are proportional to the semiconductor material and temperature gradients. As a result, semiconductors are chosen based on the material's electric conductivity, with the goal of increasing the temperature difference value. Copper electrodes connect this semiconductor. Increasing the number of modules, stages, and TEG couplings improves overall efficiency and voltage output. TEG has an exciting efficiency of 4.2 percent to 6%. When you use phases, you can enhance your efficiency by 7%.

The idea of a waste-heat thermoelectric generator has a lot of potential benefits in terms of simplicity, dependability, and safety. It appears that the successful development of new thermoelectric materials and power module designs is critical to their economic competitiveness. Reduced waste-heat thermoelectric generator costs and higher market penetration are also possibilities. In addition, the concept of a completely reversible heat engine has aided in the advancement of thermoelectric generator performance. The ideal thermoelectric generator efficiency has been considered as an upper bound for external irreversible thermoelectric generators by the engineering academic community. It is, however, a poor predictor of the efficiency of real waste-heat thermoelectric generators. Furthermore, the external reversible ideal waste-heat thermoelectric generator produces no specific power. To account for both internal and external irreversibility factors, this research proposes a true waste-heat thermoelectric generator model. This method produces a considerably more realistic forecast of generator specific power and efficiency than the ideal thermoelectric generator. (Wu, 1996).

### 1.3 The Seebeck and Peltier Effects

The thermoelectric phenomenon is the use of solid-state materials to convert heat energy into electrical energy and vice versa. A potential difference (dV) is formed between the free ends of the circuit when a temperature gradient (dT) exists between two different materials (a and b) that are in contact. The Seebeck effect is a term that describes this. The Seebeck coefficient (a) is calculated as follows:

$$(1) \quad \alpha_{ab} = \frac{dV}{dT}$$

A current will flow if the generated dV is put across some external electrical resistance, and the Seebeck effect provides the basis for a power generation mode; the refrigeration mode is based on the reverse operation of sending a current through a thermoelectric to extract heat (Fig. 1).

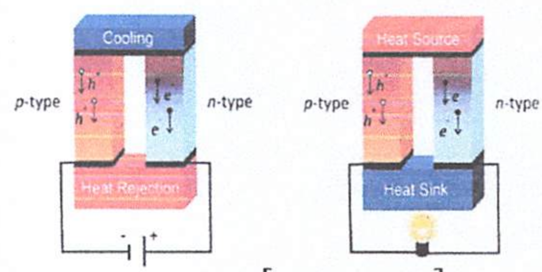
Figure 1: A illustration of the TE effect in a Peltier cooler (left) and a TE generator (right). Charge carriers flow from one end of the thermocouple to the other, carrying entropy and heat. A full device requires both n- and p-type materials.

The performance of the semiconducting materials from which a thermoelectric device is made is directly connected to its efficiency. The performance of the materials is represented by a dimensionless figure of merit, ZT, which includes the Seebeck coefficient (S), electrical conductivity (σ), and thermal conductivity (K) and can be written as:

$$(2) \quad ZT = \frac{S^2 \sigma T}{k}$$

Charge carriers (e) and lattice vibrations (L) both contribute to heat conductivity. A significant Seebeck coefficient and low thermal conductivity, which are typical of non-metallic systems, must be paired with a high electrical conductivity, which is more commonly seen in metallic phases, to achieve good performance. As a result, S, and cannot be adjusted separately, posing a problem in the development of high-performance materials. Semiconducting materials with charge carrier densities in the range of 1019–1020 cm3 provide the optimum compromise. Device efficiency () is traditionally computed as follows (using the materials figure of merit):

**Fig. 1.3.1**




$$(3) \quad n = \frac{T_h - T_c}{T_h}\left[\frac{\sqrt{1+ZT}-1}{\sqrt{1+ZT}+\frac{T_c}{T_h}}\right]$$

Where Th/Tc is the hot/cold junction temperature and ZT is the device's average temperature from Tc to Th. Increases in average ZT over the device's temperature range has a greater influence on efficiency than increases in maximum figure of merit of the component semiconductors. However, ZT for material and ZT for device must be distinguished (indicated by bold italic text here). They showed that for a finite temperature differential (Th Tc), the thermoelectric device ZT is given by:

$$(4) \quad ZT = \left(\frac{T_h - T_c(1-n)}{T_h(1-n)-T_c}\right)^2 - 1$$

The temperature dependent characteristics S(T), σ(T), and K (T) between the hot and cold sides are used to compute maximum efficiency.(Freer & Powell, 2020)

### 1.4 Theory and Generic Model of a Thermoelectric Generating System.

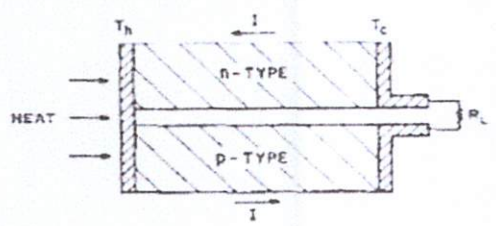



**Fig. 1.4.1 Thermocouple as power generator.**

According to (Rosi, 1968), Figure 1 graphically depicts the circuit for a basic power generating thermocouple. It involves the joining of two different materials, such as an n-type and p-type semiconductor, at their ends by a metallic conductor with higher thermal and electrical conductivities than the branch materials. The hot junction receives heat from an external source at temperature TH, while the other junction is kept at a constant lower temperature, TC. A current, I, runs through the branches as a result of the temperature differential, TH- TC, as represented by the arrows. The configuration in Fig. 1 shows a direct conversion of heat into electrical energy with conversion efficiency, Φ, by allowing current to flow through an external load resistor, RL, added into the circuit between the cold junctions, given by:

$$(5) \qquad \emptyset = \frac{power\ supplied\ to\ load}{heat\ absorbed\ at\ hot\ junction}$$

A TE (Thermoelectric) system, in general, is made up of numerous thermal masses that store and exchange heat via conduction and/or convection. Inside the TE device and/or additional elements, such as electrical heaters, heat is partially transferred to or from electricity. To ensure optimal performance, the thermal connectivity of the TE device with the rest of the system must be designed properly.

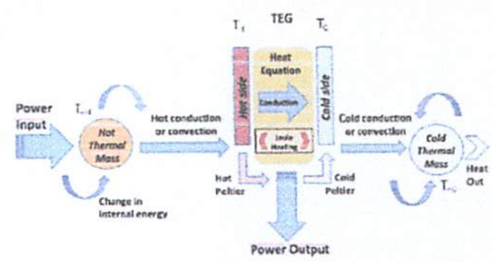



**Fig. 1.4.2 Architecture of a thermoelectric power generating system.**

The architecture of a generic TE power generating system is shown in Figure 2. On both the hot and cold sides, the TEG is usually in touch with a thermal mass. Electrical or heat power is applied to or removed from the thermal masses, resulting in changes in the thermal energy stored within the thermal masses.

A portion of this energy is transported to and from the TEG module via conduction or convection. The sides of the TEG are modelled separately from the inner half of the TEG. Inside the TEG, the heat equation (HE) deals with both heat conduction and generation (Joule heating). Additional heat is brought in from the sides where two dissimilar materials meet (Peltier effect). The process is closely related to the thermoelectric effects described by Equations 1 and 2. A portion of the energy flowing through the TEG is transformed into electrical power. (Montecucco & Knox, 2014)

$$(1) \qquad V_{OC} = \alpha \Delta T$$

$$P_P = \pi I = \alpha I T_J \quad (2)$$

## II. RESEARCH METHODS

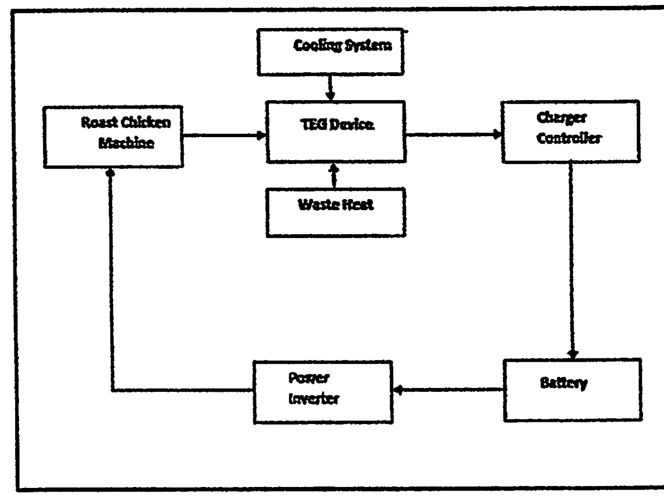
### A. RESEARCH DESIGN

In this project, the researchers are going to use an experimental research study. Experimental research is a study that strictly adheres to a scientific research design. It includes a researcher and variables that can be measured, calculated and compared. The researcher collects data and results will either support or reject the prototype.

Firstly, the researchers are going to use a p-type and n-type semiconductor pellets which is connected electrically in series and thermally in parallel and we'll covered it with a ceramics plate material for the durability of the device while absorbing the heat from the combustion in the roast chicken machine. The researchers will also use a heat sink which is place behind of the hot side of the thermoelectric generator to redirect the heat which is provided by the roast chicken machine.

Furthermore, a 6000 Watts power inverter and 11 plates rechargeable battery is also needed for the purpose of an independent power source of the roast chicken machine. The role of the thermoelectric generator device is to provide a renewable energy for the rechargeable battery for the purpose of sustaining the power that is needed for the consumption of the roast chicken machine.

### B. PROJECT DESIGN




**Project Design of the Actual Prototype**

**Fig. 2.1**

Figure 2.1 shows the diagram of how the Renewable Energy: Thermoelectric Generating Device works; while the Roast Chicken Machine is operating and while producing an efficient heat to generate the thermoelectric generating device, the diagram itself explains that heat produced will be directed into the heat sink and absorbed by the thermoelectric generator and triggers the semiconductors to create a Seebeck effect that produced an output voltage that will be stored in a rechargeable 11plates battery while at the same time, it also supplies the power needed for the roast chicken machine to operate and by using the 6kW Power Inverter, the stored power in the battery will be enough for the roast chicken machine to operate.

C. **PROJECT DEVELOPMENT**


**Fig. 2.2 ADDIE MODEL:**

ADDIE is a standard procedure and method used by instructional designers and training creators. The model's phases include analysis, design, development, implementation, and evaluation. In the present era, ADDIE is considered the most commonly implemented model for instructional design. The researchers first made a brainstorming analysis and makes an examining and articulating of the study's problem. The researchers then make a design of the proposal then further make a development, Implementation and evaluation of the actual finished prototype.

D. **PROJECT EVALUATION**

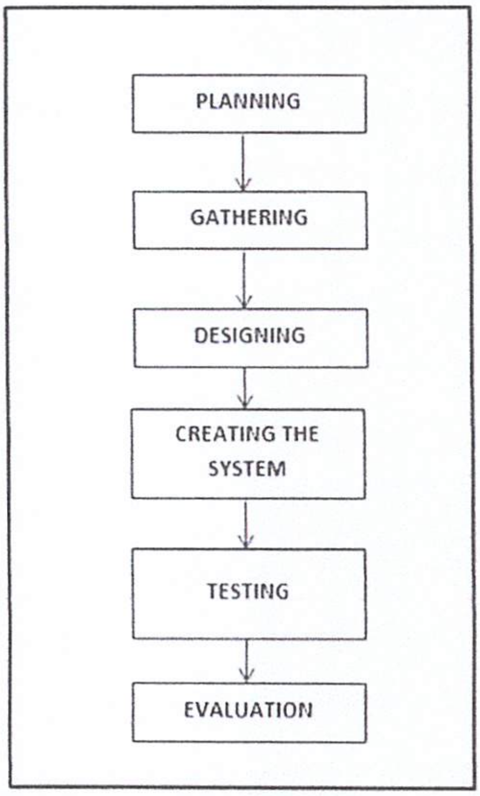



**Fig. 2.3 Project Evaluation of the Proposal**

**Fig. 2.3**

It shows the diagram flow of the general overview of the gathered data. Firstly, the researchers planned the study and gather all the needed information and designed the device that will be created by the researchers. Furthermore, when the prototype is done, the researchers will test and analyze its application. Thus, the researchers will able to evaluate the efficiency and the effectiveness of the project.

D. **PARTICIPANTS OF THE STUDY**

The researchers will present a video presentation during the testing of the mini prototype to the ten selected roast chicken machinery owners. Furthermore, the researchers will collect their insights and opinion about the proposed concept and the prototype itself. The response of the respondents will be evaluated and will be considered for the development of the project.

## E. INSTRUMENTS

1. *TEG Module* - Small and lightweight, convenient for use. Designed specifically for power generation when there is applied heat on it's hot side and cooling in it's cold side. It is a connection of p-type and n-type semiconductor connected alternately.
2. *Heat sink* - a component that increases the heat flow away from a hot device or surrounding.
3. *Cooling System* – a device that can produce cold temperature.
4. *11 Plates Battery* - Used as an alternative source for the roast chicken machine to operate. Serves as a storage device where the power generated from the TEG module is stored.
5. *Power inverter* - A device used to invert the power output of the battery to be able to run a 0.3 HP 220 V AC electric motor of the roast chicken machine.
6. *MCU Controller* – Used as a controller device to regulate the output voltage that the TEG module produced and a device used in charging the rechargeable battery.
7. *Analog Multi-tester* – A device used to monitor the output voltage that the TEG module produced.
8. *Thermometer* – A device used to monitor the temperature that the TEG module produced.

## III. RESULTS AND DISCUSSION

This chapter provides the discussion of results for this study. The researchers will use table and diagram to present the results.

### 3.1 DESIGN OF THE ACTUAL DEVICE

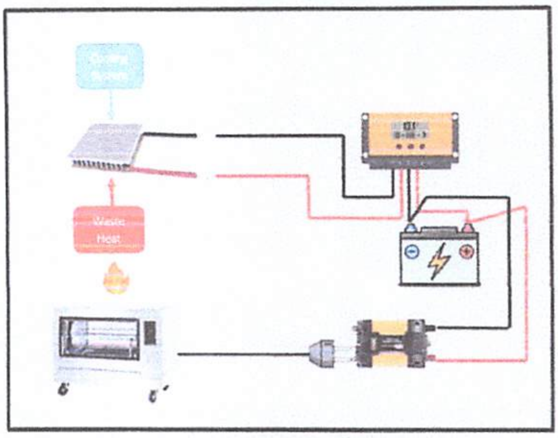



**Fig. 3.1.1: Schematic Diagram**

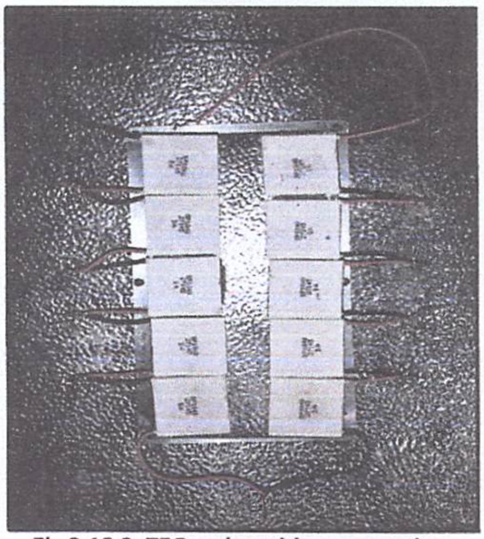


**Fig 3.12.2: TEG series wiring connection**

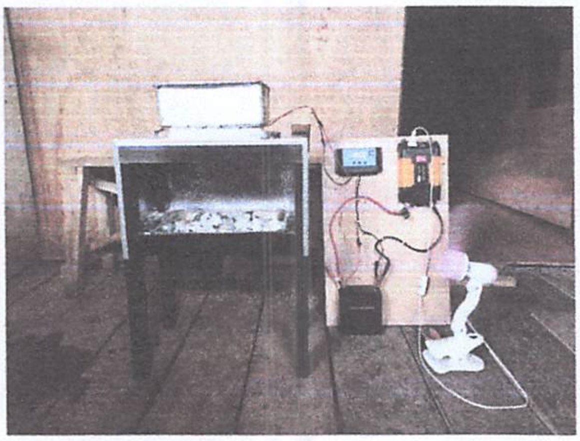


Fig. 3.1.3: Picture Diagram of the Finished Device

## 3.2 AMOUNT OF HEAT AND ITS OUPUT VOLTAGE

**Heat Index**

| No. of Trial | Heat Index | Cooling Temp. | Voltage Produced |
|---|---|---|---|
| 1 | at 50C° | at 0C° | 0.8 Volts |
| 2 | at 100C° | at 0C° | 1.4 Volts |
| 3 | at 150C° | at 0C° | 2.1 Volts |

**Table 1: Shows how much volts can be produced by a single TEG module at a specific heat index.**

| No. of Trial | Heat Index | Cooling Temp. | Voltage Produced |
|---|---|---|---|
| 1 | at 50C° | at 0C° | 6.4 Volts |
| 2 | at 100C° | at 0C° | 11.2 Volts |
| 3 | at 150C° | at 0C° | 16.8 Volts |

**Table 2. Shows how much volts can be produced by 10 TEG module (in series) at a specific heat index.**

**Operation**

| Heat Index | Cooking duration (min.) | No. of TEG module needed to supply the battery | 11 Plates Battery Capacity (32Ah), Duration of battery to supply a 1.5 A to the machine |
|---|---|---|---|
| at 50C° | 24-28 min. | A parallel connection of a series of 8 TEG module (14V) producing 1 Ampere | 21.333 hrs. |
| at 100C° | 20-24 min. | A parallel connection of a series of 8 TEG module (14V) producing 1 Ampere | 21.333 hrs. |
| at 150C° | 16-20 min. | A parallel connection of a series of 8 TEG module (14V) producing 1 Ampere | 21.333 hrs. |

**Table 3. Shows the duration of how long the battery can supply the roast chicken machine and also shows it's cooking duration as well.**

*11 plates battery charge capacity = 32Ah ; Current output for the roast chicken machine to run= 1.5A*

$Q = TA$

$Q\ (charge\ capacity)\ in\ Ah$

$A\ in\ amperes$

$T\ in\ hours$

$$T = \frac{Q}{A}$$

$$T = \frac{32}{1.5}$$

$$= 21.333\ hrs.$$

There will be an evaluation of the TEG module to determine the maximum voltage that the TEG could provide. Specifically, a single TEG can produced a peak voltage of 1.9 V at 150° C as shown in Tab. 1. However, a battery is a 12V DC supply, so a series of 8 TEG module is much needed to meet up with the voltage needed for the battery to recharge. As shown in Tab. 3, a series of 8 TEG module can produced a voltage of 16.8 V which is sufficient enough for the battery to recharge. The 11 plates battery has the capacity of 32Ah and the electric motor has a power output of 0.3 HP 220V AC 60Hz, as shown in Tab. 3. At a current supplied by the battery through inverter to run the roast chicken machine is approximately 1.5 A, so the battery can definitely supply the roast chicken machine for up to 21.333 hrs.

### 3.3 EVALUATION OF THE OWNER'S INSIGHT AND THE ELECTRIC'S BILL REDUCTION

**Owner's Rating**

| Ratings | No. of Participants (n = 10) | % of involvement |
|---|---|---|
| Satisfied | 8 | 80% |
| Dissatisfied | 2 | 20% |

**Table 4. Shows the rating of the ten selected roast chicken machinery owners.**

**Owner's Bill Reduction**

| HP | Watt | Monthly Total kWh (12 hrs. of usage) | kWh rate in PHP | Total Cost per Month |
|---|---|---|---|---|
| 0.3 | 223.71 W | 80.5356 kWh | 11 PHP | 885.89 PHP |

**Table 5. Shows the total cost of potential reduction of the owner's bill if the device will be use.**

$$\text{kWh} = \frac{watts \times time\ (hrs)}{1000}$$

$$= \frac{223.71 \times 12 \times 30}{1000}$$

$$= 80.5356\ \text{kWh}$$

$$\text{Total Cost Reduction} = 80.5356 \times 11$$

$$= 885.89\ PHP$$

Based on the provided data. It shows in table 4 that 8 out of 10 participants are satisfied and have optimistic perception that this device can give advantages in operating their business. While 2 out of 10 participants are doubted due to some concerns including high-cost, maintenance and the design may not suitable to their roast chicken machine. But overall, the satisfaction percentage of participants is above average. Meanwhile, in table 5, the researchers will able to calculate the total cost of potential reduction of the owner's bill with the used of Kwh formula.

## IV. CONCLUSIONS AND RECOMMENDATIONS

### A. CONCLUSIONS

Heat energy is a type of energy that can be transferred from one particle to another in a substance by utilizing the kinetic energy of the particles in question. In other words, according to the kinetic theory heat is transferred when particles collide with each other and bounce off. Heat is everywhere and can be transferred through three processes known as conduction, convection, and radiation. For the past decades, heat is already discovered as a source of energy or known as one of a renewable energy source. Even so, heat from the other heat sources are being neglected which will turn it into a waste heat. Specifically, heat from the roast chicken machine are one of the heat source that are being neglected so the researchers make a conclusion on how to take an action for the waste heat to be an independent source of energy for the device itself. The researchers then make a design of the actual prototype of the roast chicken machinery with a series connection of TEG module on top of it and a number of trials on it had followed after the device was finally finished. Furthermore, the researchers make simple a presentation for the roast chicken machine owners and rate their satisfaction and their perspective about the actual device. In conclusion, the thermoelectric power generating device were perceived by the participants as acceptable as more than half of the participants are satisfied with 80% of rating. To some it up, the researchers had finally make the study successfully and the device were actually functioning that corresponds with the theory that is stated in the research proposal.

### RECOMMENDATION

Based on the research's findings acquired, the following recommendations are given:

1. To use a cooling system with a monitoring system for its temperature being monitored from freezing point down to the negative degree Celsius Temperature.
2. To use more number of TEG for an efficient charging output that will be sufficient to supply the rechargeable battery and the roast chicken machine.
3. For a fast charging duration in recharging the battery, make a parallel connection of TEG modules that are connected in series and measure it using ammeter to monitor the output current that the TEG module produced.


## V. ACKNOWLEDGEMENT

First of all, thanks and appreciation to God, the Almighty, for showering blessings on us throughout our research work, which enabled us to successfully finish the research.

We would like to express our deep and sincere gratitude to our research adviser, Engr. Jerry Teleron, professor in College of Engineering and Information Technology, Surigao State College of Technology, for giving us the opportunity to do this research proposal with him as an adviser and providing guidance throughout this research. His vision, sincerity, and motivation have deeply inspired us. He has taught us the research methodology to carry out the research and present the research data as clearly as possible. It was a great privilege and honor to work and study under his guidance. We are extremely grateful for what he has offered to us. We are also extremely grateful to our parents, relatives and friends for their love, prayers, caring and unending support in both financial and emotional aspects.

Finally, our thanks to all the people who have supported us to complete the research directly or indirectly.

### VI. REFERENCES

[1] Ellabban, Omar; Abu-Rub, Haitham; Blaabjerg, Frede (2014). Renewable energy resources: Current status, future prospects and their enabling technology. Renewable and Sustainable Energy Reviews, 39(), 748–764. doi:10.1016/j.rser.2014.07.113

[2] Halder, P.K.; Paul, N.; Joardder, M.U.H.; Sarker, M. (2015). *Energy scarcity and potential of renewable energy in Bangladesh. Renewable and Sustainable Energy Reviews, 51(), 1636–1649.* doi:10.1016/j.rser.2015.07.069

[3] Sadia Ali; Sofia Anwar; Samia Nasreen (2017). *Renewable and Non-Renewable Energy and its Impact on Environmental Quality in South Asian Countries,* 178.

[4] *Sci-Hub | Reducing energy poverty: Characteristics of household electricity use in Vietnam | 10.1016/j.esd.2020.08.007*. (2020). Hkvisa.net. https://sci-hub.hkvisa.net/10.1016/j.esd.2020.08.007

[5] Wat Electrical. (2021). *Thermoelectric Generator : Design, Working Principle & Its Applications*. WatElectrical.com. https://www.watelectrical.com/what-is-a-thermoelectric-generator-working-principle-its-applications/

[6] Al-Maliki, F., & Khalifa, F. K. (2017). *Thermoelectric Device.* Retrieved December 11, 2021, from Research Gate: https://www.researchgate.net/profile/Fares-Khalifa/publication/343485880_Thermoelectric_Devices/link/5f2c7b4d92851cd302e4eba8/Thermoelectric-Devices.pdf

[7] Freer, R., & Powell, A. V. (2020). Realising the potential of thermoelectric technology: a Roadmap. *Journal of Materials Chemistry C*, *8*(2),441–463. https://doi.org/10.1039/c9tc05710b

[8] Jacks Delightus Peter, A., & Gowrishankar, D. (2013). *Waste heat energy harvesting using thermo electric generator*. *3*(7), 2–3. http://www.iosrjen.org/Papers/vol3_issue7%20(part-2)/A03720104.pdf

[9] *Thermoelectricity and thermoelectric power generation. Solid-State Electronics, 11(9), 833–868 | 10.1016/0038-1101(68)90104-4*. (2021).Sci-Hub.ru. https://sci-hub.ru/10.1016/0038-1101(68)90104-4

[10] *Accurate simulation of thermoelectric power generating systems. Applied Energy, 118, 166–172 | 10.1016/j.apenergy.2013.12.028.* (2013).Sci-Hub.ru. https://sci-hub.ru/10.1016/j.apenergy.2013.12.028

[11] *Analysis of waste-heat thermoelectric power generators. Applied Thermal Engineering, 16(1), 63–69 | 10.1016/1359-4311(95)00014-5.* (2021).Sci-Hub.ru. https://sci-hub.ru/10.1016/1359-4311(95)00014-5

## APPROVAL SHEET

This Project Study entitled **"Automated Solar Powered Chamber With Image Processing Detection Using AI In Cacao Beans"** prepared by **Catherine A. Balaez, Johanni O. Dotarot, Noel P. Galol , Norman II G.Limosnero, Arvien M. Vidal** in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical Engineering** has been examined and is recommended for acceptance and approval for ORAL EXAMINATION.

**ENGR. VRIAN JAY V. YLAYA**
Co-Author

---

**PANEL OF EXAMINERS**

Approved by the committee of ORAL EXAMINATION with a Passing Grade on May 2, 2022.

**ENGR.ROBERT R. BACARRO, MECE, MBA**
Chairman

**ENGR. JERRY I. TELERON, Ph. D.**
Member

**ENGR. FEDERICO A. AVES, Jr., MST, M.ENG'G**
Member

**ENGR. VICENTE Z. DELANTE, M.Eng'g**
Member

---

Accepted and approved in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical Engineering.

**ENGR. ROBERT R. BACARRO, MECE, MBA**

Dean, College of Engineering and Information Technology

Date: June 10, 2022

# AUTOMATED SOLAR POWERED CHAMBER WITH IMAGE PROCESSING DETECTION USING AI IN CACAO BEANS

**Vicente Z. Delante**
Surigao State College of Technology, Surigao City, Philippines
vicente.delante@gmail com

**Abstract:** This paper presents the design and development of an automatic solar powered chamber with image processing using AI in cocoa beans. The drying mechanism was based on the combination of direct radiation and convective heating with the incorporation of electric backup heaters to address the intermittent effect of drying. Arduino Uno and the raspberry pi 3b+ along with the appropriate sensors are used to monitor and control the moisture content, speed of the motor and temperature of the heating chamber. Direct radiation maximized the solar reception during daytime by providing sufficient heat inside the chamber. The electric heaters also provide reliable heat sources during night time, preventing the occurrence of moisture re-absorption by the beans. The developed system maintained a drying temperature 40-50°C by automatically switching the drying modes depending on the weather conditions. The prototype of the system is developed and powered using solar photovoltaic energy generated from 70- and 100-watts solar panels in conjunction with converter and charge controller. This study demonstrated a methodology for textural feature analysis on digital images of cocoa beans. Our results showed that using GLCM with RGB segmentation for image processing can contribute more reliable results. Our method was implemented through on –site preprocessing within a low- performance computational device. It is also helped to foster the use of modern Internet of Things (IoT) technologies among farmers and to increase the security of the food supply chain as a whole.

**Keywords** Image Processing, Mobile Application, Artificial Intelligence, Drying chamber, Raspberry Pi,

## 1. Introduction

Fermentation process is an important indicator of cocoa beans quality. Human workers currently employ the traditional drying method, which requires a significant amount of time and efforts. Advanced agricultural development and procedural operations differ significantly from those of several decades earlier, principally because of technological developments, including sensors, devices, appliances, and information technology.

Cacao seeds are the seed of Theobroma cacao (Sterculiacaea family), a tropical tree which is grown mostly in the wet tropical forest climate countries. It is a Philippines cash crop that has economic potentials for rural farmers but is otherwise beset with drying problems (Burguillos, Elauria, & De Vera, 2017) [1]. Traditionally, drying is usually carried out using natural sun drying. The various drawbacks to this method include unpredictable weather patterns, labor intensive and prolonged rate and product spoilage(Hii, Law, & Suzannah, 2012) [2].

Drying is the most important process to preserve grains, crops and foods of all varieties. The removal of moisture prevents the growth and reproduction of microorganisms causing decay and minimizes many of the moisture-mediated deterioration reactions. It brings about substantial reduction in weight and volume, minimizing packing, storage and transportation costs and enables storability of the product under ambient temperatures.

Thermodynamic relations should be considered in designing a solar dryer system for a specific product such as cocoa beans. Previous works includes Burguillos et al. (2017) which adopts a structural arrangement for the direct type, and the heating mode for the indirect type of drying fermented cacao beans. The dryer consists of an integrated drying chamber and convective heating with the incorporation of electric backup heaters to address the intermittent effect of drying, DC fans in parallel to enhance moisture removal and used antenna for mobility. Fermentation and drying are two main steps in the postharvest processing of cocoa beans. These steps play an important role in the formation of flavor and taste. These steps should be treated properly in order to improve the status of cocoa beans [3].

Information technology has indeed shifted very significantly in human life. It is undeniable that technology currently represents an essential role in the development process from time to time. We are entering the Industrial Revolution Era 4.0, where Internet of Things (IoT) technologies are very influential in everyday life. Even in the area of agriculture, such technologies [4,5] have many important roles. Feature extraction is an artificial intelligence (AI) method that selects or consolidates numerous variables as a feature, which can effectively decrease the substance of data processed while still representing the fundamental dataset.

The objective of the study is to design and develop an automated solar dryer system capable of monitoring and detecting moisture during fermentation using AI camera; programmed in raspberry pi 3b+. To reduce the moisture content of cocoa beans in less than 10% using Arduino Uno and its components relayed. Lastly to give secondary back-up power using solar power system and aims to implement a prototype for testing and evaluation. However, drying method can improve the quality of dried beans. Many researchers have reported study on the effects of drying method to the cocoa beans quality (Jinap, Thien, & Yap, 1994) [6].

Agriculture allowed people to create civilizations, fight hunger and work to combat challenges in population growth and climate change. This is why researchers are interested in developing and revising this technology to give more advantages to the community Galiche et al. (2011) [7], conducted a study on this system with analog-digital combination control method and the feasibility of its usage in solar dryers.

***Related Literature***

Solar radiation is an integral part of different renewable_energy_resources. It is the main and continuous input variable from practically inexhaustible sun. Solar energy is expected to play a very significant role in the future especially in developing countries, but it has also potential prospects for developed countries. The material presented in this paper is chosen to provide a comprehensive account of solar energy sources and conversion methods. For this purpose, explanatory background material has been introduced with the intention that engineers and scientists can have introductory preliminaries on the subject both from application and research points of view. Applications of solar energy in terms of low and high temperature collectors are given with future research directions. Furthermore, photovoltaic devices are discussed for future electric energy generations based on solar power site-exploitation and transmission by different means over long distances such as fiber-optic cables[8].

The sun has produced energy for billions of years, and it is the most important source of energy for all life forms. It is a completely renewable source of energy unlike non-renewable sources such as fossil fuels. The sun provides a consistent and steady source of solar irradiance. Solar power technologies use the sun's energy to light homes, produce hot water, heat homes, and produce electricity.

In the Philippines, the potential is even greater than the inspirational target of 1,528MW attributed to solar in the National Renewable Energy Plan until 2023. According to the DOE's 2009-2030 Power Development Plan (PDP), the country's energy consumption is seen reaching 124,067 gigawatts-hours (GWh) by 2023, from an estimated demand of 86,809 GWh by 2018 and actual demand of 55, 417 GWh in 2008. The yearly monthly daily average irradiance yield received in the horizontal plane of Surigao city is about 7.5 kW h/m2 / day with the Latitude: +9.8 (9°48'00" N) and Longitude: +125.4(125°28'12" E).

Many innovative systems have been developed that replace the traditional gravel-filled bed. When evaluating the type of system to install, consideration should be given to such factors as the type of cacao beans, space requirements, drying time, support system, and economics. These systems can be set up in either a direct and indirect place. As cacao beans production is often limited by environmental factors, interest in alternative drying practices is increasing. In this regard, automated solar powered chamber serves as a promising dryer practice that offers a solution for some serious challenges of cacao beans production such as lack of space to dry on, climate change, deforestation, rising fossil fuel prices and ecosystem degradation.

The utilization of technology is necessary to increase agricultural production [9] especially in terms of quality and competitiveness. The availability of technological innovations such as machine learning and deep learning. [10,11] is also one of the keys to improving farmer welfare and attracting the younger generation's interest in creating various derivative business opportunities.

Therefore, this work aims to use computer vision as a fast and accurate method to classify cocoa beans of fermentation, using features extracted from cocoa bean images as predictors. The proposed approach could substitute the cut-test, using [illegible] and [illegible] to evaluate [illegible]

The uniqueness of this project is that it has a switched mode that can be used manually or automatically depending on the decision of the user. It also has a password that only authorized personnel can operate or access the system. The purpose of the AI camera is to monitor the cacao beans even if the host is not around. Using this method, it helps the farmers to improve the quality of life and less hassle. The database that is contained in computer which is then accessed by the website via the web server to display the data to determine the quality of dried cacao beans as well as the temperature, and humidity inside the chamber.

### *1.2 Theoretical Framework*

Cocoa bean fermentation is still a spontaneous curing process to facilitate drying of nongerminating cocoa beans by pulp removal as well as to stimulate color and flavor development of fermented dry cocoa beans. As it is carried out on farm, cocoa bean fermentation is subjected to various agricultural and operational practices and hence fermented dry cocoa beans of variable quality are obtained. An automated solar powered chamber system will help the cacao beans to dry both indoors and outdoors. As a result, famers don't need to waste large amount of time to manually operate the traditional gravel-filled bed method. Instead, the farmers could monitor the fermenting process through the application being provided.

The Internet of things (IoT) describes the network of physical objects that are embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the Internet.[13]

Sensors are used in everyday objects such as touch-sensitive elevator buttons and lamps which dim or brighten by touching the base, besides innumerable applications of which most people are never aware. With advances in micromachinery and easy-to-use microcontroller platforms, the uses of sensors have expanded beyond the traditional fields of temperature, pressure, or flow measurement.[14]

There are numerous IoT applications in farming such as collecting data on temperature, rainfall, humidity, and wind speed.[15] This data can be used to automate drying techniques, make informed decisions to improve quality and quantity, minimize risk and waste, and reduce the effort required to manage drying.[13] For example, farmers can now monitor moisture from afar and even apply IoT-acquired data to precision ferment programs.

The Raspberry Pi is a low-cost, credit-card-sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing and to learn how to program in languages. It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.

### *1.3 Conceptual Framework*

The following figure shows the input-process-output diagram of the project.

***Figure 1. Input- Process- Output diagram of the project***


The block diagram illustrates the general concept and explains the flow of the system. The input block is the materials needed to implement a power supply project. Monitoring systems are designed using sensors such Humidity Sensor, Rain (Water) Sensor, Relay, Heating Element, DC Fan, Led Lamp, Servo Motor. The process block contains various stages: online research, analysis, system design, implementation, construction, testing, and system evaluation. Online research methods (ORMs) are ways in which researchers can collect data via the internet. An analysis is a detailed examination of the elements or structure of something. System Design System design is the process of defining the components, modules, interfaces, and data for a system to satisfy specified requirements. Implementation is the carrying out, execution, or practice of a plan, a method, or any design, idea, model, specification, standard, or policy for doing something. Construction and Testing is the testing of materials used to build new projects, add to existing projects, or amend existing construction projects. Evaluation Assesses the quality and success of a project in reaching stated goals. Presents the information collected for project activities and outcomes.

The input and process will produce an output of the project, the innovative Solar Powered Chamber with Image Processing Detection Using AI in Cacao Beans.

### *1.4 Objectives*

This project aims to design and implement an automated solar powered chamber with Image processing detection using AI in cacao beans using raspberry pi, Arduino uno and sensors to keep human intervention at a minimum and help local farmers eliminate the inconvenience and time-consuming traditional method of farming.

1. To foster the use of modern Internet of Things (IoT) technologies among farmers and to increase the security of the food supply chain as a whole.

2. To design and develop a solar dryer system capable of detecting moisture during fermentation using AI image processing.

3. To increase agricultural production especially in terms of quality and competitiveness. To increase agricultural

production especially in terms of quality and competitiveness.

4. To improve farmer's welfare and attracting the younger generation's interest in creating various derivative business opportunities.

5. To implement a prototype for testing and evaluation.

**2. Methods**

***2.1 Research Design***

A lot of research on farming and hydroponics was required to complete this investigation. The first goal was to determine what a hydroponic system is. Hydroponics, by definition, is a method of growing plants in a water-based, nutrient-rich solution. Hydroponics does not use soil, instead, the root system is supported using water. The next goal was to determine what type of water would be compared and estimate the amount needed.

***2.2 Project Design***

The figure below shows the block diagram of the project

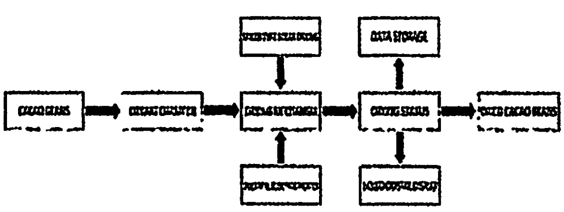


***Figure 2. Block Diagram of the project***

The diagram of the project shows three boxes, the first box represents the hydroponic system together with the sensors attached on raspberry pi which is the brain of the system. Sensors are connected to Raspberry Pi, temperature and humidity sensor together with the ultrasonic sensor connected to ADC (Analog to Digital). Then the sensor data will be inputted into the Database and display the output data on the webpage and then monitored through the webpage back to the database and to the hydroponic system in which the sensors are placed. The data on the webpage will be the final output, where the sensor data are displayed and can be controlled even if the user is far away.

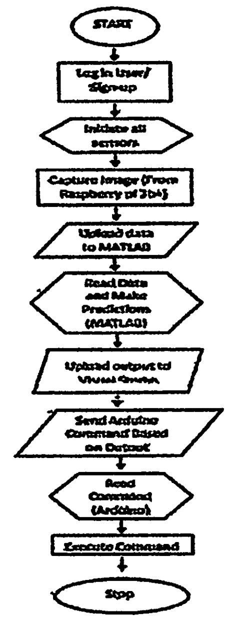



***Figure 3. Flowchart of the system***

The flowchart of the project is shown in Figure 3, which the researchers used as the basis on how the data collecting procedure is done. As shown in the figure, the project starts with log in users or signing up and then all the sensors initializing and then capture image from raspberry pi 3b+ by uploading the data to MATLAB, it will now read the data and make predictions after making predictions the output will proceed to visual studio and then the Arduino will send a command based on the output. The output will be read by the Arduino's command and finally will execute the command which ends the process.

***2.3 Project Development***

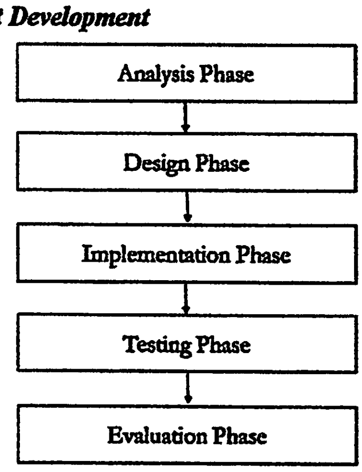



***Figure 4. Project Management Diagram***

The first stage in doing a project study is online research on the internet. In this generation, almost everything that a person wants or needs to is already on the internet. In this stage, the researcher will be able to gain some knowledge and ideas which could help them implement a good project.

The next step in developing this project study is system designing. Designing a system is a hard task because everything should be considered, the materials, finances, sizes, mechanism of the project, packaging, etc. Everything should be well planned so that there will be fewer problems on the next level of the implementation. Additional to that is programming, it creates instructions that tell a computer how to perform a task and how the project works.

The third step is the purchase of materials. All materials should be ordered or be ready as soon as possible for the construction of the project.

The fourth step is construction and testing. After completing the needed materials, the researcher can now start the implementation of the project. The first to be realized will be the internal parts, which are the frame of the chamber, to be followed by the construction of lower and upper part of the chamber that has 1x2 and 1x1, then Plain zin that encloses the outside of the chamber. We also added a tray where the cacao beans are placed. We used plastic as a cover so that the sunlight passes through the chamber in order to dry the cocoa beans. Trial and error are also needed to test if the project is working correctly or not.

Then finally, the packaging of the project should be neat and presentable. The last stage in this research project is system evaluation. The project will be evaluated according to its performance, serviceability, aesthetics, and features. The researcher will conduct a survey to be undertaken using paper-based techniques through questionnaires and personal interviews to hear the opinions of the participants.

### *2.4 Project Implementation*

The project will be implemented at a place where it can be tested and performed. Researchers conduct a test and survey together with the participants, the farmers, and professionals. The researchers and the participants will manage and monitored the project if it can meet the process expectation and the said output to the project. Professionals and farmers will test the project if it is applicable to use solar drying systems with the Internet of Things (IoT). If the project will be failed to deliver the resulting output, the researchers will fix the problem and re-tested it again. Until it meets the expectations output.

### *2.5 Project Settings*


*Figure 5. Location of the place*

The Automated solar drying system can be placed anywhere, either indoor or outdoor. The said project will be placed and tested in Brgy. Roxas, Mainit Surigao del Norte Professionals/farmers are invited to participate, observe and give feedback to the project about automated solar powered chamber with image processing detection using AI in cocoa beans. Researchers chose this location because it's easier to conduct a survey.

### *2.6 Participants of the Study*

The participants of this project study are mainly the project beneficiaries, who include the farmers and professionals. The proficient evaluators are chosen to concur to their mastery that would offer assistance to confirm whether the framework's execution is palatable sufficient for the proper implementation. In contrast, the user/evaluators/ ranchers are chosen to assess whether the framework is worthy enough to utilize the said venture.

*Table 1. Participants of the Study*

| PARTICIPANTS | f(n=10) | % |
|---|---|---|
| Professionals | 4 | 40% |
| Farmer | 5 | 50% |
| Agricultural Engineer | 1 | 10% |
| TOTAL | 10 | 100% |

### *2.7 Instruments*

In this study, the following instrument for the fulfillment of the study:

**Proteus Simulator** - The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. Electronic design engineers and technicians use the software to create schematics and electronic prints for manufacturing printed circuits.

**DHT11 Temperature and Humidity Sensor**

It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and outputs a digital signal on the data pin.

**Raspberry Pi 3 Model B Plus**

The latest product in Raspberry Pi 3 range, boasting a 64-bit quad-core processor running at 1.4GHz, dual-band 2.4GHz and 5GHz wireless LAN, Bluetooth 4.2/BLE (Bluetooth Low Energy), faster Ethernet, and PoE capability via a separate PoE (Power over Ethernet) HAT (Hardware Attached on Top).

**Water Sensor**

It detects the presence of water and when placed in locations where water should not be present, a leak.

**Led Lamp**

Led Lamp or Led light bulb is an electric light that produces light using light-emitting diodes (LEDs).

**Stepper Motor**

A stepper motor is an electromechanical device it converts electrical power into mechanical power.

**5V Single Relay**

This is a single channel Relay Module; relays are used to control or switch devices that use higher power than what most micro-controllers such as an Arduino or Raspberry Pi can handle. This particular relay module can control typical household appliances up to 15A.

**DC Fan/ Heating Element**

The direct current fans, or DC fans, are powered with a potential of fixed value such as the voltage of a battery we used 12V in DC fan.

**LCD**

Used to display data in devices such as calculators, microwave ovens, and many other electronic devices.

**Breadboard**
A construction base for prototyping electronics.

**Jumper Wire**

Are simply wires that have connector pins at each end, allowing them to be used to connect two points to each other without soldering.

**Power Inverter**

A power inverter, or invertor is a power electronic device or circuitry that changes direct current (DC) to Alternating Current (AC).

**Charge Controller**

The charge controller regulates the amperage and voltages that is delivered to the loads and any access power is delivered to the battery system so the batteries maintain their state of charge without getting overcharged.

**Software specification**

- Visual Studio Code
- SQLite
- Putty
- Raspbian
- C++
- C
- C#

**In-depth Interviewing.**

It is a qualitative interviewing technique that involves conducting individual interviews with a small number of respondents to explore their perspective on a particular idea, program, or situation

### 2.8 Research Ethics

In this study, the researcher makes sure not to violate any legal and environmental issues. The participants of this study will be voluntary, so they will have the right to withdraw from it at any point and for any reason. Next to this, participants were fully informed regarding the objectives of the study. Participant's safety was also secured; they were not harmed or abused, both physically and psychologically, during the conduction of the study. In contrast, the researcher attempted to create and maintain an atmosphere of comfort.

### 2.9 Data Collection Procedure

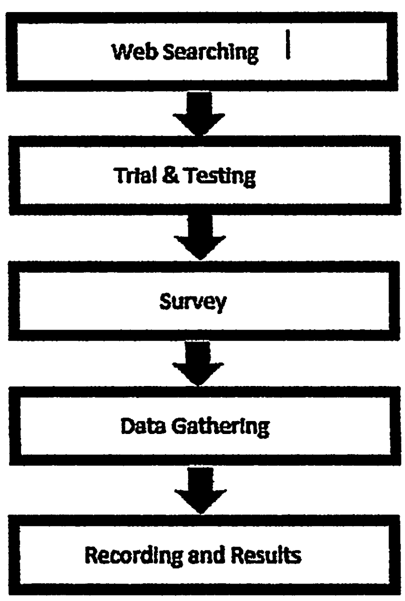



*Figure 6. Data Collection Procedure Diagram*

The diagram above shows the data collection procedure in doing this research project. These include web searching, trial & error testing, surveys/interviews, data gathering, and recording and results.

The first stage is web searching wherein the researcher collects some information that could help them understand further about the project and how to make it work.

Researchers focused on the issues and problems that are related to the study of interest in order to avoid errors in the implementation of the project. Conclusions and recommendations were also being noted.

Through a survey, researchers can collect information from a sample of individuals through their responses to questions.

Researchers gathered observations or measurements through survey and online searching

Series of trials and tests were conducted. The researchers gather data about the effectiveness of the project by conducting a survey, personal interviews, and providing some questionnaires to the participants. All of the data collected from survey questions and personal interviews were also recorded.

### 2.10 Statistical Tool

The project studies use means statistical tool. Frequency statistics simply count the number of times that each variable occurs, such as the number of males and females within the sample. Measures of central tendency give one number that represents the entire set of scores, such as the mean.

On the other hand, "Mean" Mean implies average and it is the sum of a set of data divided by the amount of data. Mean can prove to be an effective tool when comparing different sets of data.

### 2.11 Financial Analysis

*Table 2. Materials Cost Analysis*

| PARTICULARS | QTY. | UNIT COST | AMOUNT |
|---|---|---|---|
| Electrical Heating System | 1 set | ₱1,348 | ₱1,348 |
| Electronic components | 1 set. | ₱8,419.50 | ₱8,419.50 |
| Solar power system | 1 set | ₱ 14,000 | ₱14,000 |
| Construction Materials | 1 set | ₱3,225 | ₱3,225 |
| TOTAL | | | ₱26,992.5 |

Table 2 shows the Material cost analysis, which indicates the cost of each component that is used in the project. The packaging of the system is not included because it is free of charge.

*Table 3. Fixed Cost Analysis*

| PARTICULAR | QTY. | UNIT COST | AMOUNT |
|---|---|---|---|
| MATLAB | 1 | ₱10,000 | ₱10,000 |
| TOTAL | | ₱10,000 | ₱10,000 |

Table 3 shows the Fixed Cost Analysis of the project, and these are acquired to Automated solar powered chamber System with AI image processing.

*Table 4. Total Fixed Cost Analysis*

| DESCRIPTION | QTY. | AMOUNT |
|---|---|---|
| Material Cost | All | ₱ 26,992.5 |
| Fixed Cost | All | ₱10,000 |
| **OVERALL TOTAL** | | **₱36,992.5** |

Table 4 shows the overall total of the materials and the services of the project.

**Selling Price:**

Price = Variable Cost + Mark- up (35%)
Price= 26,992.5+ 26,992.5 (35%)
Price= ₱ 36,439.89≈ **₱36, 500.00**

The "Automated Solar Powered Chamber with Image Processing Detection Using AI in Cocoa Bans" selling price is based on the total price of the materials being used plus the product of markup and 35% of the materials used. The fixed cost of the project is not included on the price basis.

**Return of Investment:**

Total fixed cost= **₱10, 000**
Tax (12%) = ₱1,200.00

$$\textbf{ROI} = \frac{\textbf{Net Profit}}{\textbf{Total Investment}} * \textbf{100}$$

= (₱1,200 / ₱36,992.5) * 100
= **3.3%** ≈ **3%**

**Break-Even Analysis:**

Researchers used break-even analysis to determine the number of units or dollars of revenue needed to cover total costs.

Total fixed cost= ₱36,992.5
Variable Cost= ₱26,992.5
Selling price= ₱36,500

$$\textbf{BEA} = \frac{\textbf{Total Fixed Cost}}{\textbf{Selling Price} - \textbf{Variable cost}}$$

$$\textbf{BEA} = \frac{₱36{,}992.5}{₱36{,}500 - ₱26{,}992.5}$$

**BEA= 3.89 %** ≈ **4 units per month**

**Monthly Sales** = No. Units sold pre month x selling price

4 units x ₱36, 500.00 = ₱146,000.00

**Annual Sales** = ₱146,000 x 12 months
= ₱1,752,000.00

The breakeven analysis of the device is the basis on how much Automated Solar Powered Chamber be sold in sales in a particular month, time, or period to realize the profit being spent. In this project, the researchers must sell at least four chamber per month to profit.

## 3. RESULTS AND DISCUSSIONS

### *3.1 Technical Materials of the System*

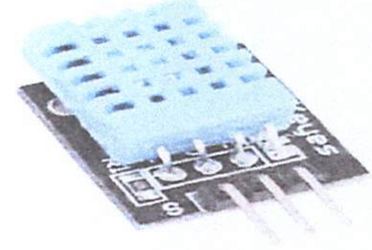


*Figure 7. DHT11 Temperature and Humidity Sensor*

It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and spits out a digital signal on the data pin.

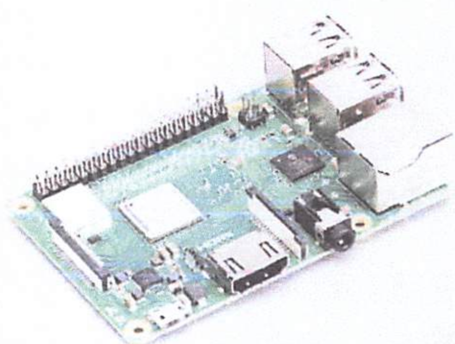


*Figure 8. Raspberry Pi 3 B+*

The Raspberry Pi is a series of single-board computers. They are low-cost, high-performance, and the size of a credit card.

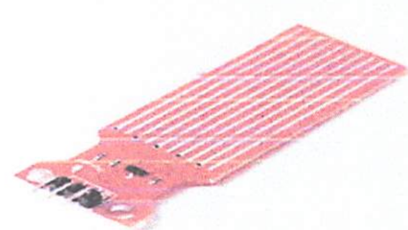


*Figure 9. Water Sensor*

It detects the presence of water and when placed in locations where water should not be present, a leak.

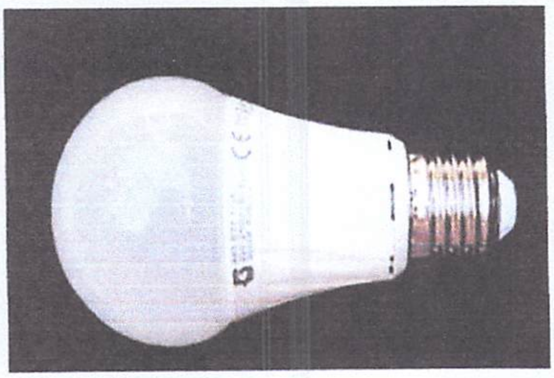


*Figure 10. LED Lamp*

Led Lamp or Led light bulb is an electric light that produces light using light-emitting diodes (LEDs).

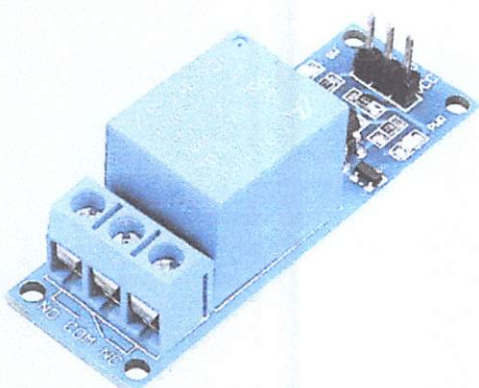


*Figure 12. 5V Single Relay*

It comprises components that make switching and connection easier and act as indicators to show if the module is powered and if the relay is active or not.

*Figure 13. Automated solar powered chamber*

The chamber where the cocoa beans being fermented.

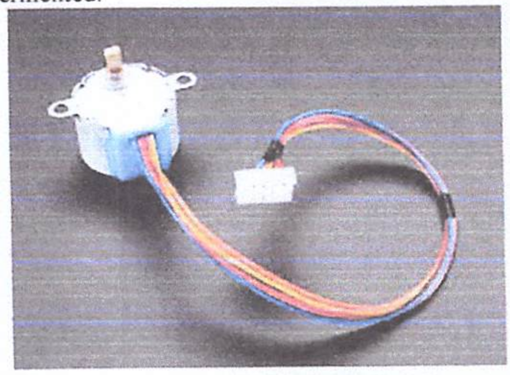


*Figure 14. Stepper Motor*

A stepper motor is an electromechanical device it converts electrical power into mechanical power.

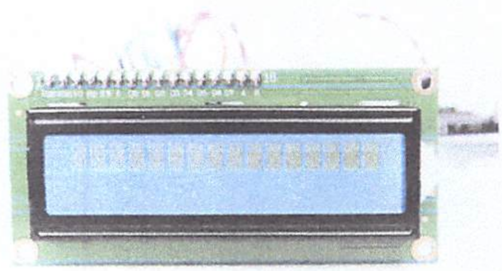


*Figure 15. LCD*

Used to display data in many other electronic devices.

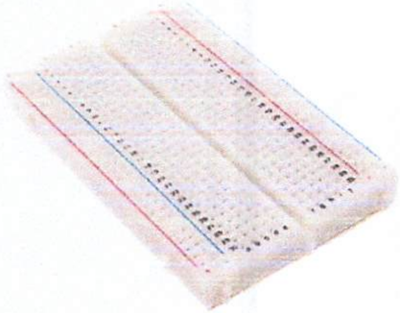


*Figure 16. Breadboard*

A construction base for prototyping electronics.

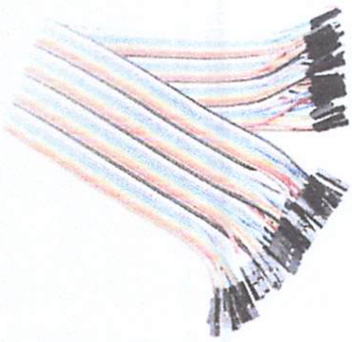


*Figure 17. Jumper Wire*

A smaller and more bendable corrugated cable is used to connect antennas and other components to network cabling.

*Figure 18. Power Inverter*

A power inverter, or invertor is a power electronic device or circuitry that changes direct current (DC) to Alternating Current (AC).

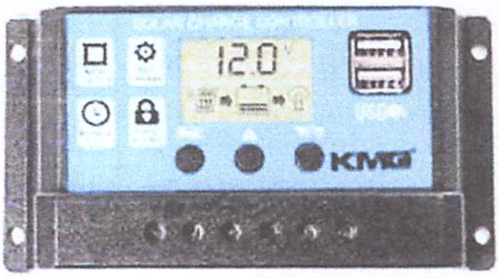



*Figure 19. Charge Controller*

The charge controller regulates the amperage and voltages that is delivered to the loads and any access power is delivered to the battery system so the batteries maintain their state of charge without getting overcharged.

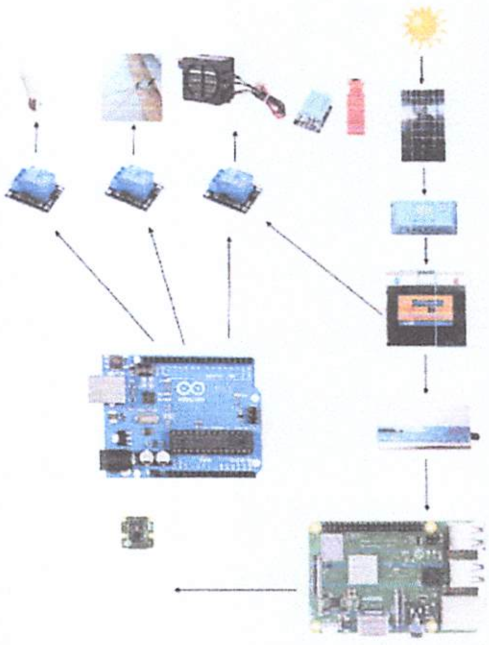


*Figure 20. Architectural Design of the System*

Figure shows the architectural design of the system. The arrows pointing to/from the components indicate whether they are inputs or outputs. The solar panel collects solar energy from the sun and converts it into an electrical power source stored in the battery. The solar charger controller charges the battery simultaneously stores energy and supply power to the system (inverter).

The Inverter USB (Universal Serial Bus) in 5Vdc 1 ampere, supplies the Arduino Uno, then all of its data signals of in specific relay module for e.g., LED lamp (pin 7), Servo motor (pin 8, pin 9, pin 10, pin 11), Main Source (pin 5), Heater Fan (pin 6) are connected to the Arduino Uno. Also, the passive sensors; Water Sensor (pin 3) and Humidity Sensor/Temperature (pin 2) sensor. The temperature sensor measures the temperature inside the chamber while the water sensor detects the water droplets from the rain. Arduino Uno microcontroller to command the Arduino to execute all of its commands.

The 5Vdc was supplied to the raspberry power port, and the camera was connected in camera slot module. Raspberry pi 3b+ camera both process and provide data to the raspberry pi 3b+ microcontroller. Burguillos et al. (2017) conducted a series of drying test using moisture reduction of cacao beans.

While operating in the drying mode, the data from the raspberry pi 3b+ camera and temperature sensor are encoded in the SD card every hour interval. It is also displayed in the LCD. Heating stops when too much heat output came out from the heater fan and when the temperature is below 35 degrees C the heater fan will automatically start.

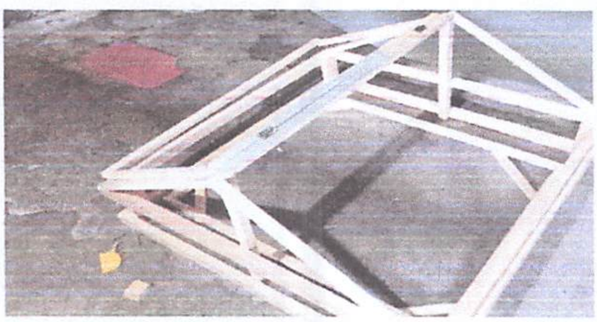
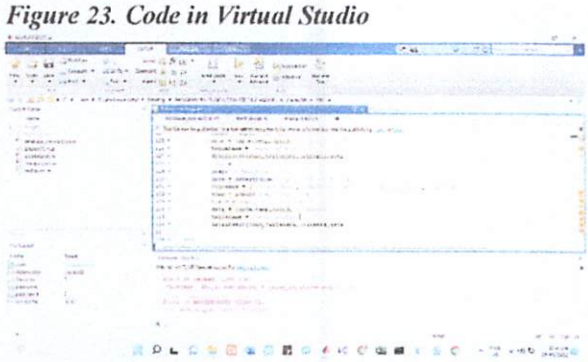


*Figure 21. Frame Design*

Shows the shows the frame design of the chamber.

*Figure 23. Code in Virtual Studio*



*3.2 Evaluation Results*

*Table 5. Temperature and Humidity of the system Day 1*

| NO | Week 1 | | Week 2 | |
|---|---|---|---|---|
| | T | H | T | H |
| 1 | 29.6.C | 74.3% | 29.6.C | 75.1% |
| 2 | 28.8.C | 80.3% | 29.9.C | 77.6% |
| 3 | 29.5.C | 76.1% | 28.1.C | 77.2% |
| 4 | 29.2.C | 78.9% | 30.2.C | 81.3% |
| 5 | 29.7.C | 77.8% | 29.2.C | 80.4% |
| 6 | 28.9.C | 79.7% | 31.5.C | 76.2% |
| 7 | 29.8.C | 80.3% | 31.3.C | 75.2% |
| **R** | **29.3.C** | **78.3%** | **29.9.C** | **77.6%** |

*Table 6. Temperature and Humidity of the system Day 2*

| NO | Week 3 | | Week 4 | |
|---|---|---|---|---|
| | T | H | T | H |
| 1 | 29.9.C | 80.5% | 31.2.C | 90.1% |
| 2 | 31.5.C | 80.9% | 30.4.C | 92.3% |
| 3 | 31.1.C | 78.2% | 28.8.C | 95.6% |
| 4 | 30.4.C | 77.6% | 29.7.C | 90.8% |
| 5 | 29.3.C | 79.4% | 30.1.C | 92.1% |
| 6 | 31.4.C | 76.7% | 31.2.C | 91.8% |
| 7 | 29.2.C | 81.1% | 31.3.C | 93.6% |
| **R** | **30.4.C** | **79.2%** | **30.4.C** | **92.32%** |

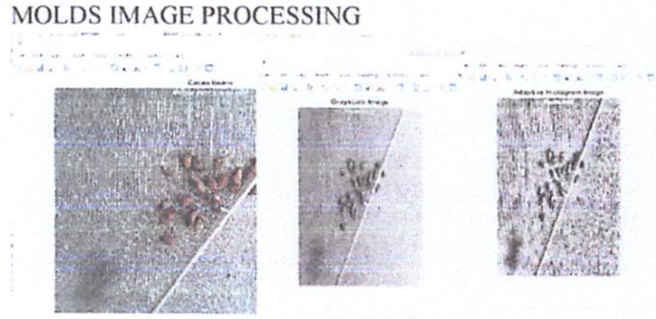
*Table 7. Temperature and Humidity of the s system Day 3*

| NO | Week 5 | | Week 6 | |
|---|---|---|---|---|
| | T | H | T | H |
| 1. | 30.3.C | 93.7% | 29.5.C | 91.6% |
| 2 | 30.1.C | 90.3% | 30.1.C | 92.3% |
| 3 | 31.8.C | 94.1% | 31.1.C | 94.7% |
| 4 | 29.1.C | 92.3% | 31.8.C | 90.1% |
| 5 | 29.3.C | 90.3% | 30.4.C | 91.5% |
| 6 | 31.1.C | 90.9% | 29.4.C | 95.5% |
| 7 | 30.9.C | 92.9% | 29.2.C | 94.7% |
| **R** | **30.2.C** | **92%** | **30.07.C** | **91.9%** |

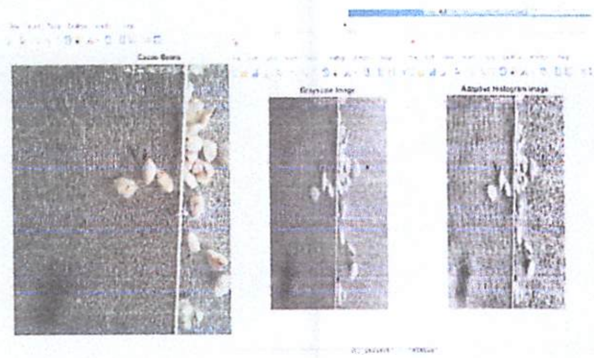
T – Temperature
H – Humidity
R – Average

**Data Analysis of Cocoa Beans**

MOLDS IMAGE PROCESSING



NOT FERMENTED IMAGE PROCESSING



### 3.3 *Performance level of the design project*

***Table 10. Evaluation of Performance Level of the project.***

| | TYPE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ACTUAL | | | | SCANNING | | | RESULTS |
| | TEMP. | HUMID. | STATE | | TEMP. | HUMID. | STATE | |
| TEST 1 | 26.50 | 89% | WET | TEST 1 | 26 | 89% | WET | GOOD |
| TEST 2 | 26.40 | 78% | WET | TEST 2 | 28 | 84% | DRY | BAD |
| TEST 3 | 37 | 68% | DRY | TEST 3 | 35 | 63% | DRY | GOOD |
| TEST 4 | 27.4 | 88% | DRY | TEST 4 | 27 | 84% | DRY | GOOD |
| TEST 5 | 34 | 80% | FERMENTED | TEST 5 | 30 | 75% | FERMENTED | GOOD |
| TEST 6 | 36 | 75% | FERMENTED | TEST 6 | 30 | 76% | FERMENTED | GOOD |
| TEST 7 | 72 | 40% | NOT FERMENTED | TEST 7 | 74 | 32% | NOT FERMENTED | GOOD |
| TEST 8 | 36 | 81% | NOT FERMENTED | TEST 8 | 30 | 74 | NOT FERMENTED | GOOD |
| TEST 9 | 39 | 42% | GOOD | TEST 9 | 40 | 38% | DRY | GOOD |
| TEST 10 | 35 | 46% | WET | TEST 10 | 32 | 69% | DRY | BAD |

The range for the remarks of the device is Wet, Fermented, Not Fermented, and Dry.

## 4. CONCLUSIONS AND RECOMMENDATIONS

***Conclusion***

After making this thesis, the researchers discovered that in order to accomplish the project, each of them should participate. Because of the unavailability of materials available in local areas, the sharing of ideas is must for improvising such parts and materials that is essential for completion of the said project. This will not only provide a wide vision of innovations, but also to test the capability of a researcher on how will her/his ideas will make an impact in securing the full operation.

Aside from the researchers' contribution to one another, there are also other things the researcher had encountered; most of them are in the electrical work.

The electric backup heaters effectively maintained drying temperature from 40 degrees Celsius to 50 degrees Celsius, eliminating the occurrence of moisture re-absorption during night time. The continuous drying process effectively shorted the drying time and addressed the intermittent effect of drying cacao beans.

The Raspberry Pi is a low-cost, credit-card-sized computer that plugs into a computer monitor or TV. It is a capable little device that enables people of all ages to explore computing and to learn how to program in languages like Scratch and Python.

***Recommendation***

Furthermore, the researchers formulated the following recommendations:

1.
2. Add Circuits Breaker to protect the system.
3. Recommended Battery of the System must exceed 50% from the actual load of the system.
4. I recommend use only solar battery for deep cycle or slow discharge purpose.
5. Execute the proper packaging to protect the system from wet weather conditions.


## 5. ACKNOWLEDGEMENTS

The researchers would like to extend their heartfelt gratitude to the people who are behind in this study.

First, to Almighty Father, who empowered the researchers to be the best versions of themselves and to keep them safe all the time. To the research adviser for sharing knowledge and for keeping the door always open whenever the researchers ran into a trouble spot or had questions about this study.

The researchers would like to thank also to the participants of the project study who freely give their precious time. To the parents and friends of the researchers, for providing them with unfailing support and continuous encouragement throughout the whole research.

This accomplishment will not be possible without the people mentioned above. Thank you.


## 6. REFERENCES


| | |
|---|---|
| [1] | Burguillos, Elauria, & De Vera, 2017 "Design, Construction and Performance Evaluation of an Indirect Solar Dryer for Fermented Cacao Beans" |
| [2] | Hii, Law, & Suzannah, 2012 "Drying kinetics of the individual layer of cocoa beans during heat pump drying" |

| | |
|---|---|
| [3] | Dina, S.F. Ambarita, H., Napitupulu, F.H., & Kawai, H (2015) "Study on effectiveness of continuous solar dryer integrated with desiccant thermal storage for drying cocoa beans" |
| [4] | Farooq, M.S.; Riaz, S.; Abid, A.; Abid, K.; Naeem, M.A. A Survey on "the Role of IoT in Agriculture for the Implementation of Smart Farming." IEEE Access 2019, 7, 156237–156271. [CrossRef] |
| [5] | Yoon, C.; Huh, M.; Kang, S.; Park, J.; Lee, C. Implement Smart Farm with IoT Technology. In Proceedings of the 20th International Conference on Advanced Communication Technology (ICACT), Chuncheon-si Gangwon-do, Korea, 11–14 February 2018; pp. 749–752 |

| | |
|---|---|
| [6] | (Jinap, Thien, & Yap, 1994). "Effect of drying on acidity and volatile fatty acids content of cocoa beans" |
| [7] | Galiche et al. (2011) "Design and Construction of a Sun Tracker System with Analog-Digital Combination Control Method and Feasibility of its Using in Solar Crop Dryers |