Negros Oriental State University
College of Engineering and Architecture
Main Campus II, Dumaguete City
Geothermal Engineering Department

DESIGN AND FABRICATION OF A COFFEE BEAN DRYER UTILIZING GEOTHERMAL HEAT IN BASLAY, DAUIN

A Project Study Presented to

The Faculty of Geothermal Engineering Department

IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS IN

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by

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ABSTRACT

Coffee is one of the main crops available in Baslay, Dauin, Negros Oriental. It undergoes drying, which is a necessary stage in coffee processing to stabilize the product. The geothermal prospect in Baslay is a thermally active area that appears more useful when drying coffee beans because it is consistent and sustainable. Using an experimental and quantitative research methodology, this study evaluates the suitability and efficacy of the coffee bean dryer using a geothermal heat resource in Baslay, with a maximum temperature of 63°C. The dryer's construction and material selection are all covered in the research. Efficiently harnessing the geothermal water source to optimize heat transfer to the dryer is essential, achieving uniform drying of 500 grams of coffee beans. The drying process involved five trials. The first two trials had different specifications from the subsequent three. Moisture analysis results showed the moisture content of the coffee beans in the trials was 3.85%, 15.62%, 5.54%, 7.40%, and in the last trial 6.44%. According to the results of the survey questionnaire, the researchers have determined that the coffee bean dryer effectively utilizes geothermal heat to dry coffee beans. Most respondents, who are members of the BASHACO, indicate their satisfaction with its performance in drying coffee beans. The precise control of the drying process allows for the optimization of geothermal energy benefits, and the utilization of Baslay's geothermal water source has been demonstrated to be an effective method for drying coffee beans.

Keywords: *coffee bean, drying, dryer, geothermal, moisture*

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CHAPTER 1

THE PROBLEM AND ITS SCOPE

1.1 Introduction

Coffee is a globally cherished beverage that is enjoyed by the people for its widespread popularity and energizing effects. Its cultivation to consumption involves a step-by-step elaborative process, with one crucial stage being the drying process. During this stage, freshly harvested coffee beans are dried to an optimal moisture level, which is important for storage and further processing. The process of drying includes removing moisture content in order to enhance storage and prolong its preservation.

A study conducted by Freites et al. states that the coffee industry has a significant impact on the world economy. More than 90% of the coffee produced globally is grown in developing countries. It provides economic support to approximately 25 million local farmers worldwide. In addition, a major global commodity, coffee demand, has proven remarkably resilient despite the changing agricultural economy. Surpassing the 2.5% growth in agriculture overall, coffee output has grown at a rate of 3.5% per year since 2008.

One of the main crops available in Baslay, Dauin, is coffee, and to move to more cost-effective and environmentally friendly practices, the geothermal manifestation that is also available and abundant in the area will be used. Coffee bean drying is a process that can be efficiently addressed by utilizing geothermal energy. The amount of time spent in drying the harvested beans becomes crucial to improving both the quality and sustainability of the coffee. Following proper bean drying reduces the environmental impact and production costs significantly as it preserves flavor.

In this study, the researchers aim to investigate the process of coffee bean drying in Baslay, Dauin, by utilizing the geothermal heat source. In addition, this research will determine the suitability of using geothermal heat for drying robusta coffee beans, farmed by local farmers near the geothermal manifestation. Geothermal energy is a renewable source that can be utilized for drying coffee beans. Given that it is a sustainable heat source in production and different agriculture processes, it also has a low environmental impact and has low potential for energy efficiency.

Furthermore, even during rainy seasons, farmers can have a consistent way to dry the coffee beans faster than the usual sun drying by using geothermal heat. The efficient use of this heat in coffee drying processes in Baslay, Dauin, Negros Oriental could serve as a guide for other coffee-producing regions with geothermal energy resources. Hence, the objective of this study is to create a thorough and eco-friendly coffee drying process that creates a balance between the demands of the coffee industry and a sustainable resource.

1.2 Statement of the Problem

The purpose of this study is to evaluate the sustainability and effectiveness of utilizing geothermal heat in coffee bean drying operations in Baslay, Dauin. In the pursuance of the study, this sought to answer the following questions:

1. What are the characteristics of the geothermal fluid used to provide heat in the coffee bean dryer?
2. What are the specific design requirements for a coffee bean dryer that uses geothermal heat in Baslay, Dauin?
3. What is the moisture content of the dried coffee beans?
4. What is the required drying time for coffee beans to meet the quality standards set by BASHACO?

1.3 Specific Objectives of the Study

To ensure that these goals are met and fulfilled at the end of the data gathering, the study includes specific objectives.

1. This study aims to determine whether the geothermal heat in Baslay, Dauin can dry the coffee beans using the fabricated coffee bean dryer to the necessary moisture level.
2. This study aims to determine whether using geothermal heat in Baslay, Dauin, to dry coffee beans is both feasible and effective.
3. This study aims to develop a practical and efficient coffee bean drying system that harnesses geothermal heat resources in Baslay, Dauin.

1.4 Significance of the Study

NORSU. Negros Oriental State University will benefit from this study because it encourages the development of research and practical learning skills, which is in line with the educational goals of the institution. This research title highlights the institution's position as one of the leaders in both research and education, significantly influencing the connection between agricultural and renewable energy. Additionally, the credibility of the institution will benefit from this, particularly in the Engineering Department.

The Environment. The potential of the research to change the coffee bean drying production process into a more environmentally conscious and sustainable endeavor makes it significant from the point of view of the environment. The use of geothermal heat provides a route toward a more sustainable and resilient agriculture industry, which is in line with larger environmental objectives.

The Students. The study provides students with a wealth of educational possibilities and developing abilities exercises. This study provides a comprehensive and diverse learning experience by integrating academic knowledge with real-world applications. It demonstrates how science is used in engineering and agriculture in everyday circumstances. It presents a challenge for students to gather data, make inferences, and offer suggestions based on scientific data regarding additional methods of distillery spent wash disposal.

The Farmers. The study is very important to the local farmers because it could bring about sustainable and creative solutions for the coffee bean drying process, which would greatly enhance the social, economic, and environmental aspects of the Coffee Bean Plantation in Baslay. The advantages go beyond helping specific farmers and supporting the general development of the nearby farming community.

Researchers. For researchers from a variety of academic fields, this study is highly significant because it provides an opportunity for meaningful scholarly contributions, interdisciplinary collaboration, and practical problem-solving in the search for innovative and sustainable approaches to coffee bean drying in Baslay, Dauin.

1.5 Scope and Limitation of the Study

This study focuses on the conceptualization, design, and development of a coffee bean drying system that utilizes geothermal heat as its primary energy source. This includes considerations for technical specifications, thermal efficiency, and material selection. The experimental sample will include three (3) consecutive trials of testing the constructed coffee bean dryer to determine its efficacy and reliability.

Since about 13.5% moisture content is recommended for storage and sale in BASHACO, the coffee bean must be dried using the coffee bean dryer to reduce its moisture content. This process will produce a stable product. Weigh the coffee beans both before and after drying to calculate the percentage of moisture removed, as well as to assess the coffee bean dryer’s performance encompassing drying efficiency and energy consumption. Limitations of the study include coffee availability, because of climate change; the harvest season came earlier than usual, causing the decrease in coffee availability. According to the chairman, the farm will likely run out of undried coffee beans by the last week of March. Another limitation is that the experiment will be conducted on a small scale (500 grams of undried coffee beans), which may not fully represent the performance of the coffee bean dryer under large production volumes. This study will also not consider the coffee’s aroma, as the researchers are solely focusing on the drying process. In addition, time constraints may affect the study; therefore, long-term impacts may not be fully captured in the findings.

Considering these limitations, the study addresses an essential component of environmentally friendly coffee processing that could provide important new information about the potential benefits and effects of geothermal coffee bean drying in Baslay, Dauin. Within the parameters of the research's scope and context, the limits provide a framework for the proper application and interpretation of the findings. These restrictions might be addressed in subsequent studies to expand and improve the knowledge already available.

1.6 Definition of Terms

Gaining a precise and clear understanding of key phrases is essential to comprehension and communication in any research project. To ensure that readers and researchers all have a consistent grasp of the language used throughout the study.

Arabica Coffee Beans. Arabica coffee beans are typically oval, have a pronounced center crease, and are larger compared to Robusta beans.

Bone Dry Coffee Beans. Coffee beans that have been dried to the complete absence of moisture content. This level of dryness is achieved by drying the beans until they no longer contain excess moisture.

Coffee Bean. A coffee bean is the bean of a coffee plant, which resembles a bush and can grow very tall. To keep the plant manageable, coffee farmers in Baslay, Dauin, typically trim it to a height of about five feet.

Coffee Bean Dryer. A coffee bean dryer is a type of dryer that is designed in this study to dry coffee beans. It is smaller in size and can be carried out easily at the geothermal water source in Baslay, Dauin.

Drying. Drying refers to the removal of the water content available in a coffee bean. It improves visibility as well as the long-term preservation of the main product.

Geothermal Hot Spring. It is a naturally occurring geothermal heat source which is used to heat the coffee beans through heat exchangers.

Robusta Coffee Bean. Robusta coffee bean is another variety of coffee beans which is mainly available in elevated areas. It is the main product used in this study, provided by BASHACO, to evaluate the effectiveness of the coffee bean dryer.

CHAPTER 2

THEORETICAL BACKGROUND

Geothermal Energy Utilization

Geothermal energy, or the heat extracted from deep underground, can be used not only for producing an electrical energy source but also for utilizing its heat directly, such as in space heating and cooling, pasteurization, and drying processes (Chiasson, 2015). The direct use of geothermal heat became popular globally as an alternative use (Njuguna, 2020) and usually depends on its temperature, typically low to medium and chemical considerations, as stated in the ESMAP Report of the World Bank Group (2022).

In the drying process, geothermal heat may be used to dry several crops, such as rice, tea, and coffee beans (Abdullah, 2010). The heat produced from the geothermal energy source can be used directly to dry agricultural products. This is beneficial since it provides a continuous and stable process of drying.

Agricultural Drying Processes

According to the study conducted by Sumotarto et al. (2000), drying agricultural products such as rice, coffee and tea can benefit from geothermal heat. In addition, tomatoes undergo a geothermal drying process after they pass the pre-treatment stage, cut into two halves, placed on stainless steel trays, and then charged into the drying chamber. The drying process uses a low-cost geothermal water source to heat atmospheric air to approximately 55% in fined tube air heat coils. It was stated that four tonnes of high-quality dried tomatoes were produced during the first year of operation (Vasilevska, 2003).

Low-enthalpy geothermal fluids are very convenient as well as applicable in the drying of agricultural products. Convenience in terms of the positive influence on the heatloading factor of the geothermal water source, which is one of the most significant factors in the exploitation of geothermal manifestation (Vasilevska, 2003).

Coffee Bean Drying

Important variables in the drying process of coffee beans include the temperature, moisture level, humidity and air flow rate. The drying temperatures of coffee beans are set to below 60°C so as not to damage the taste of coffee (Prasetyo et al., 2018). After harvest, the coffee beans' moisture content is 45% and 55% (Tetreault, 2024).

According to a study by Gachen et al. (2020), to achieve a stable product for storage and sale, a coffee bean must have a moisture reduction of 60% to 11% on a wet basis. However, it is stated in the study by Sumotarto et al. (2019) that several crops prefer temperatures of 50 to 60°C to dry. About 40% of relative humidity might be sufficient to carry out a drying procedure.

Geothermal energy utilization affects the duration of the drying phases of the coffee processing process, according to data gathered thus far from the GCP (Geothermal Coffee Process). Each type of coffee processing takes much less time with geothermal—2 to 4 days for a full wash and 7 to 10 days for natural processing (Cariaga 2023).

Heat Pipe Heat Exchanger (HPHE) Theory

In a study "*Utilization of the Heat Pipe Heat Exchanger at Low Enthalpy Geothermal Energy to Coffee Drying Process*", to improve Geothermal Energy's performance, it is essential to implement highly sufficient and effective heat transfer technology. Heat Pipe Heat Exchanger (HPHE) stands out for its compact design and ability to control heat flow, making them an excellent choice for boosting efficiency (Hakim et.al., 2020).

In a study titled "*Enhancing the performance of conventional coffee beans drying with low-temperature geothermal energy by applying HPHE: An experimental study",* HPHE is a heat transfer device that has a high conductivity value that is already well tested for several applications, it has some advantages over conventional heat exchangers. These advantages are as follows: HPHE does not require additional energy (Passive devices), is more compact and has simpler operation, and may reduce production and maintenance costs (Gunawan et al., 2021).

Heat Transfer Principle

One thing to consider when designing a heat exchanger system is to understand the principle of heat transfer and to identify the appropriate concept of the drying method. According to Bergman et al. (2002), these principles of heat transfer help to achieve a consistent heat distribution and efficient use of heat.

In terms of the conduction process, it is the transfer of geothermal heat to a heat exchanger or copper tubes inside walls. Meanwhile, involving convective heat transfer in the process of heat flow in the case of the movement of the fluid passing through the heat exchanger. Through the vent, the heat from the copper tubes is also transferred to the air inside the dryer by convection, which helps to dry the product inside the dryer.

A study conducted by Prasetyo et al., (2018), utilized a heat exchanger to obtain energy from geothermal fluid and utilized it for coffee drying. One common method of extracting geothermal energy, particularly low temperature geothermal energy, is to use a coffee drying machine to circulate fluid through a pipe that is connected to a heat exchanger.

2.1 Theoretical Framework

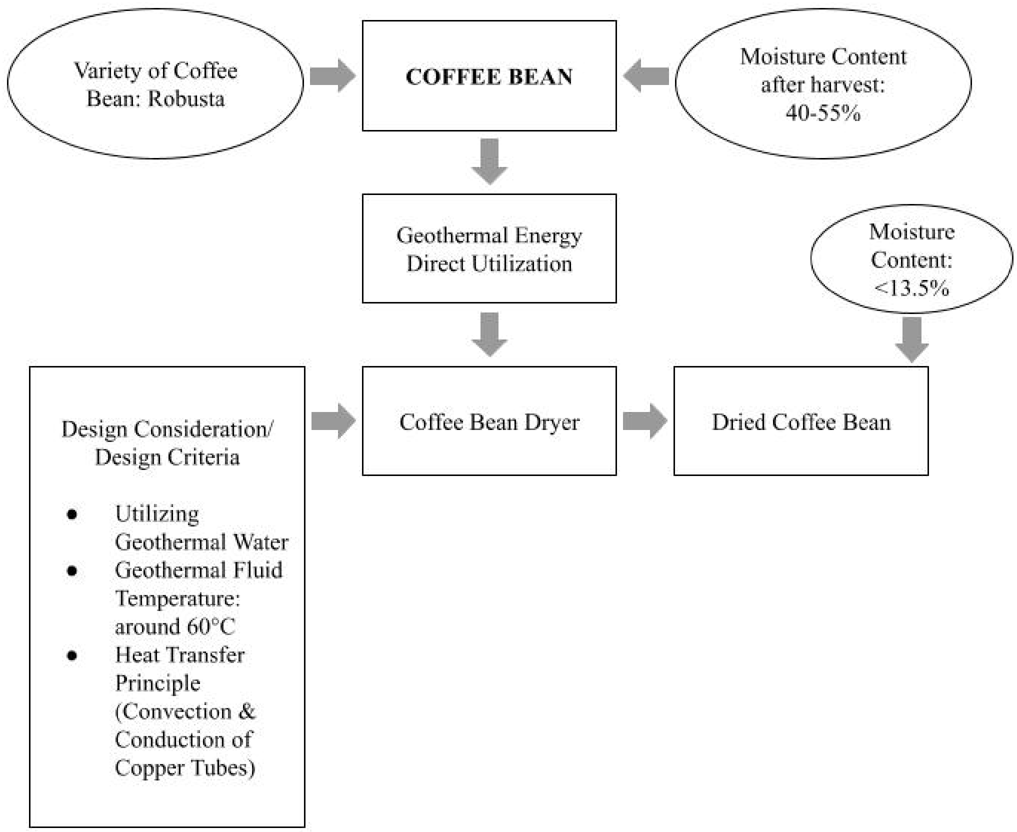


Figure 1. Theoretical Framework

2.2 Conceptual Framework

In this study, the researchers formulate a structure which presents key concepts in relation to coffee bean drying using geothermal heat sources. This is crucial since it provides a better understanding and analysis of the research experiment's main goal.

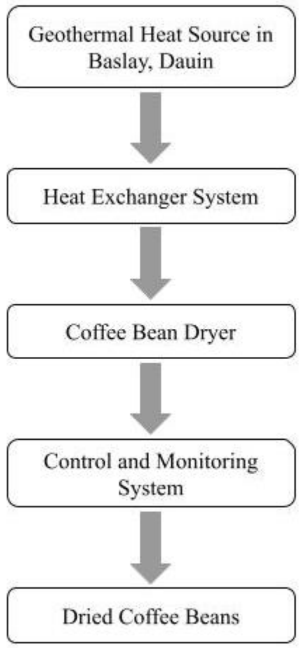


Figure 2. Conceptual Framework

The framework presents the concept of a coffee bean dryer utilizing the geothermal heat source in Baslay, Dauin. The goal of this approach is to replace traditional drying methods, including sun drying, with a prototype dryer that effectively uses geothermal heat to dry coffee beans. The framework considers technical factors that include the design and fabrication of the coffee bean dryer with the implementation of a heat exchange system to ensure that drying conditions are precisely monitored. To achieve the ideal moisture content for the dried coffee beans, careful monitoring of the temperature was applied. The dried coffee bean output serves as a comprehensive guide in determining the effectiveness of the coffee bean dryer utilizing a geothermal heat source.

CHAPTER 3

REVIEW OF RELATED LITERATURE AND STUDIES

According to a study by Dzaky et al. (2023), coffee is a drink that is brewed and considered as an important need for our everyday life through the past 50 years, the coffee consumption average for annual growth has achieved 1.9%.

Coffee production has an important drying process; this is because it reduces the moisture content of the coffee beans. Right after harvesting, the coffee beans' moisture content is 45% and 55% (Tetreault, 2024). According to another study by Gachen et al. (2020), in order to have a stable product for storage and sale, coffee beans should have a moisture reduction of 60% to 11% on a wet basis. Prasetyo et al. (2018) also stated in their study that there are two stages of coffee bean drying: first is the initial drying where the skin is removed until the moisture content reaches 40%, and the second is to dry the beans further until it reaches a moisture content of 12.5%.

It is stated by Kaffeehandel (2023) that the Robusta coffee variety originated in Central and West Africa and opened the way for coffee cultivation in lowland areas in Congo at the end of the 19th century. Aside from the largest robusta coffee production in the world, it also requires good post-harvest handling (Channabasamma et al., 2021). According to Channabasamma et al. (2021), robusta comes up well at a lower elevation where a hot and humid climate prevails and is resistant to many pests and diseases affecting coffee compared to Arabica coffee, which is susceptible to them.

Kaffeehandel (2023) claims that the robusta variety is stronger, more resistant to diseases, and more productive. Since its cultivation was not limited to Africa, Coffea canephora was also grown in northern Brazil and Asia, particularly in Indonesia, India, the

Philippines, and Vietnam. Robusta is then considered the second most popular bean in the world after Arabica, which accounts for about 40% of the coffee production globally.

Channabasamma et al. (2021) assert that the harvested coffee beans are processed by two methods: wet and dry. The coffee processed by the wet method is known as parchment coffee, and the beans processed by the dry method are called cherry coffee. In the dry method, the fresh coffee beans are spread out on a clean surface or yard and dried for about 12 to 15 days to reduce their moisture level by about 11 to 12%. Moreover, arabica coffee in India is commonly processed by the wet method, while most robusta coffee is prepared by the dry method. Channabasamma et al. (2021) concluded in their study that the total drying period of robusta coffee beans was 48, 40, and 32 hours at 40°C, 50°C, and 60°C, over 88 hours by sun-drying.

According to Bahtiar et al. (2023), the best rainfall for robusta coffee plants is between 2000 and 3000 mm/year. High rainfall throughout the year causes a decrease in harvest and lack of dry season can limit coffee harvest in lowland tropical areas. North Maluku has an average air humidity of 84% and wind velocity of 31 knots in August. The highest rainfall is in January. The largest sunshine of 89% occurs in September, whereas rain is all year round with varying intensity. Rainfall in the areas around the coffee plantations in Bale Village is approximately 2000-3000 mm/year, which is an ideal condition for robusta coffee growth.

Despite the Robusta variety's greater benefits when producing coffee, many earlier studies have shown that this variety of coffee crops is not significant to any particular region. In the study of Prasetyo et al. (2018), it is stated that the drying temperatures are set to below 60°C so as not to damage the taste of coffee. Heating at 50°C also prevents hardening, where the outside layer has dried up but the inside coffee is still wet. This phenomenon will increase the pressure of the water content inside the coffee, pressing it to the outside so that it can break. Additionally, microorganisms can develop in coffee that is still wet, which affects its quality.

Njuguna (2020) described that direct utilization of geothermal energy became popular throughout the world as an alternative use. Drying is one example of direct use. It is a mass transfer process that consists of removing the water using heat energy. It is a stage after harvesting where the coffee beans are dried to their ideal moisture level. Its main objective is to reduce the moisture content to allow for a longer storage period safely. It also reduces the weight and volume, making packaging, storage, and transportation easier.

Geothermal drying has proven beneficial in drying other products like grains, seaweed, fish, meat, fruits, and vegetables. In a study conducted by Njuguna (2020), it is noted that for all dryers, the amount of time taken to dry the grain is determined by the original moisture content of the grain being dried and the method of introduction of the hot air for drying. Different grain types also require different factors affecting drying like temperature and the flow of air. If the drying temperature is low, the grain may not dry properly and may rot, while very high temperatures could cause cracking and case hardening, and sometimes may kill the life in seed grain (Njuguna, 2020).

Meanwhile, in a study conducted by Harefa et al. (2022), it is stated that drying using residual geothermal fluid through a heat exchanger can dry at night and is available 24 hours a day without being disturbed by the weather. Fuentes (2018) explained that in general, all industrial drying processes are carried out using electrical energy. This provides the heating source to get the right temperature and starts the process of evaporation of moisture from the product. The drying is carried out at air temperatures between 35 and 80°C. Therefore, low temperature geothermal fluids can be used for the drying of agricultural products.

Preliminary tests have indicated that geothermal drying is superior in terms of cost, reliability, and efficiency compared to traditional drying methods used by farmers. According to a study of Njuguna in 2020, the Menengai geothermal dryer appears to be the optimal choice for grain drying, offered by its technological and earthly benefits. They stated that geothermal energy is environmentally friendly and is consistent and renewable, making the dryer available even during rainy seasons when sun drying is not given as an option. Through this process, this allows to dry batches of grains which saves time and minimizes handling issues. Also, the geothermal drying process proves to be more cost-effective than those alternative methods thus the heat utilized is a by-product of the electricity generation process.

Another study conducted by Gunawan et al. in 2020 found that it is suggested that the coffee beans should be dried to remove moisture content from around 65% to 11%. The potential of Indonesia's geothermal energy could be utilized either directly for this drying process or in combination with solar energy.

Other important variables in the drying process of grains are humidity and air flow rate. According to a study by Sumotarto et al. (2019), numerous crops require temperatures up to 90°C to dry. Nevertheless, most of the crops prefer 50 to 60 degrees Celsius. About 40% of relative humidity might be sufficient to carry out a drying procedure.

According to research conducted by Dzaky et al. (2023), they introduced a solar biomass hybrid system that is designed to dry coffee beans. This innovative approach collides with using coffee husk pellets for combustion with a photovoltaic thermal mechanism. This process can reduce the moisture content from 12% to 80%.

According to Sumotarto et al. (2019), the drying technique introduced and experimented with by Sandali et al. in 2018 utilizes a double-level tubular heat exchanger with geothermal water, which enhances thermal performance. By employing this heat exchanger, the drying process achieved temperatures ranging from a minimum of 46°C to a maximum of 58°C.

In a study by Martinez et al. (2018), they introduce the design of a coffee bean dryer that utilizes geothermal energy in the Berlin Geothermal Field. In their study, they aimed to address the limitations of traditional drying methods, which are often affected by weather conditions and long drying times.

However, Prasetyo et al. (2018) specifically engaged geothermal energy for drying coffee, using a heat exchanger to harness energy from geothermal brine. A conventional method for extracting geothermal energy, particularly at low temperatures, involves circulating fluid through a pipeline connected to a heat exchanger.

Additionally, according to the study conducted by Prasetyo et al. (2018), drying coffee using geothermal fluid is aptly applied at the research site because of the potential of commodities and the resources available. The coffee drying method used is semi-washed. The geothermal drying system scheme uses a heat exchanger and hot water as working fluid. Hot water with a temperature of 80°C flows in a closed loop system to heat the air inside the drying apparatus. The coffee drying is done at 50°C with a water content of 60% to 12% remaining in a total time of 12.5 hours. The total energy used for drying is 32.65 kW.

Prasetyo et al. (2018) stated that coffee processing takes a certain time and temperature to get the right water content. To improve the drying process and the resulting product, feeding required a continuous heat supply. This can be reached by using a continuous energy resource supply such as geothermal fluid flows, as stated by Sumotarto (2007). Harefa et al. (2022) claims that geothermal energy is perfect for the environment because it produces the most negligible CO_2 emissions. Aside from its good environmental impact, it has a stable and continuous heat source, less drying time, and does not depend on the weather (Prasetyo et al., 2018).

Furthermore, designing a specific dryer must take considerations to achieve a good, efficient, and effective working design. Some of these considerations include the product to be dried, the moisture level that needs to be removed, weather conditions, and the equivalent weight of the coffee beans, also considering the local conditions and its characteristics (Gachen et al., 2020). In addition, heat exchanger is also part of the dryer construction consideration, since most geothermal fluids are corrosive and scaling in nature, and cannot, therefore be used directly (Njuguna, 2020).

According to the study conducted by Sumotarto (2007), the dryer used in the research is made of a fluid-air heat exchanger to produce hot air that will be blown into a drying room filled with trays of grains or beans. The waste geothermal fluid flows into a bank of steel pipes, and the air is blown outside the pipes to extract heat from geothermal fluids inside the tubes for the drying process. The equipment does not use a drying belt to save energy for moving the belt. Instead, the beans and grains are placed on trays in the drying room. The only moving part is an air blower that can be designed to move by geothermal energy (pressure), while its heat content is used for the heat exchanger. The air blower is placed on one side of the heat exchanger while the drying room is on the other side. The drying duration depends on the original humidity of the products. By doing several drying experiments, an ideal drying time can be found for which the product is perfectly dried. The dryer is designed as simple to assist the technical feasibility of geothermal energy direct utilization. If the drying is proven to be feasible, then the technology and design can be improved while the scale can be increased to meet a commercial project.

Meanwhile, a study conducted by Maharjan, found that the tunnel and the conveyor dryers can be adopted in different food processing industries for drying varieties of food like vegetables, fruits, nuts, grains, etc. Apart from that it also has high yield production capacity and can be controlled in a simple way by the temperature of the air. This can also be called a continuous countercurrent tray dryer in which the air for drying products is heated using geothermal water. Also, the air coming from the dryer is recirculated after condensing a part of the moisture content. A stream of fresh air for drying may be used, if necessary, by regulating the diaphragm. In this case, the temperature and humidity of the drying air are independent of atmospheric conditions.

Moreover, in a study by Hendrarsakti et al. (2019), a coffee bean dryer simulator is designed using geothermal energy, where the geothermal heat source energy in steam or water (brine) is transferred to fresh water. Then the heat of fresh water is transferred through a heat exchanger to air which is blown to the coffee bean using a fan. The heat exchanger built was a compact one with the former type of flat plate finned pipe.

Sumotarto et al. (2019) claimed that the utilization of geothermal resources in cascade levels is a constant operation of geothermal heat by integrating different technologies for electricity generation, distribution, and use of thermal energy, drying and dehydration processes, recreational use, and any direct use of geothermal heat. The heat from geothermal hot springs, however, in the Batukuwung area can be flown through the metallic pipe and utilized the heat to flow through air in the drying room. Heat energy from geothermal resources can be used directly as well as indirectly. Heat transfer in heat exchanger tools can be utilized through the metal medium. This heat transfer can take place in several ways.

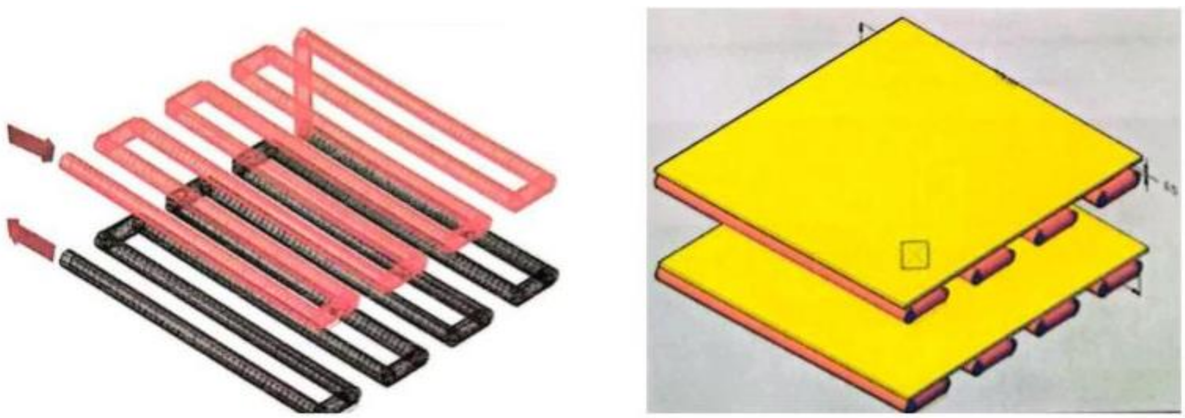


Figure 3. Copper Tube Formation Flow Diagram (Cañada, 2017)

(A) (B)

Figure 4. (A) Drying Chamber without Insulation, (B) Skeletal Structure of the Drying Chamber (Cañada, 2017)

The drying chamber used is composed of copper tubes and two trays. The copper tubes will serve as a heat exchanger to produce hot air to dry agricultural products. The casing of the chamber is made of plain steel sheet. It is then covered with an insulator to prevent heat loss. To reduce heat loss in the drying chamber, roofing insulation was used. It was located between the drying casing and the outer casing (Cañada, 2017).


(A)


(B)

Figure 5. (A) Inside View of the Dehydrator, (B) Outside View of the Dehydrator (Alderite et.al., 2022)

The design of the dehydrator was based on the researcher's ideas and past similar projects that also used geothermal water as its source. The project output has a single box-type shape with a drawer like a door to which the tray for the chili peppers was attached. For the fitting, angle bars were used. The casing of the dehydrator was made of marine plywood. The frame and the marine plywood are connected with screws. The frame which was made of angle bars was drilled to fit the screws. Copper tubes were used as the heat exchanger; one inlet and one outlet were only present in the incubator. The insulating foam was also installed inside the dehydrator (Alderite et.al., 2022).

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Research Design

This study uses an Experimental Research Design and a Quantitative Approach to examine the viability and efficacy of using geothermal heat to dry coffee beans in the agricultural setting of Baslay, Dauin. The quantitative method evaluates the effect of geothermal heat on the effectiveness of the coffee drying process by methodically measuring and analyzing variables including temperature and drying rates. The experimental research strategy consists of controlled studies in which various parameters are methodically modified to see how they affect the drying results.

The study aims to contribute significantly to the field of coffee bean drying processing technology as well as sustainable agricultural practices in geothermal-rich regions such as Baslay, Dauin, by using this methodological framework to provide qualitative proof and quantitative insights into the potential benefits and challenges associated with integrating geothermal heat into coffee bean drying practices.

4.2 Survey Design

In this study, the survey questionnaire is designed to evaluate the effectiveness and quality of the coffee bean dryer. The primary objective of this survey questionnaire is to assess the performance of the dryer, its acceptability among the members of BASHACO in terms of the drying process and the quality of its design and fabrication. Two sets of questionnaires will be made for this purpose. The first set is intended for the members of BASHACO and will consist of five questions focusing on the level of acceptability among these members, specifically in terms of its performance in the drying process. The second set of questionnaires is intended for NORSU

University Engineer's Office members including the engineers and architects and the College of Industrial Technology, including the mechanical and electronics instructors. The questionnaire will consist of 7 questions that will aim to evaluate the efficiency, design, and fabrication of the dryer.

The two sets of questionnaires will have the same section where demographic data like age and gender will be gathered for authenticity and legitimacy. Set one survey questionnaire will be rated using a five-point scale from 'Unacceptable' to 'Completely Acceptable' meanwhile the set two questionnaires will be rated with a scale of 'Excellent' to 'Poor'. The data that will be gathered will be kept secure and will be used solely for research purposes only.

4.3 Flow of the Study

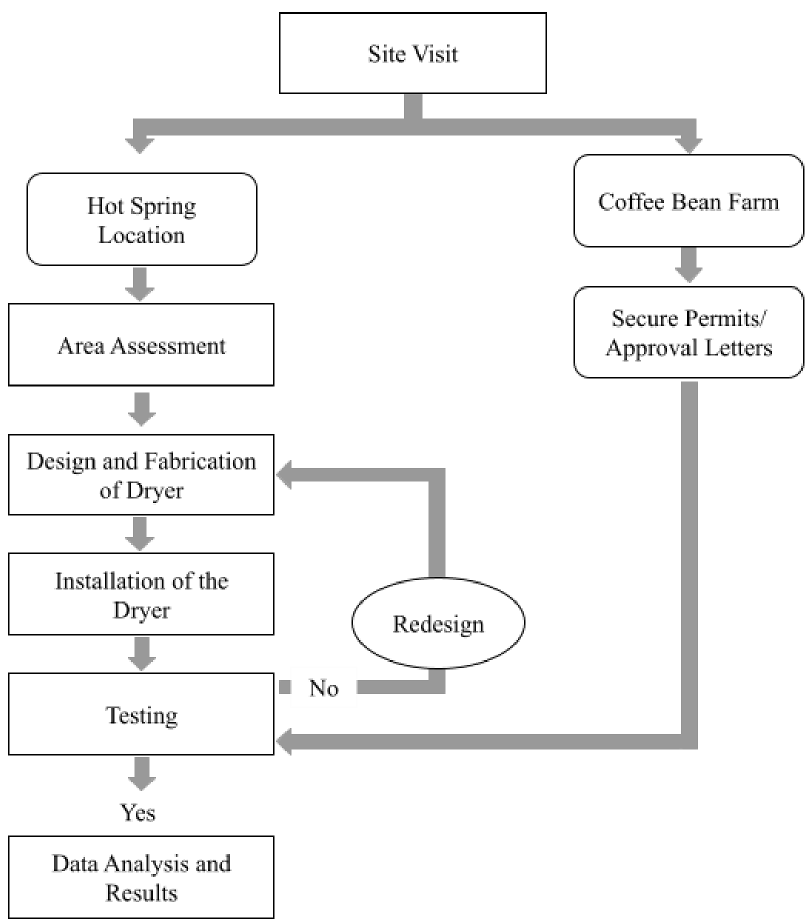


Figure 6. The process flow of the study

This study arises from a combination of innovative technologies, renewable energy, and sustainable agriculture within the coffee processing industry. Baslay, Dauin, located in an area rich in geothermal energy, presents a singular chance to investigate and utilize geothermal heat as a substitute energy source for coffee bean drying. Geothermal energy offers an effective source that has the potential to lessen the environmental impact of conventional drying technologies by providing a consistent heat source for the drying process.

In conducting this study, the researchers undergo site visits first on both rainy and sunny days. These involved assessing the hot spring located in Baslay, Dauin and evaluating the geothermal water's temperature, its pH level, and the accessibility of the area. The researchers also visited the coffee bean farm and talked to the chairman to ensure the researchers could purchase fresh coffee beans. Securing permits and approvals is important to carry out the research experiment.

However, it is critical to investigate the engineering and design principles for using geothermal heat in a coffee bean drying system. After assessing the area, the researchers designed a coffee bean dryer that utilizes geothermal fluid. Aiming to establish ideal parameters for geothermal based drying and drying parameters should be considered when designing a dryer to select the appropriate materials while being able to take the temperature and drying time of coffee beans into account. When designing the dryer, it's crucial for researchers to factor in the moisture content of the coffee beans.

Install the coffee bean dryer after the fabrication considering the design requirements. Following that, the researchers then proceeded with the drying process and testing. After 3 consecutive trials, fortunately, the researchers were able to gather data, analyze the results, and assess the dryer's effectiveness.

Upon completion of this study, the researchers aim to offer recommendations and guidelines that consider technological and other relevant factors when implementing geothermal heat in coffee bean drying systems.

4.4 Period of the Study

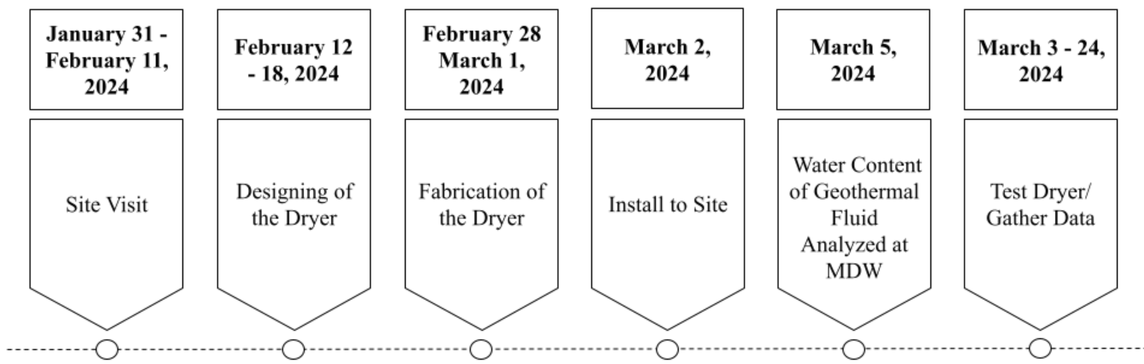


Figure 7. A diagram showing the period of the study

During the period from January 31 to February 11, 2024, researchers conducted site visits on both rainy and sunny days to assess various factors crucial for their study. These visits involved evaluating the temperature of the geothermal source intended for coffee bean drying, and the pH level of the fluid, as well as assessing the accessibility of the area.

In addition, the researchers visited the coffee bean farm in Baslay, Dauin, to ensure that the coffee beans were available and could be purchased in March. The researchers also wrote to the City Mayor, the barangay captain, and the chairman of BASHACO; these letters were processed and signed to ensure that the project study was conducted with the permission and support of these important officials.

After the site visit, the researchers were able to identify some important dryer design considerations. The dryer was designed from February 12 to February 18, 2024. After a thorough assessment, the dryer's design was enhanced to be cost-effective. From February

18 to 28, the researchers took time to canvas and look for the right materials and equipment for the dryer fabrication. Once the materials were finalized and purchased, the fabrication started. In a short span of time, the fabrication happened from February 28 to March 1, 2024.

The researchers were in a hurry to complete the fabrication due to the decreasing availability of coffee beans in Baslay, Dauin. Farmers explained that the harvesting season came earlier than expected because of climate change, which also caused it to end earlier. On March 2, the researchers installed the dryer at Baslay, Dauin. The coffee bean dryer was relocated to the upper part of the terrain in Baslay because the geothermal fluid flow in the lower part is not strong enough for the fluid to flow in our inlet pipes. After the installment, the researchers conducted a series of tests from March 3 to March 24, 2024.

4.5 Site Selection

To ensure the reliability and validity of the research study, the researchers chose a site that was compatible and relevant to it.

Baslay, Dauin An Ideal Research Site

Figure 8. A map locating Baslay Hot Spring and Coffee Farm in Dauin.

Baslay is a barangay in the Municipality of Dauin, in the Province of Negros Oriental, has a geothermal manifestation that is advantageous to use as a heat source for drying, with a measured temperature of 63°C. Baslay, which is also well known for its superior coffee bean farming, will certainly help the researchers in conducting this study. These resources show that Baslay, Dauin is an ideal location for this kind of research, owing to the assistance of coffee beans farmed by farmers and renewable geothermal energy.

Site Evaluation Procedures

During site visits, the researchers assess the possible area for conducting the experiment. It includes measuring the temperature of the hot spring, evaluating pH levels, and identifying whether the area is accessible. These procedures determine the suitability of the area as the research site.

Figure 9. Geothermal Hot Spring in Baslay, Dauin

Moreover, the researchers conducted interviews and observations during the farm visit to gather relevant information to be considered in designing and fabricating the coffee bean dryer. It includes assessing the moisture content, drying time, temperature, method of drying, and coffee bean variety.

Availability of Coffee Beans

Since it is harvesting season, there is a supply of coffee beans at the plantation located in Baslay, Dauin. Coordination with BASHACO enables researchers to purchase coffee beans that are already peeled off their skin and ready to be dried.

Figure 10. Coffee farm located in Baslay, Dauin.

4.6 Variables and Measurement

Several variables can be identified along with corresponding measurements in this study, where the objectives involve designing a portable coffee bean dryer using geothermal heat and drying coffee beans at a specific temperature. These factors are essential for evaluating the impact and efficiency of the drying system based on geothermal energy.

Geothermal hot spring in Baslay, Dauin as one of the independent variables, researchers need to measure specifically its temperature which requires specialized tools designed to withstand high temperatures and provide accurate readings. In terms of the design specifications of the coffee bean dryer, measurements and records are made of the materials used, and other relevant factors during the design and building phases. Additionally, the quantity of coffee bean varieties will be considered. The transfer of heat from the pipes connected into the heat source to the copper tubes as heat exchanger inside the dryer needs to be determined. Also, the exhaust temperatures of the dryer. The specific types and features of the coffee bean, including its weight before and after it dries, and moisture content will be observed and measured.

However, as for the dependent variables, these are the drying times in hours or days required to achieve the desired moisture content in coffee beans. Further monitor and record the drying temperature inside the oven. Regarding the local conditions and characteristics, the ambient temperature of the study area in Baslay, Dauin, is a critical factor influencing the drying process. It can be assessed by constantly checking in during the study period. Besides temperature, relative humidity plays a significant role in the drying process. It affects the moisture content of the bean and the efficiency of the drying system.

This research uses a survey questionnaire to collect information about important aspects of designing and fabricating a coffee bean dryer that uses geothermal heat. The survey was made to check how well the dryer works and its ability to consistently dry coffee beans over 29 hours and measure the level of acceptability of the dried coffee beans produced. The survey has different parts to gather important details from participants. Below are the important details the researchers are looking at and how it is measured.

In this case, the independent variable is the "Design and Fabrication Evaluation". This variable focuses on evaluating the performance, efficiency and design of the coffee bean dryer. The respondents will be asked to provide a scale of ‘Excellent’ to ‘Poor’ feedback about the overall design, durability, and efficiency of the coffee bean dryer. The dependent variable is the “Level of Acceptability” of the dried coffee beans. The primary objective of this variable is to assess the level of acceptability of the respondents of the drying time and coffee beans after undergoing the drying process using the coffee bean dryer. Regarding the controlled variables, the researchers collected the age and gender of the respondents.

The researchers made a questionnaire answerable from "Not Acceptable" to "Complete Acceptable." This method allows the researchers to assess the respondents' acceptance of our dryer in terms of its drying ability and drying time.

For the respondents to have a clear understanding and legitimate feedback, the researchers showed and explained the dried coffee beans and dryer to them. The researchers analyzed their feedback and kept it safe because this feedback is important for the researchers to be able to give recommendations and conclusions.

4.7 Design Requirements and Consideration

Regarding design requirements and considerations, the researchers mainly focused on some aspects, such as temperature control and air vents. The researchers ensured the dryer would meet the recommended temperature for drying coffee beans, about 45 to 50 degrees. The researchers finalized these considerations because previous research stated, “Case Hardening may occur if it exceeds 50 degrees where this could damage coffee beans” (Hendrarsakti et.al., 2019).

The goal of the coffee bean dryer mainly focuses on mass reduction. It is important to notice the mass reduction caused by drying coffee beans along with the moisture content.

Also, an airway or air vent was considered to promote uniform drying and prevent moisture accumulation in some parts.

Lastly, a very important consideration is that the dryer should be easy to carry, compact, and easy to transport with a removable platform and removable stand for easy placement or relocation. Selecting quality materials that are cost-effective, but durable promotes the dryer's effectiveness and efficiency.

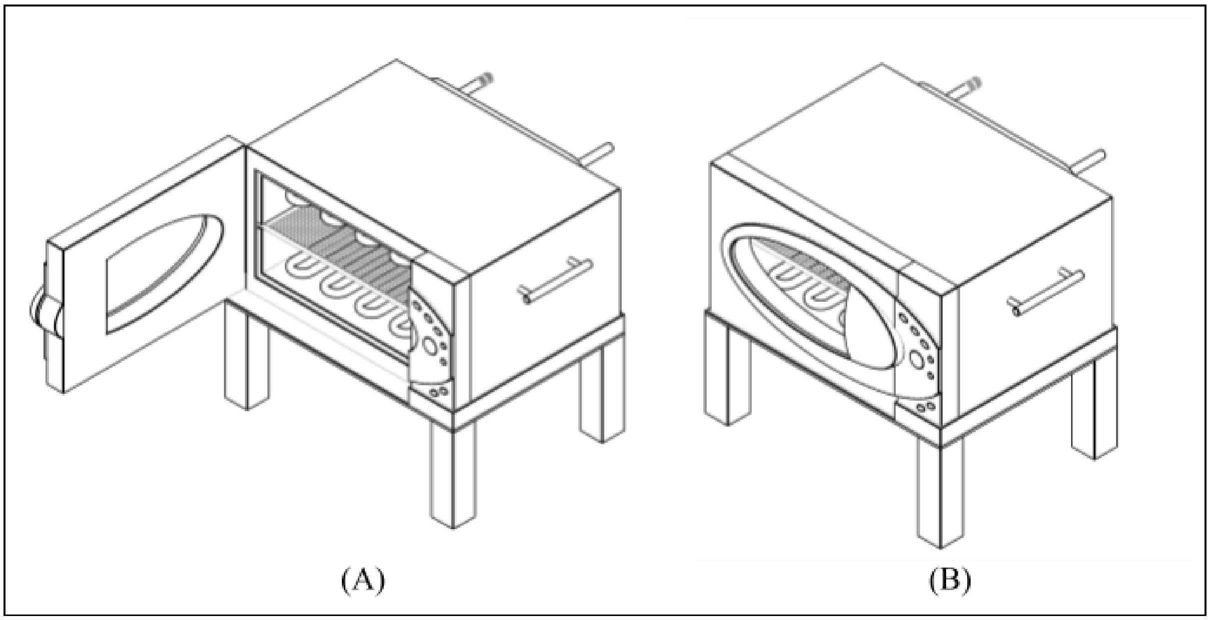


Figure 11. (A) Open Dryer Front Isometric View, (B) Closed Dryer Front Isometric View

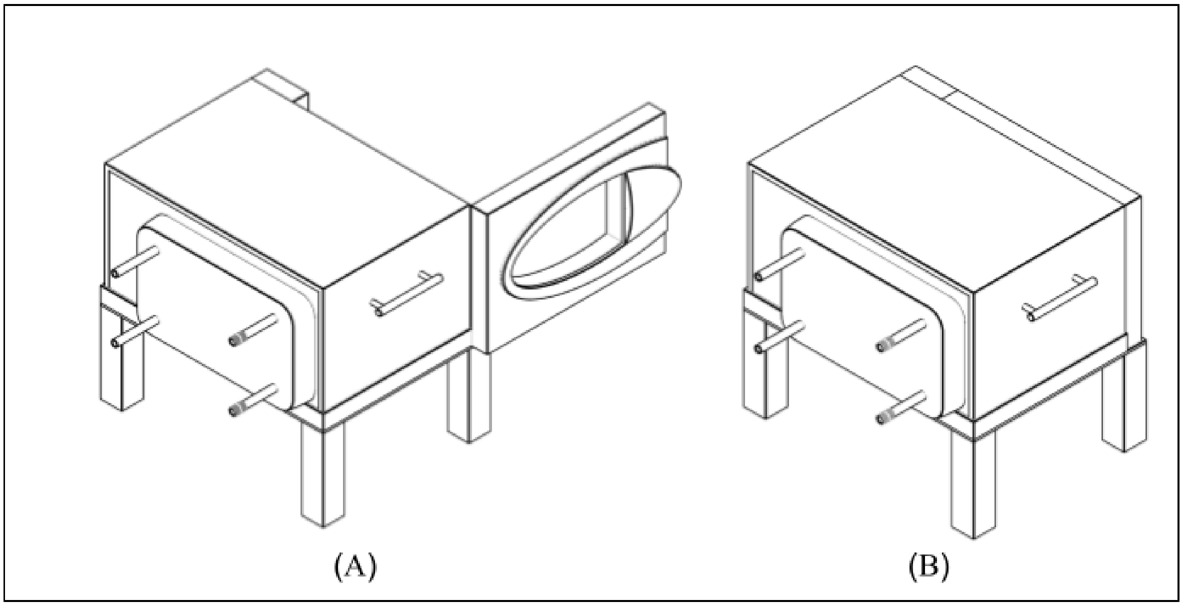


Figure 12. (A) Open Dryer Rear Isometric View, (B) Closed Dryer Rear Isometric View

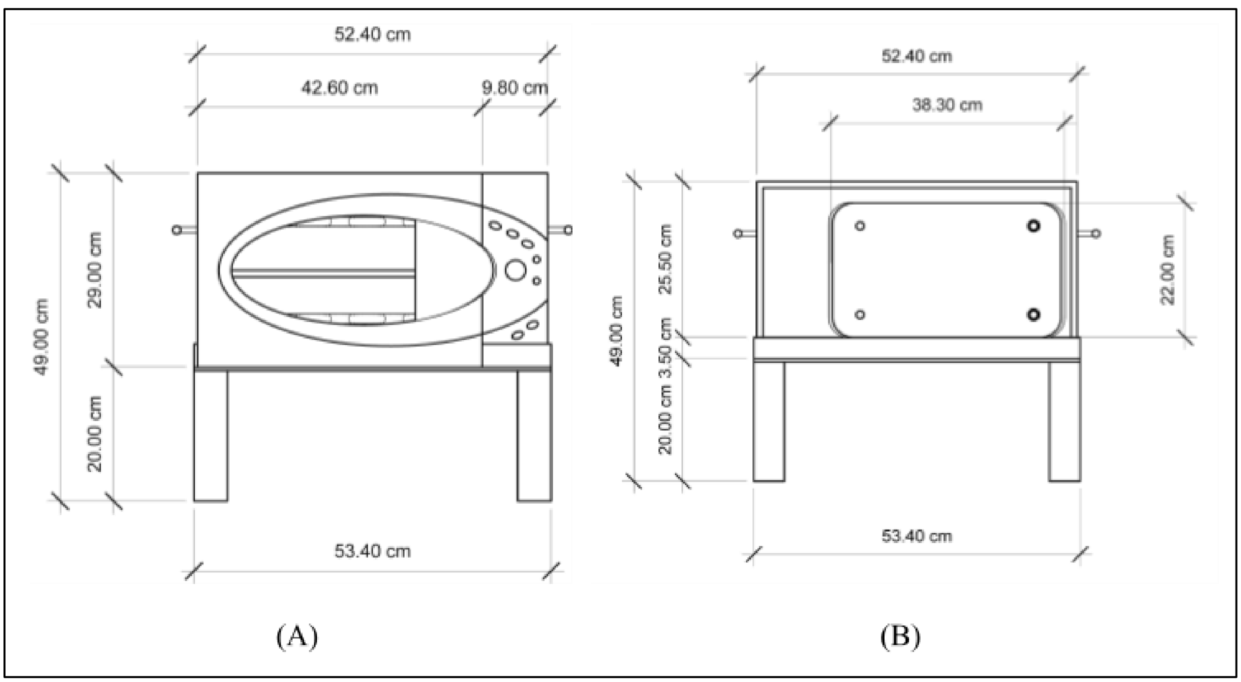
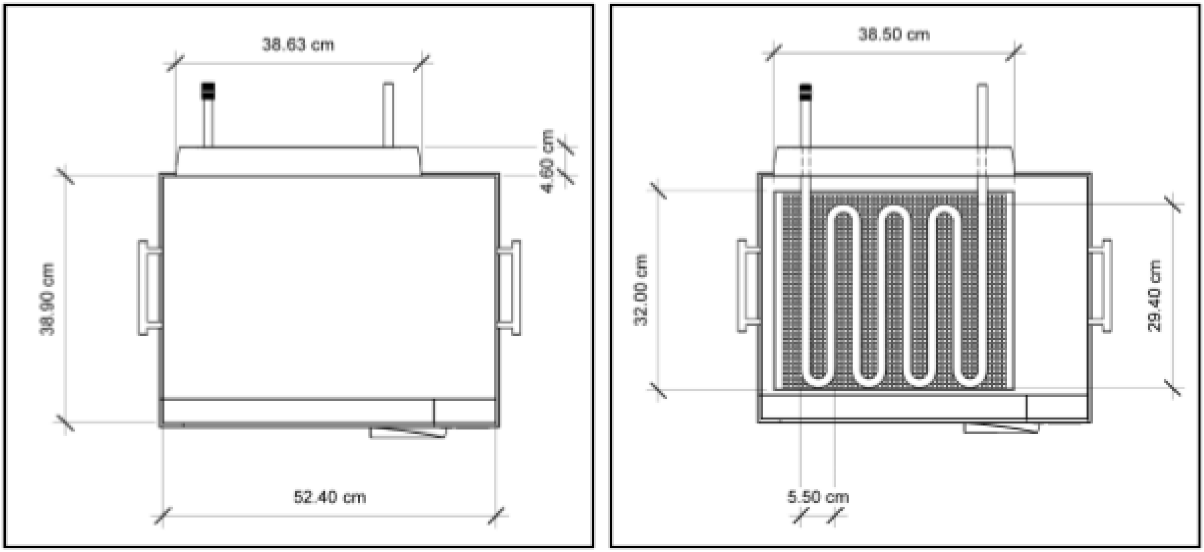
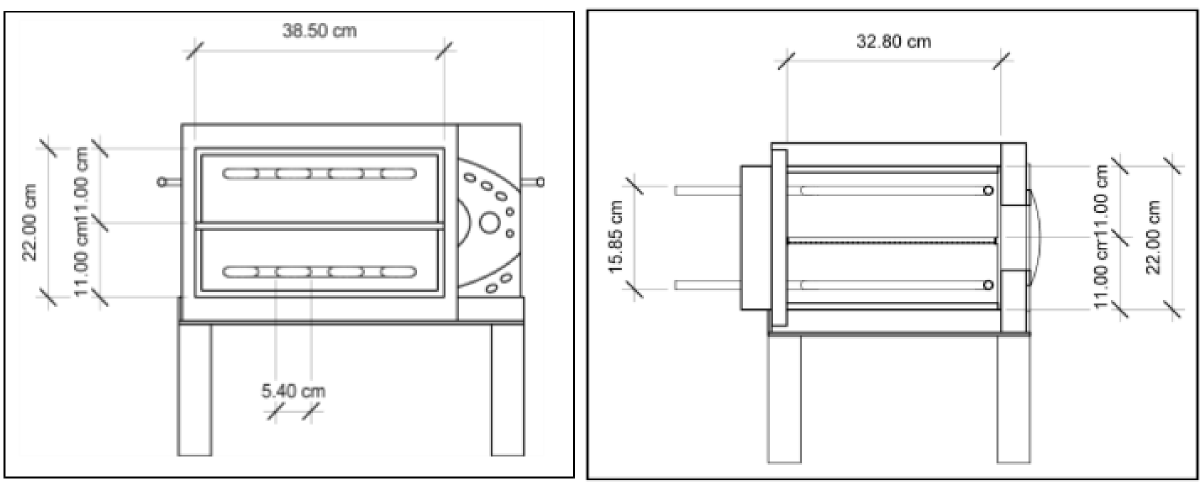


Figure 13. (A) Front view of the proposed coffee bean dryer, (B) Rear view of the proposed coffee bean dryer



(A) (B)

Figure 14. (A) Top view of the proposed coffee bean dryer, (B) Top view section of the proposed coffee bean dryer



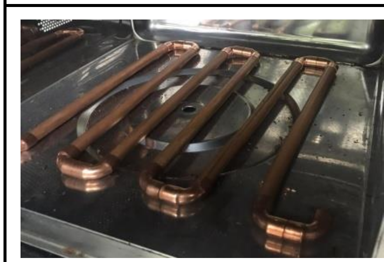
(A) (B)

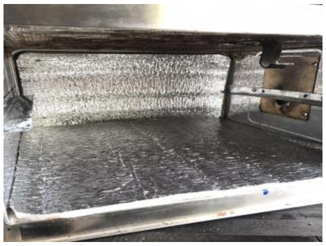
Figure 15. (A) Front view section of the proposed coffee bean dryer, (B) Left side view section of the proposed coffee bean dryer

4.8 Materials and Equipment

The development of the coffee bean dryer utilizing geothermal hot spring energy requires precise selection of materials and equipment to ensure effective heat capture and transfer. The researchers utilized the following materials and equipment to advance their research in constructing a coffee bean dryer powered by geothermal hot spring energy.

Table 1. A table showing the materials and equipment used in this research.

Illustration	Materials/Equipment	Function
	Hot and Cold Multiplex Pipe	These pipes transport the geothermal fluid to the copper heat exchanger tubes.
	Pipe Insulation Foam	The purpose of this pipe insulation foam is to reduce heat loss and maintain the heat being transferred.
	Pipe Fittings	Female pipe fittings secure and avoid leakage from both connections by connecting the pipe and the copper tubes.
	Copper Tubes	The copper tubes are formed into seven loops to serve as a heat exchanger, transferring heat within the dryer.

	Insulation Foam	Insulation foam maintains the dryers inside oven temperature consistent and reduces heat loss.
	Aluminum Tray	The aluminum tray is used as the heat-conductive surface, which helps the coffee beans be spread out evenly.
	Heat Resistant Spray Paint	The heat-resistant spray protects against high temperatures and prevents corrosion.
	Oven Thermometer	The oven thermometer in a coffee bean dryer accurately measures and monitors the internal temperature
	Weighing Scale	A weighing scale provides an accurate way to measure an object's mass or weight.

	Digital Thermometer	A digital thermometer will monitor the geothermal fluid's temperature at the source and at the upper and lower outlets.
	Gas Detector	A gas detector will be used to ensure that no harmful gases can harm the researchers.
	pH meter	A pH meter will be used to check the pH of the geothermal fluid, measuring its acidity and alkalinity.

4.9 Fabrication of the Dryer

Fabricating the coffee bean dryer involves various steps, such as designing, assembling, and constructing the equipment. Design specifications and factors are required and considered in creating the dryer, along with selecting materials that meet effectiveness and durability standards. The steps involved in fabricating the dryer are as follows:

1. Make the interior drying chamber using stainless steel and drill small circles at the side of this chamber, it will serve as an air vent to allow proper airflow.
2. Add another protective exterior to prevent water from getting inside the dryer; this is to balance air flow and heat loss.

3. In constructing the 7-loop heat exchanger positioned at the top and bottom of the dryer, 12 copper tubes of the same length, 26.5 cm, and four copper tubes, 29.5 cm long, were cut for the dryer's inlets and outlets.
4. Weld the cut copper tubes with an elbow to form a loop. Ensure it fits in the dryer.
5. Attach the insulation foam to reduce heat loss and maintain a consistent temperature within the dryer.
6. Trim the aluminum screen to create a tray where the coffee beans are spread out. Also, put a frame on it to guarantee it is stable and can endure the beans' weight.
7. Attach an angle bracket to support the tray within the dryer.
8. Drill a hole in the inlets and outlets of the dryer.
9. Create an easy-to-carry plywood platform with a detachable stand to place the coffee bean dryer on. This will help place the dryer on a sturdy surface.
10. Spray heat-resistant paint on its interior to protect from corrosion and the exterior to make it look presentable and to cover any rust.
11. Check each component for proper assembly, alignment, and functionality to ensure the overall readiness of the dryer.

A comprehensive inspection is conducted before installation at the research site to ensure the dryer is fully prepared for use. Each step in the fabrication process is performed carefully and pays attention to every detail, resulting in a thoroughly inspected and ready-to-use dryer.

Figure 16. Fabrication of the seven (7) Looped Copper Tubes

Figure 17. Application of the Insulation Foam and Aluminum Tray

4.10 Installation of the Dryer

After fabrication, the coffee bean dryer was installed at the assessed research site. During installation, it was necessary to ensure that the dryer was placed on a sturdy surface and safe area that could support its weight, particularly during the drying process. Also, to secure the dryer, it was positioned in an elevated area where the equipment is accessible to the geothermal water flow.

Figure 18. Installation of the fabricated coffee bean dryer

Furthermore, the researchers connected the insulated pipes from the source to the coffee bean dryer, ensuring the water flowed properly. Pipes are insulated to reduce heat loss and maintain consistent temperatures within the piping system. The final setup of the fabricated coffee bean dryer ensures all portions are securely connected and properly positioned, to effectively produce dried coffee beans that will achieve the moisture content required. The research location was surrounded by caution tape and signage to inform the locals and visitors that an experiment was underway. Also, a tarp was placed to notify the people that the researchers had coordinated and approved with the municipality mayor, barangay officials, and BASHACO to proceed with the research experiment.

Figure 19. Final setup of the fabricated coffee bean dryer

4.11 Experimentation of the Study

In this study, the researchers conducted a series of trials to evaluate the performance of the designed coffee bean dryer. The dryer was constructed to utilize geothermal heat from the local hot spring in Baslay, Dauin, Negros Oriental, with a maximum temperature of 63 °C, making it an energy-efficient solution for drying coffee beans. The experiment requires a power source as well as a prototype.

The researchers carried out five (5) trials, in which the first two trials had different specifications than the three consecutive trials. For the first trial, the researchers had a continuous mixing process at two-hour intervals on three occasions, followed by a resting period of 15 hours, and were remixed every 3 hours twice, and ultimately an hour twice during the second day, for 29 hours. The second trial resulted in an unsuccessful test due to bad weather conditions and a complete closure lasting for 29 hours. Overnight, heavy rainfall caused a malfunction in the pipeline that disrupted operations. The remaining three consecutive trials have the exact specifications in all aspects.

The following procedure was followed step by step during the experiment for the three consecutive trials:

1. Set up the coffee bean dryer near the geothermal source, ensuring a safe distance to avoid potential hazards.
2. Connect the pipes from the geothermal source to the coffee bean dryer and preheat the dryer for one hour.
3. Prepare the coffee beans, ensuring they are clean and free from debris.
4. Place the coffee beans within the dryer, evenly spreading across the drying tray to ensure uniform exposure to heat.
5. Place the oven thermometer inside the coffee bean dryer to monitor the temperature at various points.
6. Frequently monitor the flow of the geothermal water to ensure continuous running water and maintain optimal drying conditions.
7. After 5 hours, mix the coffee beans and put them back inside the dryer to continue the drying process.
8. The drying process continued until the coffee beans reached a target of 29 hours, suitable for storage and roasting.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Geothermal Water Characterization

The properties of geothermal water from the Baslay, Dauin hot spring, serving as the heat source, are examined to assess their suitability for utilization in Metro Dumaguete Water Laboratory.

Table 2. Physico-Chemical Analysis Result of the Geothermal Fluid in Baslay, Dauin

Parameter	Method	Result	Units of Measurement
pH	pH Meter	**3.3**	
Total Dissolved Solids	Gravimetry	**2,420**	mg/L
Acidity	Titration Method	**580**	As mg $CaCO_3$/L
Alkalinity	Titration Method	**Beyond Detection Range**	As mg $CaCO_3$/L
Chloride	Argentometry	**5.0**	mg/L
Practical Salinity	Electrical Conductivity	**2.60**	Practical Salinity Unit
Sulfate	Nephelometry	**384**	mg/L

Sample Description: Surface Water

Sample No./Location: 01 - Baslay, Dauin, Negros Oriental

Date and Time of Sampling: March 05, 2024 - 04:50 AM

Date and Time Received: March 05, 2024 - 11:43 AM

Date Analyzed: March 05 - 11, 2024

Sampling Point: Spring

Source of Sample: Spring, Untreated

5.2 Specifications of the Coffee Bean Dryer

The coffee bean dryer necessitates specific design specifications, including precise temperature regulation during the drying phase to prevent over-drying or under-drying of beans. It is crucial to monitor the mass reduction resulting from coffee drying, along with moisture content. Additionally, an efficient air vent is essential to ensure uniform drying and prevent moisture accumulation in some areas. The dryer's design should prioritize compactness and ease of transport, considering both its length and height for convenient observation. Material selection should prioritize suitability, durability, and cost-effectiveness to enhance the dryer's longevity.

(A) (B)

Figure 20. (A) Front Elevation of the Fabricated Coffee Bean Dryer, (B) Rear Elevation of the Fabricated Coffee Bean Dryer

(A) (B)

Figure 21. (A) A close look of the Fabricated Coffee Bean Dryer, (B) Aluminum tray of the Fabricated Coffee Bean Dryer

Figure 22. Left and Right Elevation of the Fabricated Coffee Bean Dryer

After one month of operation, observable corrosion has begun to manifest on the coffee bean dryer and the copper tubes. This corrosion is attributed to the various dissolved substances and other minerals. The presence of sulfides, especially hydrogen sulfide (H_2S), is a common cause of corrosion in materials. When these fluids come into direct contact with the oven and copper tubes, this can initiate corrosion processes, leading to the deterioration of the metal surface over time as clearly shown in the picture above.

5.3 Costs of the Fabrication

The following materials shown in the table are used to fabricate the coffee bean dryer. The researchers ensured the dryer would be cost-effective, reliable, and efficient while utilizing geothermal heat.

Table 3. Costs of the materials used in fabrication

Quantity	Unit	Material Description	Unit Price	Total Price
1x1	Meter	Aluminum Screen	Php 200.00	Php 200.00
8	Meter	¾ Unitec Pipe	Php 246.00	Php 1968.00
14	Feet	½" Copper Tube 28mm	Php 78.00	Php 1,092.00
4	Length (L=6.7 feet)	Rubber Insulation ¾"x½"	Php 122.00/length	Php 488.00
2	Pieces	Copper Female Socket Fitting 20mm x ¾"	Php 259.00	Php 518.00
2	Pieces	Flare Union ½"	Php 91.50	Php 183.00
2	Pieces	Flare Nut ½"	Php 80.00	Php 160.00
28	Pieces	Copper Tube Elbow ½"	Php 22.50	Php 620.00
1	Piece	Reducer ¾"x½"	Php 109.00	Php 109.00
1	Bottle	300 mL Contact Bond	Php 85.00	Php 85.00
1	Piece	Heat Resistant Pylox Spray Paint Silver	Php 246.00	Php 246.00
4	Pieces	Eveready Battery	Php 105.00	Php 105.00
1	Piece	Oven Thermometer	Php 210.00	Php 210.00
1	Piece	Digital Weighing Scale	Php 195.00	Php 195.00
1	Meter	Insulation Foam Single 10mm x 1m	Php 78.00	Php 78.00
Total Cost:				**Php 6,597.00**

5.4 Moisture Content Analysis

A moisture analyzer is an essential tool used to evaluate the moisture content of coffee beans. Its major function entails weighing a sample of the coffee beans before and after drying them using a controlled heating process. Given that they are made especially for such applications, it offers measurements that are highly precise and accurate.

Table 4. A table showing the data collected using the Moisture Analyzer

Trial	Weight, g	Time, min	Moisture Content
1	1.355	8.24	3.98%
2	1.271	21.12	15.62%
3	1.114	10.06	5.54%
4	1.261	15.0	7.40%
5	1.321	11.12	6.44%

Figure 23. 1st trial: 1.355 grams = 3.98%M = 08:24 min

Figure 24. 2nd trial: 1.271 grams = 15.62 % = 21.12 mins (FAILED)

Figure 25. 3rd trial: 1.123 grams = 5.54 %M = 10:06 min

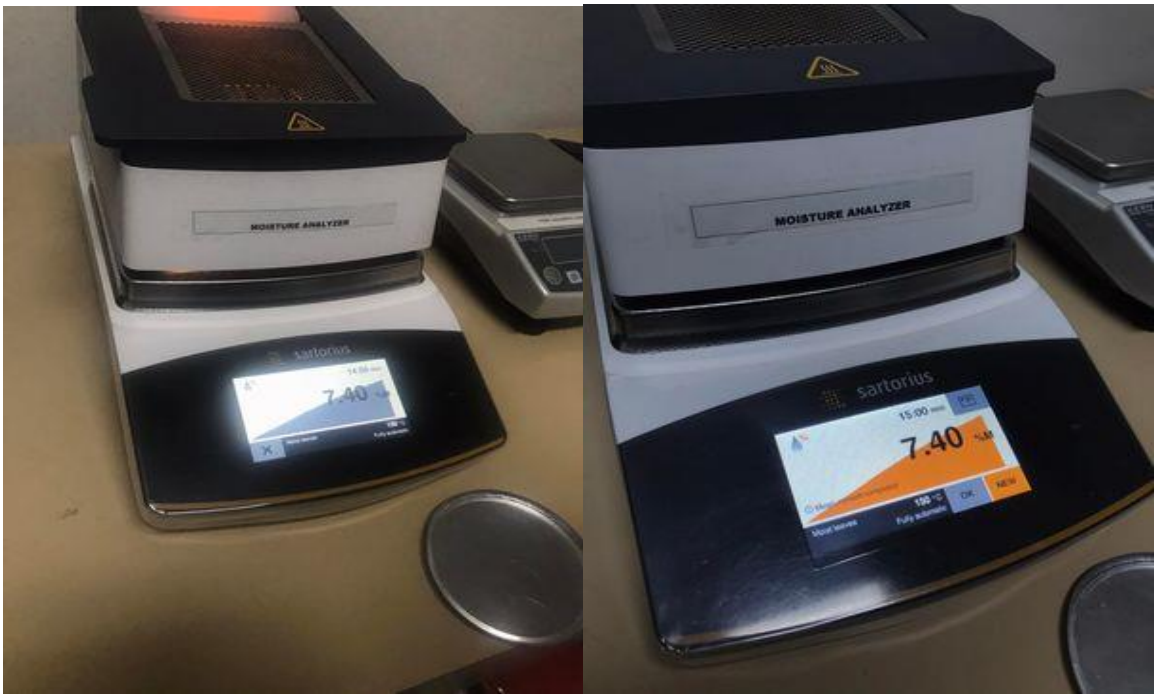


Figure 26. 4th trial: 1.261 grams = 7.40 % = 15.0 mins

Figure 27. 5th trial **=** 1.321 grams= 6.44 % = 11.12 mins

To find out if the required moisture content was reached, it is crucial to calculate the moisture content of the dried coffee beans.

Trial 1

Table 5. Trial No.1 Findings (March 3-4, 2024)

Time (In & Out)	Weight, g	Time, hr
10:00 am	500	0
10:33 am-12:33 pm	459	2
12:43 pm-2:43 pm	424	2
2:51 pm- 4:51 pm	402	2
5:00 pm- 8:00 am	297	15
8:20 am- 11:20 am	280	3
11:35 am- 2:35 pm	267	3
2:45 pm- 3:45 pm	265	1
3:50 pm- 4:50 pm	263	1
Total Time		**29**

Table 6. Trial No. 1 Temperature Findings with the Specific Time

Time (In & Out)	Temperature, ^{0}C				
	Source	Upper Outlet	Lower Outlet	Ambient	Oven
10:00 am	61	60	61	23	45
5:00 pm- 8:00 am	60	59	60	23	50
8:20 am- 11:20 am	61.5	61	61	23	49
2:45 pm- 3:45 pm	61	61	61	23	45
3:50 pm- 4:50 pm	61	61	61	23	45

Solving for the Moisture Content (After Drying)

Given: $\boldsymbol{MC_{initial}}$= 45%

$\boldsymbol{Weight\ Before\ Drying}$ = 462 g

$\boldsymbol{Weight\ After\ Drying}$ = 263 g

$$Weight\ Loss = Weight_{before\ drying} - Weight_{after\ drying}$$
$$Weight\ Loss = 462\ g - 263\ g$$
$$Weight\ Loss = 199\ g$$

$$\boldsymbol{\%\ Dry\ Matter_{Final}} = \left[\frac{(\mathbf{100\%} - \boldsymbol{MC\ initial})\ (\boldsymbol{Weight\ Before\ Drying})}{(\boldsymbol{Weight\ Before\ Drying} - \boldsymbol{Weight\ Loss})}\right]$$

$$\boldsymbol{\%\ Dry\ Matter_{Final}} = \left[\frac{(\mathbf{1-0.45})(\mathbf{462}\boldsymbol{g})}{(\mathbf{462}\boldsymbol{g} - \mathbf{199}\boldsymbol{g})}\right] \times \mathbf{100}$$

$\boldsymbol{\%\ Dry\ Matter_{Final}}$= 96.61%

$\boldsymbol{\%\ Moisture\ Content_{After\ Drying}}$= 100% - 96.61%

$\boldsymbol{\%\ Moisture\ Content_{After\ Drying}}$= **3.39%**

$$Moisture\ Loss = \left[\frac{\boldsymbol{Weight\ Loss}}{(\boldsymbol{WeightBefore\ Drying})\ (\boldsymbol{MC\ initial})}\right] \times \mathbf{100}$$

$$Moisture\ Loss = \left[\frac{\mathbf{199}\boldsymbol{g}}{(\mathbf{462}\ \boldsymbol{g})\ (\mathbf{0.45})}\right] \times \mathbf{100}$$

$Moisture\ Loss$ = 95.71%

Figure 28. The container has a weight of 50 grams, and the researchers have opted to dry 500 grams of coffee beans per trial. (March 3, 10:00 AM)

Figure 29. The weight of the coffee beans was recorded as having decreased from 459 grams to 424 grams (March 3, 12:33 PM)

Figure 30. The coffee beans were weighed and observed to have decreased from 424 grams to 402 grams (March 3, 2:43 PM)

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Figure 31. The coffee beans underwent weighing, revealing a reduction in weight from 402 grams to 297 grams. (4:51 PM)

Trial 2

Table 7. Trial No.2 Findings (March 9-10, 2024)

Time (In & Out)	**Temperature, ^{0}C**					**Weight, g**	**Time, hr**
	Source	**Upper Outlet**	**Lower Outlet**	**Ambient**	**Oven**		
11:20 am-4:20pm	63	62	62	18	45	303	29

Table 8 shows that due to inclement weather conditions with prolonged overcast skies and complete closure lasting for 29 hours, resulted in an unsuccessful testing. The pipeline experienced a malfunction due to heavy rainfall overnight, leading to operational disruption. This failure is evidenced by the decrease in weight from 500 grams to 303 grams, indicating an unsuccessful testing phase.

Solving for the Moisture Content (After Drying)

Given: $\boldsymbol{MC_{initial}}$= 45%
$\boldsymbol{Weight\ Before\ Drying}$ = 465 g
$\boldsymbol{Weight\ After\ Drying}$ = 303 g

$$Weight\ Loss = Weight_{before\ drying} - Weight_{after\ drying}$$
$$Weight\ Loss = 465\ g - 303\ g$$
$$Weight\ Loss = 162\ g$$

$$\boldsymbol{\%\ Dry\ Matter_{Final}} = \left[\frac{(\boldsymbol{100\% - MC\ initial})\ (\boldsymbol{Weight\ Before\ Drying})}{(\boldsymbol{Weight\ Before\ Drying - Weight\ Loss})}\right]$$

$$\boldsymbol{\%\ Dry\ Matter_{Final}} = \left[\frac{(\boldsymbol{1-0.45})(\boldsymbol{465g})}{(\boldsymbol{465g-162g})}\right] \times \boldsymbol{100}$$

$$\boldsymbol{\%\ Dry\ Matter_{Final}} = 84.40\%$$

$$\boldsymbol{\%\ Moisture\ Content_{After\ Drying}} = 100\% - 84.40\%$$
$$\boldsymbol{\%\ Moisture\ Content_{After\ Drying}} = \mathbf{15.60\%}$$

$$Moisture\ Loss = \left[\frac{\boldsymbol{Weight\ Loss}}{(\boldsymbol{WeightBefore\ Drying})\ (\boldsymbol{MC\ initial})}\right] \times \boldsymbol{100}$$

$$Moisture\ Loss = \left[\frac{\boldsymbol{162\ g}}{(\boldsymbol{465\ g})\ (\boldsymbol{0.45})}\right] \times \boldsymbol{100}$$

$$Moisture\ Loss = 77.41\%$$

Trial 3

Table 8. Trial No.3 Findings (March 16-17, 2024)

Time (In & Out)	Temperature, ºC					Weight, g	Time, hr
	Source	Upper Outlet	Lower Outlet	Ambient	Oven		
9:55 am-3:00 pm	61	60	61	22	46	262	29

The coffee bean dryer was preheated for one hour prior to the insertion of the coffee beans and the table shows that subsequently, after five hours of drying, the beans underwent a brief mixing period of five minutes before being reinserted into the dryer for continued processing. This process resulted in a reduction in weight from 500 grams to 262 grams.

Figure 32. Dried Coffee Beans from 500 grams to 262 grams.

Solving for the Moisture Content (After Drying)

Given: $\boldsymbol{MC_{initial}}$= 45%

$\boldsymbol{Weight\ Before\ Drying}$ = 450 g

$\boldsymbol{Weight\ After\ Drying}$ = 262 g

$$Weight\ Loss = Weight_{before\ drying} - Weight_{after\ drying}$$
$$Weight\ Loss = 450\ g - 262\ g$$
$$Weight\ Loss = 188\ g$$

$$\boldsymbol{\%\ Dry\ Matter_{Final}} = \left[\frac{(\mathbf{100\% - MC\ initial})\ (\boldsymbol{Weight\ Before\ Drying})}{(\boldsymbol{Weight\ Before\ Drying - Weight\ Loss})}\right]$$

$$\boldsymbol{\%\ Dry\ Matter_{Final}} = \left[\frac{(\mathbf{1-0.45})(\mathbf{450}\boldsymbol{g})}{(\mathbf{450}\boldsymbol{g}-\mathbf{188}\boldsymbol{g})}\right]$$

$\boldsymbol{\%\ Dry\ Matter_{Final}}$= 94.46%

$\boldsymbol{\%\ Moisture\ Content_{After\ Drying}}$= 100% - 94.46%

$\boldsymbol{\%\ Moisture\ Content_{After\ Drying}}$= **5.53%**

$$Moisture\ Loss = \left[\frac{\boldsymbol{Weight\ Loss}}{(\boldsymbol{WeightBefore\ Drying})\ (\boldsymbol{MC\ initial})}\right] \times \mathbf{100}$$

$$Moisture\ Loss = \left[\frac{\mathbf{188}\ \boldsymbol{g}}{(\mathbf{450}\ \boldsymbol{g})\ (\mathbf{0.45})}\right] \times \mathbf{100}$$

$Moisture\ Loss$ =92.83%

Trial 4

Table 9. Trial No.4 Findings (March 18-19, 2024)

Time (In & Out)	Temperature, ^{0}C					Weight, g	Time, hr
	Source	Upper Outlet	Lower Outlet	Ambient	Oven		
9:25 am-2:30 pm	61	61	61	22	47	265	29

On March 15th, the researchers acquired a total of 1.5 kilograms of coffee beans after harvesting. Following this, on March 16th, a batch comprising 500 grams of beans was selected for immediate drying, while the rest of the beans were stored in refrigeration for subsequent drying scheduled on March 18th. It is worth noting that on this day, the coffee beans underwent a washing process using water due to the emission of an unpleasant odor. Post-drying, the weight of the beans decreased from the initial 500 grams to 265 grams.

Figure 33. Dried Coffee Beans from 500 grams to 265 grams.

Solving for the Moisture Content (After Drying)

Given: $\boldsymbol{MC_{initial}}$= 45%

$\boldsymbol{Weight\ Before\ Drying}$ = 447 g

$\boldsymbol{Weight\ After\ Drying}$ = 265 g

$Weight\ Loss = Weight_{before\ drying} - Weight_{after\ drying}$

$Weight\ Loss = 447\ g - 265\ g$

$Weight\ Loss = 182\ g$

$\boldsymbol{\%\ Dry\ Matter_{Final}} = \left[\frac{(\boldsymbol{100\%-MC\ initial})\ (\boldsymbol{Weight\ Before\ Drying})}{(\boldsymbol{Weight\ Before\ Drying-Weight\ Loss})}\right]$

$\boldsymbol{\%\ Dry\ Matter_{Final}} = \left[\frac{(\boldsymbol{1-0.45})(\boldsymbol{447g})}{(\boldsymbol{447g-182g})}\right]$

$\boldsymbol{\%\ Dry\ Matter_{Final}}$= 92.77%

$\boldsymbol{\%\ Moisture\ Content_{After\ Drying}}$=100% - 92.77%

$\boldsymbol{\%\ Moisture\ Content_{After\ Drying}} = \mathbf{7.23\%}$

$Moisture\ Loss = \left[\frac{\boldsymbol{Weight\ Loss}}{(\boldsymbol{Weight\ Before\ Drying})\ (\boldsymbol{MC\ initial})}\right] \times \mathbf{100}$

$Moisture\ Loss = \left[\frac{\boldsymbol{182\ g}}{(\ \boldsymbol{447\ g})\ (\boldsymbol{0.45})}\right] \times \mathbf{100}$

$Moisture\ Loss$ = 90.47%

Trial 5

Table 10. Trial No.5 Findings (March 23-24, 2024)

Time (In & Out)	Temperature, ℃					Weight, g	Time, hr
	Source	Upper Outlet	Lower Outlet	Ambient	Oven		
11:20 am-4:25 pm	62	61	61	24	46	238	29

The dryer was preheated for one hour before the insertion of the coffee beans. Subsequently, following a five-hour drying period, the beans underwent a brief mixing interval of five minutes before being reinserted into the dryer for continued processing. As a result of this processing, the initial weight of 500 grams decreased to 238 grams.

Figure 34. Dried Coffee Beans from 500 grams to 238 grams

Solving for the Moisture Content (After Drying)

Given: $\boldsymbol{MC_{initial}}$= 45%
$\boldsymbol{Weight\ Before\ Drying}$ = 406 g
$\boldsymbol{Weight\ After\ Drying}$ = 238 g

$Weight\ Loss = Weight_{before\ drying} - Weight_{after\ drying}$
$Weight\ Loss = 406\ g - 238\ g$
$Weight\ Loss = 168\ g$

$\boldsymbol{\%\ Dry\ Matter_{Final}}= \left[\frac{\boldsymbol{(100\% - MC\ initial)\ (Weight\ Before\ Drying)}}{\boldsymbol{(Weight\ Before\ Drying - Weight\ Loss)}}\right]$

$\boldsymbol{\%\ Dry\ Matter_{Final}}= \left[\frac{\boldsymbol{(1-0.45)(406g)}}{\boldsymbol{(406g-168g)}}\right]$

$\boldsymbol{\%\ Dry\ Matter_{Final}}$= 93.43%

$\boldsymbol{\%\ Moisture\ Content_{After\ Drying}}$= 100% - 93.43%
$\boldsymbol{\%\ Moisture\ Content_{After\ Drying}}$= **6.57%**

$Moisture\ Loss = \left[\frac{\boldsymbol{Weight\ Loss}}{\boldsymbol{(Weight\ Before\ Drying)\ (MC\ initial)}}\right] \times \mathbf{100}$

$Moisture\ Loss = \left[\frac{\boldsymbol{168\ g}}{\boldsymbol{(\ 406\ g)\ (0.45)}}\right] \times \mathbf{100}$

$Moisture\ Loss$ = 91.40%

5.5 Moisture Content (After Drying)

Table 11. A table illustrating the collected and analyzed data based on the Moisture Content (After Drying)

Trial	% Dry Matter (Final)	% Moisture Content (After Drying)	% Moisture Loss
1	95.98	4.02	94.89
2	84.40	15.60	77.4
3	94.46	5.53	92.83
4	92.77	7.23	90.47
5	93.43	6.57	91.40

The researchers used a moisture analyzer and a formula to assess the moisture content of coffee beans. The moisture analyzer provides a more accurate and precise method, while the formula offers a manual approach. Both methods yielded similar results, but the moisture analyzer's results were more accurate.

5.6 Flow Rate

The researchers used a 1000 mL measuring cup to measure the flow rate by timing the water filling from the upper and lower outlets, making it easy to measure the flow rate.

Solving for Flow Rate (Upper Outlet)

Given: Volume = 1000 mL

Time = 22.39 seconds

Flow Rate $= \frac{Volume}{Time}$

Flow Rate $= \frac{1000\,mL\,(0.00001\,m^3/mL)}{22.39\,seconds}$

Flow Rate $= \frac{0.01m^3}{22.39\,s}$

Flow Rate $= 0.00004466$ m^3/s or 0.0446 L/s

Solving for Flow Rate (Lower Outlet)

Given: Volume = 1000 mL

Time = 18. 7 seconds

Flow Rate $= \frac{Volume}{Time}$

Flow Rate $= \frac{1000\,mL\,(0.00001\,m^3/mL)}{18.7\,seconds}$

Flow Rate $= \frac{0.01\,m^3}{18.7\,s}$

Flow Rate $= 0.00005347$ m^3/s or 0.05347 L/s

5.7 Heat Transfer Rate of the Copper Tubes

This study calculates energy transfer when the dryer operates with steady-state heat flow. The heat flow is determined by calculation. The air outside the heat exchanger is assumed to flow convectively into the dryer from the geothermal source through the loops of copper tubes.

The heat transfer process involves both conduction and convection. Through conduction, the geothermal water transfers its heat into the copper tubes inside walls.

$$q_r = \frac{2\pi Lk\,(T_1 - T_2)}{ln(\frac{r_2}{r_1})}$$

However, the movement of water within the tubes involves convective heat transfer. The vent in the dryer helps reduce humidity by allowing moist air to escape, ensuring that the drying process is efficient. In this case, the heat from the copper tubes is transferred to the air inside the dryer by convection and this heated air helps to dry the coffee beans. The moisture from the beans is then evaporated into the air.

$$q_r = \frac{(T_1 - T_2)}{\frac{1}{2\pi r_1 L h_1} + \frac{ln(r_2/r_1)}{2\pi L k} + \frac{1}{2\pi r_2 L h_2}}$$

Where q_r = rate of heat transfer (W)
r = pipe radius (m)
L = copper tube length (m)
T = temperature (K)
k = thermal conductivity (W/m-K)
h = convection heat transfer coefficient (W/m^2-K)

Given:

T_{source}= 63°C+273.15=336.15K
T_{oven}= 48°C+273.15=321.15K
r_1= 0.00635m
r_2= 0.014m
L= 2.18m
k= 400 W/m-K
h_1= 50 W/m^2-K
h_2= 25 W/m^2-K

$$q_r = \frac{(T_{source} - T_{oven})}{\frac{1}{2\pi r_1 L h_1} + \frac{ln(r_2/r_1)}{2\pi L k} + \frac{1}{2\pi r_2 L h_2}}$$

$$q_r = \frac{(336.15K - 321.15K)}{\frac{1}{2\pi(0.00635m)(2.18m)(50\,W/m^2-K)} + \frac{ln(0.014m)/0.00635m)}{2\pi(2.18m)(400\ W/m-K)} + \frac{1}{2\pi(0.014m)(2.18m)(25\,W/m^2-K)}}$$

$$q_r = \frac{15K}{\frac{1}{4.34890671\,W/K} + \frac{0.7906025167}{5478.937588\,W/K} + \frac{1}{4.794070389\,W/K}}$$

q_r= *34.19363291* W

The calculated rate of heat transfer from the source into the copper tubes is 34.19363291 W, which means that the geothermal water source in Baslay, Dauin, is sufficient to dry the coffee beans.

5.8 Log Mean Temperature Difference

In this study, the average heat or energy produced within the loops of copper tubes is determined using the log mean temperature difference method. This solves the nonlinear temperature changes across the heat exchanger from the entrance to the exit.

$$\Delta T_{LM} = \frac{[(Tin - T_{dF}) - (Tout - T_{di})]}{ln(\frac{Tin - T_{dF}}{Tout - T_{di}})}$$

where Tin = inlet temperature to the copper tube
$Tout$ = outlet temperature to the copper tube
T_{di}= average initial dryer temperature
T_{dF}= average final dryer temperature

$$\Delta T_{LM} = \frac{(63°C - 46.4\ °C) - (62°C - 0°C)}{ln(\frac{63°C - 46.4\ °C}{62°C - 0°C})}$$

ΔT_{LM}= 34.45°C

The calculated average heat produced within the copper tubes is 34.45°C, which is a sufficient temperature for drying coffee beans.

5.9 Calculation of Time

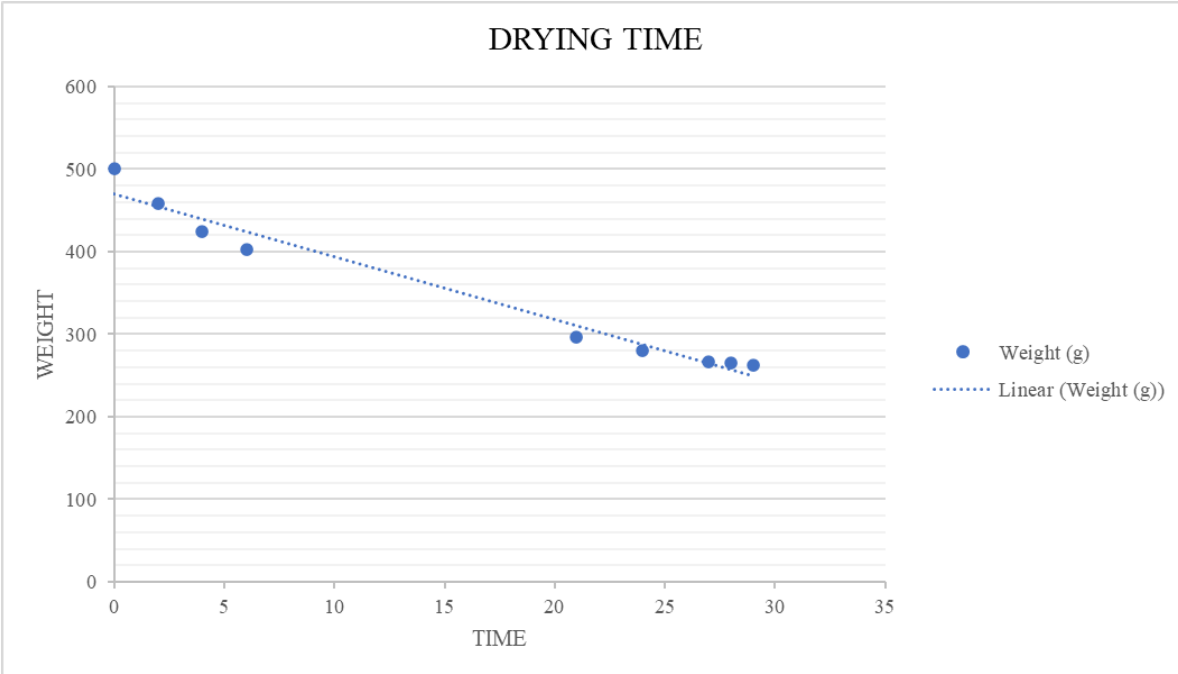

Figure 35. Calculation of Drying Time

The figure above shows the calculation of time. This is shown to identify the exact time at which we can achieve 13.5% moisture content. Hence, within the 29 hours of drying coffee beans, the ideal moisture content can be achieved between 21 and 24 hours.

5.10 Regression Analysis

Table 12. Drying Time, Moisture Content and Weight of Sample

Weight, g	Drying Time, hr	Moisture Content *	Moisture Content **
500	0	0.4949348	97.99423916
459	2	0.449820044	81.75871155
424	4	0.404404245	67.89911481
402	6	0.371809453	59.18736828
297	21	0.149721886	17.60857806
280	24	0.098097857	10.87677393
267	27	0.054185019	5.728923711
265	28	0.047046792	4.936946755
263	29	0.0398	4.144969798

*wet basis
**dry basis

This table contains data results from what the researchers solved. It describes the relationship between the three variables, such as the drying time, the coffee bean's weight, and the amount of moisture removed.

Table 13. Regression Analysis Summary Output

Regression Summary Values	
Multiple R	0.998577765
R Square	0.997157554
Adjusted R Square	0.99675149
Standard Error	0.010912546
Observation	9

This table presents the summary output of the regression analysis used to predict the moisture content of coffee beans. Multiple R which has a value of 0.998577765 measures the strength of the relationship between the observed and predicted values. R Square which is 0.997157554 indicates how well the data fits the model. It means about 99.71% of the variability content can be explained by the figure.

Independent Variable: x axis, Drying Time

Dependent Variable: y axis, Moisture Content

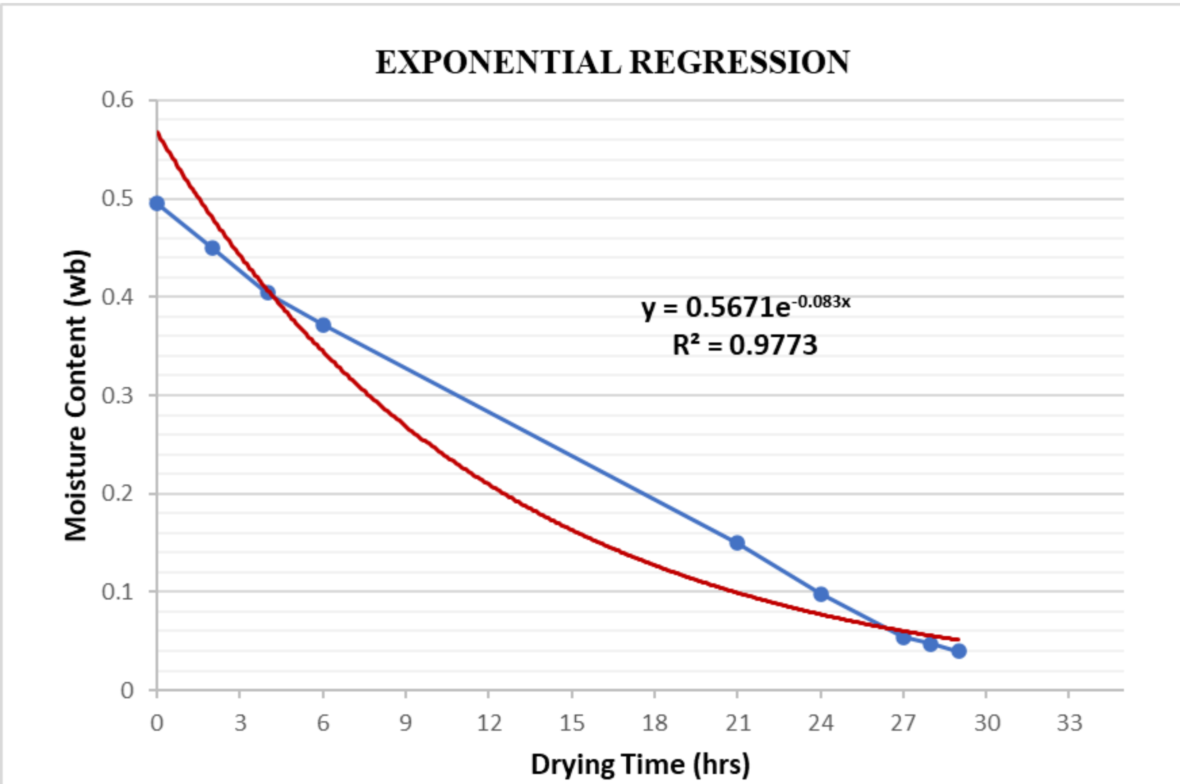

Figure 36. Exponential Regression

An exponential regression plot is used to show the relationship between the dependent variable y which is the moisture content and the independent variable x which is the drying time in hours. The blue line represents the observed values of moisture content, however the predicted moisture content values of dried coffee beans as the red line.

Therefore, the exponential curve indicates that the moisture content of the beans drops exponentially with increasing drying time.

Table 14. Residual Output

Observation	Observed Moisture Content *	Predicted Moisture Content *	Residuals
1	0.4949348	0.477177018	0.017757782
2	0.449820044	0.446187329	0.003632715
3	0.404404245	0.41519764	-0.010793395
4	0.371809453	0.384207951	-0.012398498
5	0.149721886	0.151785285	-0.002063399
6	0.098097857	0.105300751	-0.007202894
7	0.054185019	0.058816218	-0.004631199
8	0.047046792	0.043321374	0.003725419
9	0.0398	0.027826529	0.011973471

*wet basis

This table presents the analyzed residual output. In this study, the residual differentiates the observed and predicted values of the moisture content on a wet basis. Observed values of moisture content are from the data gathered during the experiment; meanwhile, predicted moisture content comes from regression analysis. It indicates a good fit when the residual values are small and randomly distributed. However, large residuals suggest that the model may not adequately capture the underlying relationship.

Hence, in this study, since the residual values are equivalent to zero, then the predicted moisture content is the best fit based on the data observed in the experiment. The ideal moisture content, 13.5%, of dried coffee beans from BASHACO is achieved after drying for around 21 to 24 hours.

5.11 Average Temperature Data

Table 15. Average temperature data of the source, inside the dryer, upper and lower exhausts, and ambient in every trial

Trial	Source, °C	Dryer, °C	Exhaust, °C		Ambient, °C
			Upper	Lower	
1	61	46	60	61	23
2	63	48	62	62	18
3	61	46	60	61	22
4	61	47	61	61	22
5	62	46	61	61	24
Average	**62**	**47**	**61**	**61**	**22**

This table presents the average temperature of the geothermal hot spring which suggests that it is a good source for drying coffee beans. Furthermore, the dryer's average temperature shows the constant drying temperature achieved within the equipment. Monitoring also the upper and lower exhaust temperature of the dryer reveals that it has less heat loss during the drying process, while considering the ambient temperature as a factor affecting the drying procedure throughout the experiment.

5.12 Research Respondents

A total of 47 respondents were able to answer the survey questionnaire. 35 of the respondents are from Baslay Highlands Agriculture Cooperative (BASHACO), 6 respondents are engineers and architects from the University Engineer's Office and another 6 respondents are mechanical and electronic instructors from College of Industrial Technology (CIT).

Table 16. Summary of Feedback from the respondents (Level of Acceptability)

No.	1	2	3	4	5
1	0	0	3	21	14
2	0	0	3	20	12
3	0	0	5	20	10
4	0	0	5	15	15
5	0	0	4	15	16

The researchers asked the respondents to evaluate their level of acceptance of this dryer. Wherein '1-Unacceptable' is the lowest rating and '5-Completely Acceptable' is the highest rating. In table 16, a summary of feedback from the respondents' point of view are shown, this analysis shows that the evaluated questions are generally well received, indicating a high level of acceptability regarding the dryer's ability to complete its drying cycle within 29 hours and of course as well as its ability to dry the coffee beans. On the second set of questionnaires, the researchers asked the respondents to assess the dryer and rate the dryer from "Excellent" to "Poor." Each row represents a different survey instance, with counts of responses for each rating.

Table 17. Summary of Feedback from the respondents (Engineer's Office)

No.	Excellent	Good	Fair	Poor
1	6	0	0	0
2	5	1	0	0
3	5	1	0	0
4	4	2	0	0
5	6	0	0	0
6	5	1	0	0
7	5	1	0	0

In table 17 shown above, most of the respondents answered “Excellent”, while some answered “Good”. Therefore, based on the feedback from engineers and architects, the design and fabrication of the dryer met its desirable design and fabrication. However, the “Good” responses indicate that there is still room for improvement.

Table 18. Summary of Feedback from the respondents (CIT Instructors)

No.	Excellent	Good	Fair	Poor
1	3	3	0	0
2	3	3	0	0
3	4	2	0	0
4	4	2	0	0
5	3	3	0	0
6	3	3	0	0
7	2	4	0	0

In table 18, the responses of ‘Excellent’ and ‘Good’ are relatively balanced. This indicates that the instructors have mixed opinions about the dryer’s design and fabrication. The mixed opinions highlight that, although the dryer’s design and fabrication are generally well-received, further enhancements could improve its overall design.

Therefore, the majority of ratings are either ‘Excellent’ or ‘Good’, suggesting general satisfaction with the design and fabrication. Some gave ‘Fair’ ratings indication that most items exceed expectations. Note that the survey questionnaire is found in Appendices on page 96.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In this study, the researchers intended to examine the effectiveness of the designed coffee bean dryer by drying coffee beans. Consequently, four out of five trials have effectively dried the coffee beans, based on the data acquired. Take note that poor weather was the primary reason why one trial failed. Disregarding the failed trial, the four trials successfully dried the coffee beans, with a result of 3.98% in the first trial, 15.62% in the second, 5.54% in the third, 7.40% in the fourth, and 6.44% in the last trial. The last three consecutive trials used the same procedure for the drying process, which was 29 hours.

Therefore, the researchers concluded that the ideal moisture content of dried coffee beans of BASHACO, which is 13.5%, is achieved after drying for around 21 to 24 hours. Hence, the dryer is effective. The feedback received from respondents, shown in the respondents' section, supports and justifies the effectiveness of the design and fabrication of the dryer as well as the level of its acceptability among the respondents. The survey results showed that most respondents are satisfied with the coffee bean dryer's design and performance. However, areas for improvement, such as durability and scalability, exist.

6.2 Recommendations

The following outlines essential recommendations for enhancing the design and operation of the coffee bean dryer: This section presents critical recommendations for optimizing the coffee bean dryer’s design and operation. Addressing factors such as drying time, temperature control, and energy efficiency, the following suggestions are crucial to improving the overall performance of the coffee bean dryer.

- The researchers recommend that a continuous mixing process be conducted for every batch of the drying process. According to the data gathered, the coffee beans that were mixed several times had a quicker reduction of moisture content in 29 hours. The findings support the recommendation of constant mixing to ensure faster, uniform drying, and consistent moisture reduction of the coffee beans.
- The researchers recommend using fresh, newly harvested coffee beans. They strictly advise not refrigerating the coffee beans and refraining from washing them with water before drying.
- The researchers recommend that the dryer be secured in the upper portion to prevent water from the geothermal fluid or rainwater from entering it.
- The researchers recommend constructing a drying chamber and placing the coffee bean dryer inside it so that sulfuric air will not directly contact the beans.
- The researchers recommend utilizing geothermal heat sources and hybrid coffee bean drying that uses solar to have a more efficient and shorter drying time with lower moisture content.
- The researchers recommend designing and fabricating coffee bean dryers on a larger scale. Utilizing dryers and heat exchangers of bigger sizes will achieve greater scalability and production.
- The researchers recommend designing a portable stand for the portable coffee bean dryer that is easily removed or attached so that it can be easily relocated to another location. This would help the researchers have a suitable location regarding geothermal heat sources and terrain conditions.

- Lastly, the researchers recommend that it is best to use materials that do not easily corrode. This enhances durability and efficiency, ensuring a longer operational life span and reducing the need for replacements.

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APPENDICES

Appendix A

Special Permit from the Municipal Mayor of Dauin, Negros Oriental to Conduct the Research

Republic of the Philippines
Province of Negros Oriental
Municipality of Dauin
OFFICE OF THE MAYOR
Telephone No. (035) 527-9733
Email: lgudauin@yahoo.com

SPECIAL PERMIT

To Whom it May Concern:

Special Permit is hereby granted to the **4th Year Students of Negros Oriental State University (NORSU) taking up Bachelor of Science in Geothermal Engineering** represented by Ellyn Mae A. Bernaldez, Jessel A. Orito, Ronalyn Duhaylungsod and Cheri Mae Tinguban, to conduct their study entitled "Design and Fabrication of Coffee Bean Dryer Utilizing Geothermal Heat in Baslay, Dauin" per the attached letter request, provided that the Research Advisor will supervise during the conduct of the activity and that they shall coordinate with the Municipal LDRRM unit for assistance. Provided further that a copy of the research study shall be furnished to this office in due course.

Violations on any of the above guidelines will be a ground for revocation of this permit and implementation of penalties and other disciplinary actions.

ISSUED this **22nd** day of **January 2024** at **Dauin, Negros Oriental, Philippines**.

GALICANO A. TRUITA
Municipal Mayor

Amount Paid: ₱165.00
O.R. No. 7806073
Date Paid: 1/22/24

Appendix B

Permission Letter to the Municipal Mayor of Dauin, Negros Oriental to Conduct the Research

R.A. 9299 **Republic of the Philippines** June 25, 2004
NEGROS ORIENTAL STATE UNIVERSITY
NOHS (1907) I NOTS (1927) I EVSAT (1956) I CVPC (1983)
Kagawasan Ave., Dumaguete City, Negros Oriental, Philippines 6200
COLLEGE OF ENGINEERING AND ARCHITECTURE
Main Campus II, Bajumpandan, Dumaguete City 6200

January 11, 2023

HON. GALICANO A. TRUITA
Municipal Mayor
Dauin, Negros Oriental

Sir:

Greetings!

We, the 4th year students taking up Bachelor of Science in Geothermal Engineering of Negros Oriental State University would like to ask permission to conduct our study entitled **"Design and Fabrication of Coffee Bean Dryer Utilizing Geothermal Heat in Baslay, Dauin"**. The purpose of the study is to design and fabricate a Coffee Bean Dryer that is feasible, efficient, and cost-effective. Also, the researchers aim that the study would help the cooperative/community in drying coffee faster, easier, and more efficiently while utilizing the geothermal resource in the locality. Rest assured that our research activities will not disrupt the location site and that we will adhere to all safety and security protocols mandated by the area.

Here are the specific activities we intend to do in the area:

1. Visit the site in Baslay, Dauin Hot Spring on January 22, 2024, Monday at 7:00 am to check the parameters including the pH, temperature, and accessibility of the area.
2. Visit the Coffee farm to determine the moisture content of the coffee bean and the type/variety of coffee they have on January 22, 2024, Monday at 1:00 pm.
3. Install the prototype designed Coffee Bean Dryer to the site located at Baslay, Dauin Hot Spring on March 24, 2024, Sunday at 7:00 am.
4. Visit the area once the fabricated Coffee Bean Dryer is installed to monitor moisture content of the coffee beans on March 25 -28, Monday to Thursday at 7:00 am.

We would be happy to speak with you in person and provide you with further information about our project study. Thank you and more power!

ELLYN MAE A. BERNALDEZ
Researcher
+639559446426|bernaldez.ellynmae.a@gmail.com

JESSEL A. ORITO
Researcher
+639927217863|orito.jessel.a@gmail.com

RONALYN B. DUHAYLUNGSOD
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+639076002198|duhaylungsod.ronalyn.b@gmail.com

CHERI MAE E. TINGUBAN
Researcher
+639066574550|tinguban.cherimae.e@gmail.com

Noted by:

ENGR. LEIZL M. HONCULADA, M.Eng.
Research Adviser

ENGR. ANGEL M. HONCULADA, M.Eng.
Chairman, Geothermal Engineering

ENGR. JOSEF VIL S. VILLANUEVA, Ph. D.
Dean, College of Engineering and Architecture

Approved by,

Permission Letter to the Barangay Captain of Baslay, Dauin to Conduct the Research

R.A. 9299 **Republic of the Philippines** June 25, 2004
NEGROS ORIENTAL STATE UNIVERSITY
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Kagawasan Ave., Dumaguete City, Negros Oriental, Philippines 6200
COLLEGE OF ENGINEERING AND ARCHITECTURE
Main Campus II, Bajumpandan, Dumaguete City 6200

January 11, 2023

HON. FELIX DAYOT
Barangay Captain
Baslay, Dauin, Negros Oriental

Sir:

Greetings!

We, the 4th year students taking up Bachelor of Science in Geothermal Engineering of Negros Oriental State University would like to ask permission to conduct our study entitled **"Design and Fabrication of Coffee Bean Dryer Utilizing Geothermal Heat in Baslay, Dauin"**. The purpose of the study is to design and fabricate a Coffee Bean Dryer that is feasible, efficient, and cost-effective. Also, the researchers aim that the study would help the cooperative/community in drying coffee faster, easier, and more efficiently while utilizing the geothermal resource in the locality. Rest assured that our research activities will not disrupt the location site and that we will adhere to all safety and security protocols mandated by the area.

Here are the specific activities we intend to do in the area:

1. Visit the site in Baslay, Dauin Hot Spring on January 22, 2024, Monday at 7:00 am to check the parameters including the pH, temperature, and accessibility of the area.
2. Visit the Coffee farm to determine the moisture content of the coffee bean and the type/variety of coffee they have on January 22, 2024, Monday at 1:00 pm.
3. Install the prototype designed Coffee Bean Dryer to the site located at Baslay, Dauin Hot Spring on March 24, 2024, Sunday at 7:00 am.
4. Visit the area once the fabricated Coffee Bean Dryer is installed to monitor moisture content of the coffee beans on March 25 -28, Monday to Thursday at 7:00 am.

We would be happy to speak with you in person and provide you with further information about our project study. Thank you and more power!

ELLYN MAE A. BERNALDEZ
Researcher
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CHERI MAE E. TINGUBAN
Researcher
+639066574550|tinguban.cherimae.e@gmail.com

Noted by:

ENGR. LEIZL M. HONCULADA, M.Eng.
Research Adviser

ENGR. ANGEL M. HONCULADA, M.Eng.
Chairman, Geothermal Engineering

ENGR. JOSEF WILL S. VILLANUEVA, Ph. D.
Dean, College of Engineering and Architecture

Approved by:

HON. FELIX DAYOT
Barangay Captain
Baslay, Dauin, Negros Oriental

Permission Letter to the Chairman of Baslay Highland Agriculture Cooperative (BASHACO) to Conduct the Research

R.A. 9299 Republic of the Philippines June 25, 2004
NEGROS ORIENTAL STATE UNIVERSITY
NOHS (1907) I NOTS (1927) I EVSAT (1956) I CVPC (1983)
Kagawasan Ave., Dumaguete City, Negros Oriental, Philippines 6200
COLLEGE OF ENGINEERING AND ARCHITECTURE
Main Campus II, Bajumpandan, Dumaguete City 6200

February 11, 2023

FORESTER RUEL INOJALDO PEREZ, MSc.
Chairman, Baslay Highland Agriculture Cooperative (BASHACO)
Baslay, Dauin, Negros Oriental

Sir:

Greetings!

We, the 4th year students taking up Bachelor of Science in Geothermal Engineering of Negros Oriental State University would like to ask permission to conduct our study entitled **"Design and Fabrication of Coffee Bean Dryer Utilizing Geothermal Heat in Baslay, Dauin"**. The purpose of the study is to design and fabricate a Coffee Bean Dryer that is feasible, efficient, and cost-effective. Also, the researchers aim that the study would help the cooperative/community in drying coffee faster, easier, and more efficiently while utilizing the geothermal resource in the locality. Rest assured that our research activities will not disrupt the location site and that we will adhere to all safety and security protocols mandated by the area.

Here are the specific activities we intend to do in the area:

1. Install the prototype designed Coffee Bean Dryer to the site located at Baslay, Dauin Hot Spring
2. Visit the area once the fabricated Coffee Bean Dryer is installed to monitor moisture content of the coffee beans

Additionally, in line with this, the researchers would like to express our interest in purchasing two (2) kilograms of your undried and newly harvested coffee beans.

We look forward to the possibility of establishing a fruitful collaboration with your esteemed coffee establishment. Further assistance and guidance from your organization is deeply appreciated. We will be waiting patiently for your response. Thank you and more power!

ELLYN MAE A. BERNALDEZ
Researcher
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Researcher
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Noted by:

ENGR. LEIZL M. HONCULADA, M.Eng.
Research Adviser

ENGR. ANGEL M. HONCULADA, M.Eng.
Chairman, Geothermal Engineering

ENGR. JOSEF NOEL S. VILLANUEVA, Ph. D.
Dean, College of Engineering and Architecture

Approved by,

FORESTER RUEL INOJALDO PEREZ, MSc.
Chairman, Baslay Highland Agriculture Cooperative (BASHACO)
Baslay, Dauin, Negros Oriental

Request Letter to Baslay Highland Agriculture Cooperative (BASHACO) to Conduct a Survey Questionnaire

Republic of the Philippines
NEGROS ORIENTAL STATE UNIVERSITY
BACHELOR OF SCIENCE IN GEOTHERMAL ENGINEERING
COLLEGE OF ENGINEERING AND ARCHITECTURE
Main Campus II, Bajumpandan, Dumaguete City 6200

May 2024

Baslay Highland Agriculture Cooperative (BASHACO)
Baslay, Dauin, Negros Oriental

Greetings,

We are 4th year Geothermal Engineering Students, we are currently conducting a research study exploring the possibility of using geothermal heat to dry coffee beans in Baslay, Dauin. Our goal is to examine how tapping into geothermal energy could possibly help transform the way coffee beans are dried in Baslay, offering a sustainable solution that supports wider efforts towards sustainability and efficient resource use.

For this research questionnaire, the researchers selected the members and farmers of the Baslay Cooperative as our respondents. Your participation in this questionnaire will provide valuable insights that may contribute to the development of environmentally friendly coffee bean drying methods, benefiting both the coffee industry and the environment. Thank you for your participation.

Researchers,

ELLYN MAE A. BERNALDEZ
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JESSEL A. ORITO
Researcher
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CHERI MAE E. TINGUBAN
Researcher
+639066574550|tinguban.cherimae.e@gmail.com

Request Letter to the Negros Oriental State University (NORSU) Engineer's Office to Conduct a Survey Questionnaire

Republic of the Philippines
NEGROS ORIENTAL STATE UNIVERSITY
BACHELOR OF SCIENCE IN GEOTHERMAL ENGINEERING
COLLEGE OF ENGINEERING AND ARCHITECTURE
Main Campus II, Bajumpandan, Dumaguete City 6200

June 2024

ENGR. CHRISTOPHER B. PATRIMONIO
University Engineer, Negros Oriental State University (NORSU)
Dumaguete City, Negros Oriental

Greetings,

We are 4th year Geothermal Engineering Students, we are currently conducting a research study exploring the possibility of using geothermal heat to dry coffee beans in Baslay, Dauin. Our goal is to examine how tapping into geothermal energy could possibly help transform the way coffee beans are dried in Baslay, offering a sustainable solution that supports wider efforts towards sustainability and efficient resource use.

For this research questionnaire, the researchers selected the members of the Engineer's Office of Negros Oriental State University as our respondents to examine the effectiveness of our dryer. Your participation in this questionnaire will provide valuable insights that may contribute to the development of coffee bean drying methods, benefiting both the coffee industry and the environment. Thank you for your participation.

Researchers,

ELLYN MAE A. BERNALDEZ
Researcher
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JESSEL A. ORITO
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CHERI MAE E. TINGUBAN
Researcher
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Approved by:

ENGR. CHRISTOPHER B. PATRIMONIO
University Engineer, Negros Oriental State University (NORSU)
Dumaguete City, Negros Oriental

Request Letter to the Dean of the College of Industrial Technology to Conduct a Survey Questionnaire

Republic of the Philippines
NEGROS ORIENTAL STATE UNIVERSITY
BACHELOR OF SCIENCE IN GEOTHERMAL ENGINEERING
COLLEGE OF ENGINEERING AND ARCHITECTURE
Main Campus II, Bajumpandan, Dumaguete City 6200

June 2024

DR. HERMINIO S. TINGUBAN
Dean, College of Industrial Technology
Negros Oriental State University (NORSU)

Greetings,

We are 4th year Geothermal Engineering Students, we are currently conducting a research study exploring the possibility of using geothermal heat to dry coffee beans in Baslay, Dauin. Our goal is to examine how tapping into geothermal energy could possibly help transform the way coffee beans are dried in Baslay, offering a sustainable solution that supports wider efforts towards sustainability and efficient resource use.

For this research questionnaire, the researchers selected the instructors of the College of Industrial Technology of Negros Oriental State University as our respondents to examine the effectiveness of our dryer. Your participation in this questionnaire will provide valuable insights that may contribute to the development of coffee bean drying methods, benefiting both the coffee industry and the environment. Thank you for your participation.

Researchers,

ELLYN MAE A. BERNALDEZ
Researcher
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JESSEL A. ORITO
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Approved by:

DR. HERMINIO S. TINGUBAN
Dean, College of Industrial Technology
Negros Oriental State University (NORSU)

Request Letter to Metro Dumaguete Water (MDW)

R.A. 9299 **Republic of the Philippines** June 25, 2004
NEGROS ORIENTAL STATE UNIVERSITY
NOHS (1907) I NOTS (1927) I EVSAT (1956) I CVPC (1983)
Kagawasan Ave., Dumaguete City, Negros Oriental, Philippines 6200
COLLEGE OF ENGINEERING AND ARCHITECTURE
Main Campus II, Bajumpandan, Dumaguete City 6200

February 6, 2023

Metro Dumaguete Water
DCWS Bldng., Diego Dela Vina St.
Dumaguete City, Philippines 6200

Ma'am/Sir:

Good day!!

We, the 4th year Geothermal Engineering students from Negros Oriental State University, are currently engaged in a research project entitled **"Design and Fabrication of Coffee Bean Dryer Utilizing Geothermal Heat in Baslay, Dauin".**

As part of our study, we kindly request your assistance in conducting tests on the geothermal water's chemical components. We would also like to inquire about the laboratory's sample collection requirements.

Here are the specific chemical content we would like to be tested:

1. Salinity
2. TDS
3. Density
4. Silica Content
5. Chloride Content
6. CO2 Concentration

Additionally, further assistance and guidance from your organization is deeply appreciated. We will be waiting patiently for your response. Thank you and more power!

Researchers,

E.bernaldez
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Researcher
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CHERI MAE E. TINGUBAN
Researcher
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Certification Letter Given to the General Manager of Baslay Highland Agriculture Cooperative (BASHACO)

R.A. 9299 Republic of the Philippines June 25, 2004
NEGROS ORIENTAL STATE UNIVERSITY
NOHS (1907) I NOTS (1927) I EVSAT (1956) I CVPC (1983)
Kagawasan Ave., Dumaguete City, Negros Oriental, Philippines 6200
COLLEGE OF ENGINEERING AND ARCHITECTURE
Main Campus II, Bajumpandan, Dumaguete City 6200

May 2024

MR. NOEL INOVINO ALIABO
General Manager, Baslay Highland Agriculture Cooperative (BASHACO)
Baslay, Dauin, Negros Oriental

To Whom It May Concern,

Subject: Certification of Coffee Beans Dryness Inspection

We hereby certify that Mr. Noel Inovino Aliabo, the General Manager of BASHACO, has conducted a thorough inspection of the dryness of coffee beans on these specified dates given: March 4, 10, 17, 19 and 24 of 2024. Mr. Aliabo's expertise in coffee bean quality assessment and his position within BASHACO make him highly qualified to perform such inspections.

During the inspection, Mr. Aliabo employed industry-standard methods and protocols to evaluate the dryness levels of the coffee beans. His meticulous attention to detail ensured that the beans met the required standards of dryness.

Based on Mr. Aliabo's assessment, we can confirm that the coffee beans inspected on these specific dates met the specified dryness criteria and are suitable for the intended purposes.

Enclosed herewith is the certified record of the data collected, bearing the signature of Mr. Noel Inovino Aliao, acquired during his examination of the coffee beans.

Sincerely,

E.bernaldez
ELLYN MAE A. BERNALDEZ
Researcher
+639559446426|bernaldez.ellynmae.a@gmail.com

JESSEL A. ORITO
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CHERI MAE E. TINGUBAN
Researcher
+639066574550|tinguban.cherimae.e@gmail.com

Noted by:

ENGR. LEIZL M. HONCULADA, M.Eng.
Research Adviser

MR. NOEL INOVINO ALIABO
General Manager, Baslay Highland Agriculture Cooperative (BASHACO)
Baslay, Dauin, Negros Oriental

Appendix C

Data Gathered of the Coffee Bean Drying signed by the General Manager of Baslay Dauin Agriculture Cooperative (BASHACO)

R.A. 9299 Republic of the Philippines June 25, 2004
NEGROS ORIENTAL STATE UNIVERSITY
NOHS (1907) I NOTS (1927) I EVSAT (1956) I CVPC (1983)
Kagawasan Ave., Dumaguete City, Negros Oriental, Philippines 6200
COLLEGE OF ENGINEERING AND ARCHITECTURE
Main Campus II, Bajumpandan, Dumaguete City 6200

Research Title: **"DESIGN AND FABRICATION OF COFFEE BEAN DRYER UTILIZING GEOTHERMAL HEAT IN BASLAY, DAUIN"**

Table 1. Data Gathered of the Coffee Bean Drying

Trial No.	Date	Time Dried	Notes	Moisture Content Loss	Status
1	March 4, 2024	29 hrs	The mixture was hand mixed every two hours on three occasions, followed by a closure period of 15 hours. Subsequently, it was mixed again every three hours twice, and finally, every hour twice. 500 grams = 263 grams	47.4%	Dry
2	March 10, 2024	29 hrs	Due to inclement weather conditions with prolonged overcast skies and complete closure lasting for 29 hours, the operation was unsuccessful. The pipeline ceased functioning due to heavy rainfall overnight. 500 grams = 303 grams	39.4 %	Semi Dry Shells, Semi Wet Beans
3	March 17, 2024	29 hrs	The dryer was preheated for one hour prior to the insertion of the coffee beans. After five hours of drying, the beans were briefly mixed for five minutes before being returned to the dryer for further processing. 500 grams = 262 grams	47.6 %	Dry
4	March 19, 2024	29 hrs	The coffee beans were harvested on March 15th, a total of 1.5 kilograms of beans were acquired by researchers. Subsequently, 500 grams were subjected to drying on March 16th, while the remaining portion was refrigerated for later drying in the dryer on March 18th. Make note that the coffee beans were washed with water on this day due to the emission of an undesirable odor. 500 grams = 265 grams	47%	Dry
5	March 24, 2024	29 hrs	The dryer was preheated for one hour prior to the insertion of the coffee beans. After five hours of drying, the beans were briefly mixed for five minutes before being returned to the dryer for further processing. 500 grams = 239 grams	52.2%	Dry

Noted by:

MR. NOEL INOVINO ALIABO
General Manager, Baslay Highland Agriculture Cooperative (BASHACO)
Baslay, Dauin, Negros Oriental

Physico-chemical Analysis Result from Metro Dumaguete Water (MDW)

Metro Dumaguete Water
A Metro Pacific Water Company

Date: March 11, 2024
Code: PCA-COM-240305-0019
RAW No.: 2024-0129

Name: **Jessel A. Orito**
Address: Dumaguete City
Contact Number: 0939 001 0970 / 0992 721 7863
Sample Description: Surface Water
Sample No./Location: 01 – Baslay Dauin Negros Oriental
Date and Time of Sampling: March 05, 2024 – 04:50 A.M.
Date and Time Received: March 05, 2024 – 11:43 A.M.
Date Analyzed: March 05 - 11, 2024
Sampling Point: Spring
Source of Sample: Spring, Untreated

PHYSICO-CHEMICAL ANALYSIS RESULT

PARAMETER	METHOD	RESULT	UNITS OF MEASUREMENT
Total Dissolved Solids	Gravimetry	**2,420**	mg/L
Acidity	Titration Method	**580**	as mg $CaCO_3$/L
Alkalinity	Titration Method	**Beyond Detection Range**	as mg $CaCO_3$/L
Chloride	Argentometry	**5.0**	mg/L
Practical Salinity	Electrical Conductivity	**2.60**	Practical Salinity Unit
Sulfate	Nephelometry	**384**	mg/L

NOTE:
The results given in this report were obtained at the time of the test and refer only to the sample received.

REFERENCES:
ᶠPhilippine National Standards for Drinking Water (PNSDW), 2017.
Standard Methods for the Examination of Water and Wastewater, 23rd ed., APHA Washington D.C

Analyzed by:
Hara Elloiza T. Cataylo, RChT
Chemical Analyst
PRC. Lic. No. 0002139

Certified by:
Camille Marie Cabrera, RCh, M. S.
Laboratory Head/ Chemist
PRC Reg. 0011045

DCWD Office Building, Diego de la Vina Road,
Brgy. Daro, Dumaguete City, Negros Oriental, Philippines 6200
www.dgtwater.com
info@dgtwater.com

Moisture Content Results from Innovation and Technology Support Office (ITSO)

RA 9299 — Republic of the Philippines — June 25, 2004

NEGROS ORIENTAL STATE UNIVERSITY

NOPS (1907) NOTS (1927) EVSAT (1968) CVPC (1983)

Kagawasan Avenue. Dumaguete City, Negros Oriental, Philippines 6200

Phone: (63) (35) 225-9400 Fax: 225-4751 Email: president office@norsu.edu.ph www.norsu.edu.ph

GCL — ISO 9001 — 18Q19869

Innovation and Technology Support Office

Research Innovation Laboratory Testing Center

ANALYTICAL LABORATORY TEST REPORT

VISION

A dynamic, competitive and globally responsible state university.

MISSION

The University shall provide excellent instruction, relevant and responsive research and extension services, and quality-assured production through competent and highly motivated human capital.

QUALITY POLICY

Negros Oriental State University commits itself to provide quality instruction, research, extension services and production as well as to comply with applicable regulatory requirements and continual improvement of its management system.

Physico Chemical Test	Microbiological Test	Mechanical Test
☐ pH	☐ XSA	☐ UTM
☐ Temperature	☐ PA	☐ Torsion
☐ °Brix	☐ TC	☐ Fatigue
☐ Water Activity	☐ EC	☐ Creep
☐ Salinity	☐ ETB	☐ Hardness
☐ Turbidity	☐ YMR	
☐ Conductivity	☐ BC	
☐ Dissolved Oxygen	☐ SL	
■ Percent Moisture	☐ LS	
☐ TDS	☐ AQ	
☐ Shelf Life	☐ VP	
☐ UV-VIS		
☐ HPLC		
☐ FTIR		
☐ GC		
☐ TGA		

TEST REPORT

Company: **NORSU CEA Students**

Recipient: **Cheri Mae E. Tinguban**

Recipient Email: -

Quantity Submitted: **5 Samples**

Testing Period: **April 18, 2024**

Test Report Number: **0005**

Date of Issue: **May 16, 2024**

Pages: **2**

Date Received: **April 18, 2024**

Items highlighted above are the tests conducted as per client's request. Test result is attached on the succeeding page.

JOHANN HEINRICH P. MALONGO, M.E., LL.B., Ph.D.
Director, ITSO
Negros Oriental State University
Dumaguete City

This Laboratory Testing Center is for Research, Innovation and Development for faculty, students, researchers, and MSMEs. It is currently onboard for the second surveillance audit of ISO 9001:2015 under GCL International.

Research Innovation Laboratory Testing Center
Mechatronics Building, NORSU-Main Campus 1
South Kagawasan Avenue, Capitol Area
Dumaguete City, Negros Oriental
norsurideo@gmail.com
522-5050 loc 1025

Page 1 of 2

Moisture Content Results from Innovation and Technology Support Office (ITSO)

RA 9299 Republic of the Philippines June 25, 2004

NEGROS ORIENTAL STATE UNIVERSITY

NOPS (1907) NOTS (1927) EVSAT (1968) CVPC (1983)

Kagawasan Avenue, Dumaguete City, Negros Oriental, Philippines 6200

Phone: (63) (35) 225-9400 Fax: 225-4751 Email: president.office@norsu.edu.ph www.norsu.edu.ph

18Q19869

Innovation and Technology Support Office

Research Innovation Laboratory Testing Center

VISION

A dynamic, competitive and globally responsible state university.

MISSION

The University shall provide excellent instruction, relevant and responsive research and extension services, and quality-assured production through competent and highly motivated human capital.

QUALITY POLICY

Negros Oriental State University commits itself to provide quality instruction, research, extension services and production as well as to comply with applicable regulatory requirements and continual improvement of its management system.

Percent Moisture

Sample	Description	Result (% M)
1	*Coffee Beans*	3.98
2	*Coffee Beans*	15.62
3	*Coffee Beans*	5.54
4	*Coffee Beans*	7.40
5	*Coffee Beans*	6.44

Reference: SARTORIUS MOISTURE ANALYZER
Model: MA160
CSA Group Compliance Certificate no. 70006866

Certified by: LOUIE B. CABILIN
Registered Chemical Technician, PRC 0010182

Approved by: JOHANN HEINRICH P. MAMONGO, M.E., LL.B., Ph.D.
Director, ITSO
Negros Oriental State University
Dumaguete City

Page 2 of 2

Appendix D

Documentation

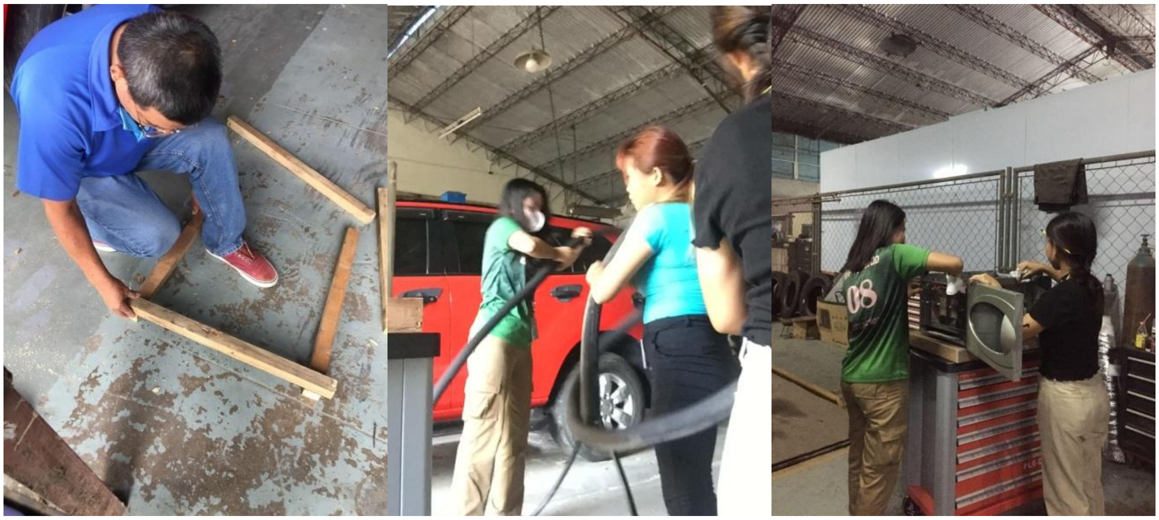
Purpose: Site Visits
Date: January 31, 2024, Wednesday, 10:33 AM

Purpose: Site Visits
Date: February 11, 2024. Sunday, 2:39 PM

Purpose: Fabrication of the dryer
Date: February 28, 2024, Wednesday, 3:29 PM

Purpose: Fabrication of the dryer
Date: February 29, 2024, Thursday, 3:22 PM

Purpose: Fabrication of the dryer
Date: March 1, 2024, Friday, 10:09 AM



Purpose: Installation of the constructed dryer
Date: March 2, 2024, Saturday, 11:29 AM

Purpose: 1st Trial of drying the coffee beans
Date: March 3, 2024, Sunday, 10:13 AM

Drying the coffee beans using tissue paper to reduce the moisture content derived from freshly peeled cherry coffee beans. 10:14 AM

Organizing the pipes to facilitate continuous flow of geothermal fluid. 10:14 AM

Purpose: 2nd Trial
Date: March 9, 2024, Saturday

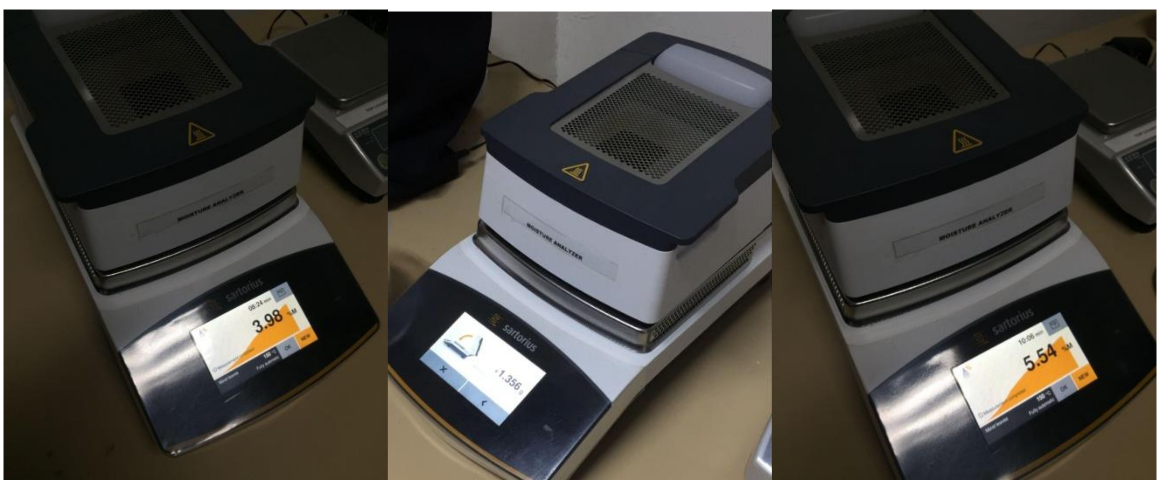
Date: March 10, 2024, Sunday

Purpose: 3rd Trial
Date: March 16, 2024, 3:03 PM

Purpose: 4th Trial
Date: March 19, 2024, Friday

Purpose: Removal of the dryer
Date: March 24, 2024, Sunday

Purpose: Moisture content testing using the Moisture Content Analyzer at NORSU ITSO
Date: April 18, 2024, 1:43 PM



Appendix E

Survey Questionnaire (Level of Acceptability) from BASHACO

Republic of the Philippines
NEGROS ORIENTAL STATE UNIVERSITY
BACHELOR OF SCIENCE IN GEOTHERMAL ENGINEERING
COLLEGE OF ENGINEERING AND ARCHITECTURE
Main Campus II, Bajumpandan, Dumaguete City 6200

Research Questionnaire

Name (Optional): Annabelle Age: ______ Sex: F

Level of Acceptability

Directions: Please carefully read the questions and write a check (✔) to indicate what you think about each one.

Note: 1 - Unacceptable
2 - Somewhat Acceptable
3 - Acceptable
4 - Very Acceptable
5 - Completely Acceptable

Questions	1	2	3	4	5
1. How would you rate the dryness of the coffee beans achieved using the geothermal heat coffee bean dryer?					✔
2. How satisfied are you with the consistent performance of our coffee bean dryer when drying small batches of coffee beans?				✔	
3. Are you satisfied with the 29-hour drying time for the coffee beans?					✔
4. How effective do you find our coffee bean dryer in preventing over-drying?				✔	
5. If utilized, what is your level of acceptability in using geothermal heat as the heat source in drying coffee beans?				✔	

Additional Feedback:

Survey Questionnaire (Design and Fabrication) from College of Industrial Technology (CIT)

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COLLEGE OF ENGINEERING AND ARCHITECTURE
Main Campus II, Bajumpandan, Dumaguete City 6200

Research Questionnaire

Name: JUNAR AMAPO Age: 53 Sex: M

I. Design and Fabrication Evaluation

Directions: Please read the questions and indicate your opinion by placing a check (✓) next to the appropriate response for each one.

Attached below is the photos of the coffee bean dryer

Questions	Excellent	Good	Fair	Poor
1. How would you rate the quality of materials used in the fabrication of the coffee bean dryer?	✓			
2. How would you rate the durability of the coffee bean dryer?		✓		
3. How effective is the dryer in drying the coffee beans?		✓		
4. Is the coffee bean dryer user friendly?		✓		
5. Does the design of the coffee bean dryer meet your expectations?		✓		
6. How would you rate the overall design of the coffee bean dryer?		✓		
7. Would you recommend this dryer to others?		✓		

Additional Feedback:

Survey Questionnaire (Design and Fabrication) from University Engineer's Office

Republic of the Philippines
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BACHELOR OF SCIENCE IN GEOTHERMAL ENGINEERING
COLLEGE OF ENGINEERING AND ARCHITECTURE
Main Campus II, Bajumpandan, Dumaguete City 6200

Research Questionnaire

Name: Engr. Celestina O. Favor, C.E. Age: 38 Sex: Female

I. Design and Fabrication Evaluation

Directions: Please read the questions and indicate your opinion by placing a check (✓) next to the appropriate response for each one.

Attached below is the photos of the coffee bean dryer

Questions	Excellent	Good	Fair	Poor
1. How would you rate the quality of materials used in the fabrication of the coffee bean dryer?	✓			
2. How would you rate the durability of the coffee bean dryer?		✓		
3. How effective is the dryer in drying the coffee beans?	✓			
4. Is the coffee bean dryer user friendly?		✓		
5. Does the design of the coffee bean dryer meet your expectations?	✓			
6. How would you rate the overall design of the coffee bean dryer?	✓			
7. Would you recommend this dryer to others?	✓			

Additional Feedback:

The Researchers

CURRICULUM VITAE

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EDUCATION

- Upper Secondary Education (Senior High School)
  Bais City National Science High School S.Y 2017-2019
  With Honors
- Lower Secondary Education (Junior High School)
  Bais City National Science High School S.Y 2013-2017
  With Honors
- Elementary
  Magsaysay Memorial Elementary School S.Y 2007-2010
  Bais City Pilot School S.Y 2011-2013
  1st Honorable Mention

WORK EXPERIENCE

- Work Immersion Intern 2019
  City Engineering's Office
  Bais City
- On the Job Training Intern 2023
  URC-SURE Bais Distillery
  Bais City

TRAININGS/ SEMINARS/ CONFERENCES

- Industry 4.0: SMARTER INDIVIDUAL, SMARTER AND BETTER FUTURE"
  Conference conducted by the Commission on Higher Education
  May 12, 2022
- Optimizing Geothermal Power Plant Operations Webinar
  NORSU Student Unit
  May 30, 2024

- Laboratory Safety and Fire Drill Training
  Negros Oriental State University- Main Campus II
  May 11, 2024
- R.I.D.E (Research, Innovation, Development and Extension Congress)
  Negros Oriental State University- Main Campus I
  October 20-21, 2022
- Environment, Sustainability and Green Jobs
  GE FORUM
  June 3, 2023
- Job Entry Skills Training
  Public Employment Service Office
  May 30, 2023

CURRICULUM VITAE

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EDUCATION

- Upper Secondary Education (Senior High School)
  Campalanas National High School, S.Y 2017 - 2019
  Consistent Honor Student
- Lower Secondary Education (Junior High School)
  Campalanas National High School, S.Y 2013 - 2017
  Consistent Honor Student
- Elementary
  Cadoldolan Elementary School, S.Y 2007 - 2013
  Consistent Honor Student

WORK EXPERIENCE

- Work Immersion Intern October 2018
  Technical Education Skills Development Authority (TESDA)
  Tigbawan, Lazi, Siquijor
- Work Immersion Intern November 2018
  Elnard Integrated Farm
  Candura, San Juan, Siquijor
- On-the-Job Training July - September 2023
  Energy Development Corporation (EDC)
  Palinpinon, Valencia

TRAININGS/SEMINARS

- "Kabataang Siquijor: Rising to the Challenge in Strengthening Leadership Foundation and Transforming Young Peace Builders"
  Supreme Student Government Leadership Summit 2018
  December 8-10, 2018
- Industry 4.0: SMARTER INDIVIDUAL, SMARTER AND BETTER FUTURE
  Commission on Higher Education (CHED) Webinar

May 12, 2022

- Working in a Bubble: Drilling Operations Under a Pandemic
  National Geothermal of the Philippines (NGAP) Webinar
  July 07, 2022
- Fostering a Research, Innovation, Development and Extension (RIDE) Culture during Global Crisis
  Office of the Research, Innovation, Development and Extension (RIDE)
  Negros Oriental State University (NORSU)
  October 20-21, 2022
- Opportunities for Women in Renewable Energy and Sustainability WING Philippines
  PAGES Webinar
  February 24, 2023
- Environment, Sustainability and Green Jobs
  GE FORUM 2023
  June 03, 2023
- Laboratory Safety and Fire Drill
  Negros Oriental State University - Main Campus II
  May 11, 2024
- Optimizing Geothermal Power Plant Operations: Insights from Negros Oriental
  Pambansang Samahan ng Inhinyerong Mekanikal - NORSU Student Unit
  May 30, 2024
- Job Entry Skills Training
  Public Employment Service Office
  May 31, 2024

CURRICULUM VITAE

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+63.992.7217863
orito.jessel.a@gmail.com

EDUCATION

- Upper Secondary Education (Senior High School)
  Valencia National High School, S.Y. 2017–2019
  Consistent Honor Student
- Lower Secondary Education (Junior High School)
  Valencia National High School, S.Y. 2013–2017
  Consistent Honor Student
- Elementary
  Vicente I. Villa Memorial School, S.Y. 2007–2013
  Apolong, Valencia, Negros Oriental
  Consistent Honor Student

WORK EXPERIENCE

- Work Immersion Intern 2018
  Foundation University
  Dumaguete City
- On-the-Job Training July-September 2023
  Energy Development Corporation (EDC)
  Palinpinon, Valencia

TRAININGS/SEMINARS

- Desktop Publishing Course Technology, Livelihood, & Education – ICT
  Valencia National High School
  August 11, 2014
- Internet of Things: Applications and Business Opportunities Webinar
  University of the East-Manila
  May 08, 2021
- Industry 4.0: SMARTER INDIVIDUAL, SMARTER AND BETTER FUTURE Webinar

Commission on Higher Education (CHED)
May 12, 2022

- Fostering on Research, Innovation, Development and Extension (RIDE) Culture during Global Crisis
  Office of the Research, Innovation, Development and Extension (RIDE)
  Negros Oriental State University-Main Campus I
  October 20, 2022
- Environment, Sustainability, and Green Jobs
  PAGES GE FORUM 2023
  Negros Oriental State University-Main Campus II
  June 03, 2023
- IP Roadshow
  Negros Oriental State University-Main Campus I
  September 22, 2023
- Laboratory Safety and Fire Drill Training
  Negros Oriental State University - Main Campus II
  May 11, 2024
- Optimizing Geothermal Power Plant Operations: Insights from Negros Oriental Webinar
  Pambansang Samahan ng Inhinyerong Mekanikal - NORSU Student Unit
  May 30, 2024
- Job Entry Skills Training
  Negros Oriental State University-Main Campus I
  Public Employment Service Office
  May 31, 2024

CURRICULUM VITAE

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tinguban.cherimae.e@gmail.com

EDUCATION

- Upper Secondary Education (Senior High School)
  Negros Oriental High School, S.Y 2017 – 2019
  With Honors
- Lower Secondary Education (Junior High School)
  Negros Oriental High School, S.Y 2013 – 2017
- Elementary
  West City Elementary School, S.Y 2007 – 2013

WORK EXPERIENCE

- Negros Oriental High School, Senior High School
  Kagawasan Ave., Dumaguete City
  November 2018
- Philippine Coconut Authority of the Philippines
  4th Floor, Gov. M.C. Perdices Coliseum Complex
  Capitol Area, Dumaguete City
  January 2019
- Energy Development Corporation (EDC)
  Palinpinon, Valencia
  July 2023 - September 2023

TRAININGS/SEMINARS

- Red Cross Youth Organization, Philippine Red Cross NEGOR, Training
  Negros Oriental High School Chapter, S.Y 2017 – 2018
  April 2018
- Industry 4.0: SMARTER INDIVIDUAL, SMARTER AND BETTER FUTURE
  Commission on Higher Education (CHED), Webinar
  May 12, 2022
- Working in a Bubble: Drilling Operations Under a Pandemic, Webinar
  National Geothermal of the Philippines (NGAP)

July 07, 2022

- Fostering a Research, Innovation, Development and Extension (RIDE) Culture during Global Crisis, Conference
  Office of the Research, Innovation, Development and Extension (RIDE)
  October 20-21, 2022
- Opportunities for Women in Renewable Energy and Sustainability, Webinar
  WING Philippines
  February 24, 2023
- Environment, Sustainability and Green Jobs, Conference
  GE FORUM 2023
  June 03, 2023
- Laboratory Safety and Fire Drill, Training
  Negros Oriental State University - Main Campus II
  May 11, 2024
- Optimizing Geothermal Power Plant Operations: Insights from Negros Oriental Pambansang Samahan ng Inhinyerong Mekanikal - NORSU Student Unit
  May 30, 2024
- Job Entry Skills Training
  Public Employment Service Office
  May 31, 2024