CERTIFICATE OF RESEARCH

This project titled "DESIGN AND FABRICATION OF A DOMESTIC PASSIVE SOLAR FOOD DRYER FOR HOUSEHOLD USE" submitted by Momodou Lamin Jarjusey (210032105), Yankuba B Saidykhan (210032107), Telleh Baldeh (210032111) and MD. Mamun Mia (200032106) has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Bachelor of Science Technical Education in Mechanical Engineering.

Supervisor

____

Prof. Dr. Shamsuddin Ahmed
Professor

Head of the Department

____

Prof. Dr. Md Hamidur Rahman
Professor

Department of Mechanical and Production Engineering (MPE) Islamic University of Technology (IUT)

DECLARATION

I hereby declare that this project entitled "DESIGN AND FABRICATION OF A DOMESTIC PASSIVE SOLAR FOOD DRYER FOR HOUSEHOLD USE" is an authentic report of study carried out as requirement for the award of degree B.Sc.TE (Mechanical Engineering) at Islamic University of Technology, Gazipur, Dhaka, under the supervision of [Prof. Dr. Shamsuddin Ahmed], Professor, MPE, IUT in the year 2022.

The matter embodied in this project has not been submitted in part or full to any other institute for award of any degree.

Momodou Lamin Jarjusey

210032105

Yankuba B Saidykhan
210032107

Telleh Baldeh
210032111

Md. Mamun Mia
200032106

ACKNOWLEDGEMENT

In the Name of Allah, the Most Beneficent, the Most Merciful. First of all, we are grateful to ALLAH (SWT), the most benevolent and kind to provide us the strength and ability to write this dissertation. We want to thank our project supervisor, Prof. Dr. Shamsuddin Ahmed, for his strong and patient support through unpredictable problems during the project and his precious advice when we faced difficulties. His generosity, kindness and strong supervision during work made us feel less stressed in confronting unexpected troubles and be more productive in our personal life.

In the next step, we would like express our deep acknowledgment to our father and mother for their continued support and dedication towards our higher study.

Finally, we would like to acknowledge gratefully for the financial support by Islamic University of Technology, if any financial support was provided for this project.

ABSTRACT

The sun drying system is advantageous in that it decreases agricultural produce waste and aids in its preservation. It works by using Sunlight can be utilized to dry any and warm the air packaged food item. The sun drier was created to solve the drawbacks of sun drying naturally, being in direct sunshine and the potential for pests and rodents. inadequate supervision, and higher costs associated with mechanical dryers.

This project describes the fabrication of a domestic passive solar food dryer for home use. It's the dyer made of an integrated sun drying chamber with three trays, a solar drying panel, a battery, an inverter, lights, charge controller, and solar collector (air warmer). The solar absorber heats the air that enters through the air inlet, that is then directed through the drying chamber to aid throughout the drying procedures (i.e., decreasing the amount of moisture in food or agricultural products loaded). The layout will be determined by Bangladesh's geographic position. Our site's latitude and longitude, for appropriate design specifications, are 23.7^0 North and 93.4^0 on the Equator line.

The dryer measures 50 cm by 70 cm by 100 cm in terms of length, width, and height. The construction will mostly use locally accessible materials, namely metal (M.S Angle, plastic wood, plain glass, mild steel metal sheet, and stainless still or (SS) net for the trays).

The dryer's ideal temperature is 60 ^{0}C, and the surrounding air temperature is 30 ^{0}C. The banana and cassava will have a mass of water removed of 153.6 gm and 199.9 gm, respectively, when using the solar dryer, as opposed to 125.3 gm and 156.8 gm, respectively, when using the sun drying technique. For ten dried potatoes and fish over the course of a single day, this suggests a difference of 43.1 gm and 28.3 gm, respectively. Food dries quite quickly in the dryer, which indicates that it can dry goods to an acceptable moisture level.

Table of Contents

List of Figure

List of Tables

Nomenclature

T1	Ambient Temperature
T0	The Temperature of the Air Intake
$lat\phi$	latitude
β	Angle tilt
R	Horizontal Surface
M_a	Mass Flow Rate of Air
V_a	Average Air Speed
Q_s	Energy Stored
L	Length of The Solar Collector
ρ_a	Density of air
Q_L	The Heat Energy Losses
Ac	Area of The Collector
Q_u	rate of useful energy collected by the air (W)
A_c	collector area (m^2)
τ	the transmittance of the top glazing
T_c	temperature of the collector absorber (K)
Q_L	composed of different convection and radiation parts
α	Solar absorber (Wm^{-2} K^{-1})
I_c	isolation on the collector surface
ρ	density of air
C_p	specific heat capacity of air at constant pressure (J/
Δ	temperature elevation
V'_a	volumetric flowrate of air
M_i	the mass of the sample before drying
M_f	the mass of the sample after drying.
ML	the Moisture Loss
M.C	the moisture content

Chapter One

INTRODUCTION

1.1 Importance of The Study

i. This study will help to understanding solar energy on how a passive solar food dryer harness solar energy as renewable resource reducing pressure on non-renewable energy sources.
ii. The study encourages innovation and improvements in the efficiency and effectiveness of solar dryers and also provides practical learning opportunities for students.
iii. The study provides educational opportunities in research fields such as engineering, environment science and sustainable development.
iv. The study can lower household energy expenditures and provide a cost-effective alternative for small scale food processing, benefiting local economics and potentially creating job possibilities.
v. It helps to access affordable food preservation technology can empower communities improving food security and resilience against market fluctuation, and supply chain disruptions.

1.2 Problem Statement

i. Traditional methods like sun drying often result in uneven drying due to variations in sunlight, temperature, and humidity. This inconsistency can cause the quality of the dried product.
ii. Sun drying exposes products to contaminants such as dust, dirt, insects, birds, and rodents. This can lead to health risks and reduce the marketability of the product.
iii. Prolonged exposure to sunlight and high temperatures can lead to the loss of essential nutrients, vitamins, and flavors in the dried product.
iv. Traditional sun drying is labor-intensive, requiring constant monitoring and manual handling to protect the product from unexpected weather changes and pests.
v. Sun drying requires large open spaces, which may not always be available or practical, especially in urban or densely populated areas.
vi. It is challenging to maintain consistent quality and standards in traditional drying methods, affecting the overall market value and consumer acceptance of the product.
vii. Increase labor expenses and excessive handling of crops, particularly in inclement weather, are other drawbacks of open sun drying that can lead to costly crop damage and quality loss.

viii. In order to address this issue, modify the ergonomic requirements, and generate a higher-quality output, the sustainable solar dryer used in this study was built (Harmain, 2012).

1.3 Aims and Objectives

Aims

The project aims to create a novel kind of passive solar food dryer for residential usage, utilizing fan extractor technology in addition to solar energy. This sustainable method satisfies the need for efficient food drying methods while promoting the use of renewable energy sources.

Objectives

1. To design a compact and user-friendly domestic passive solar food dryer system for a variety of foods considering ambient temperature, humidity, and air movement inside the dryer.
2. To fabricate the above system along with installation of a fan extractor and test the performance by changing air circulation for determining the drying efficiency.
3. To ensure the preservation of food nutrients and flavors during the drying process.
4. To make a way for ensuring the fresh foods last longer

1.4 Scope of The Project

i. Using the knowledge gleaned from the books, a solar dryer was designed.

ii. Obtain the materials that will be needed for the fabrication.

iii. We'll analyze the weight loss, drying air temperature, and collector efficiency of the solar dryer in comparison to other drying techniques. (Harmain, 2012).

1.5 Some Background to The Concept

Solar energy has long been thought to be a source of high temperatures. Man has utilized solar radiation for personal comfort, agricultural needs, and home heating since the beginning of time. There are numerous accounts in the literature of Archimedes's experiments in the 18th century with mirrors that are level to focus sunlight (Chen et al., 2005).

In the 20th century, research on solar energy applications became modern. A solar boiler, tiny steam engines, and solar batteries show examples of progress, but marketing them to competitors' low-cost fuel-using engines will be challenging. The mid-1970s shortages of natural gas and oil, coupled with growing fossil fuel prices and the depletion of other resources, spurred American efforts to make solar energy into a practical power source. As a result, motivate in using sun light for power production, cooling and heating was piqued once more (Of & Dryer, 2011).

1.6 Power Storing for Sun

Solar radiation can be used to generate both electrical and thermal energy. This can be achieved by converting heat energy using heat-absorbing devices or electrical energy using photovoltaic collectors. In order to capture solar radiation and convert it into thermal energy, two main collectors are used: collecting flat plate collectors and concentrating collectors. Throughout this project, a lot of attention is paid to flat plate collectors, commonly referred to as non-focusing collectors (Oguntola & Nwaokocha, 2010).

1.7 Why Sun-Dried Food is Valuable

Individuals have been drying vegetables other products, fruits, potatoes, and fish for ages, throughout many different nations. All of these agricultural products can be much more widely available if solar drying is made available everywhere. It's important to remember that before canning was developed at the end of the eighteenth century, food was essentially solely preserved by drying. (Whitfield, 2000).

When compared to canning jars and freezer containers, drying requires less energy and less storage space. It was also said that drying has very little effect on food's nutritional content. Additionally, food scientists have discovered that food may be kept fresher longer by keeping its moisture content ranging from ten to twenty percent. This prevents food from being ruined by mold, bacteria, yeast, and enzymes. Food successfully destroys bacteria when the inside temperature hits 145 °F. Food that has been dried retains most of its nutritional value while tasting concentrated. Transporting dried goods is simple and doesn't require any specialized storage equipment. Traditional methods of using the sun to dry food crops like vegetables outside are insufficient since the goods decay quickly (Oguntola & Nwaokocha, 2010).

Research findings indicate that food items that are sun dried are not as good as those that are dried in a solar dryer in terms of components such as taste, color, and the growth of mold. Sun-dried foods are premium products with higher nutritious content that can be stored for extended periods of time and transported more affordably. The design and construction of a home-use passive solar food drier was the subject of this project.

1.8 Project Planning

The Final Year Project is broken up into FYP 1 and FYP 2. Research and a review of the literature from journals, articles, and other sources pertaining to the project topic were the main goals of FYP 1. The completion of the literature review procedure took eight weeks. The project's schedule was managed via a Gantt chart system and a Microsoft Excel worksheet.

The benefits and drawbacks of the solar dyer product have been identified following the completion of the literature review. I will then start to draw out my thoughts for a new feature design. It takes roughly four weeks to complete the solar dryer's sketch. The drawing was completed by hand on an A4 sheet of paper. The sketching concept idea is transferred into Auto CAD and Solid Work with actual dimensions after the finest ideas have been selected. The preparation of the progress presentation comes next, and it takes two weeks to complete both of these duties. At the conclusion of this semester, these FYP 1 presentations were completed. I have to be ready for the presentation this week, including the speech and slide show. I have to finish writing the draft report and turn it in after the presentation.

The fabrication process will begin and be followed by data analysis for the next 14 weeks for FYP 2. In order to make the final presentation, the final report will be drafted. Preparing and completing this will take around a week. The UMP thesis structure is followed when writing a report, and supervisor supervision is also helpful. Approximately fourteen weeks are needed to finish all of the planned tasks.

Chapter Two

LITERATURE REVIEW

2.1 Introduction of Literature Review

Crops that are traditionally sun dried are exposed to insects, moisture, and dust, which lowers quality and accelerates spoiling. With the aid of solar energy, solar dryers may dry crops more thoroughly by heating the air. Studies reveal that solar dryers can dry crops more quickly while preserving their quality compared to sun drying. Farmers in remote areas may find the dryers to be reasonably priced.

2.1.1 Drying

Drying is a fantastic technique to conserve food, thus solar dryers are a helpful tool for sustainable food preservation development. It's plausible that before cooking, dried food was the earliest food preservation technique ever employed by humans (Alamu, 2010). Food that can be safely preserved for an extended period of time requires the drying out of agricultural products. Putting the produce on rooftops, mats, or sun-dried floors is known as "sun drying," and it is the oldest method of agricultural food drying that humans have ever discovered. Because agricultural products are exposed to the elements, they are more vulnerable to deterioration from rain, wind, moisture, and dust Additionally, the product deteriorates and ruins itself more because it dries out slowly and is only viable in ideal weather, both of which raise the possibility of mold growth (Of & Dryer, 2011). These are but a handful of the problems with this strategy.

To finish the procedure, a large amount of land, labor, and time are needed. According to Al-Juamily et al. (2007), a range of sun dryer types can be used to control the final moisture content, speed up the drying process, prevent waste from bacterial action, and protect products from the previously mentioned downsides. The development of technology and civilization made it possible to create artificial mechanical drying. The cost and energy intensity of this procedure, however, eventually raises the cost of the finished good. As a result of later developments, "sun drying" has evolved into "solar drying."

Insects, rain, and dust pose the biggest threats to agricultural goods. Sun dryers are specific instruments made to regulate the drying process. When "sun drying" is done artificially, on the other hand, solar dryers produce lower product moisture content, higher drying temperatures, and less spoiling. When considering artificial mechanical drying methods, this method uses less money, time, and space. So, solar drying is a more effective way to address all of the problems associated with mechanical drying, both artificial and natural. The world's food and energy problems might be resolved by sun dryers. As per Of and Dryer (2011), sun dryers are a useful tool for the efficient drying of agricultural products and for preserving the majority of foods.

Solar-powered dryers are an excellent tool for:

- Agricultural crops are dried
- Fruits and vegetables that are dehydrated are processed by food firms.
- Fish and potatoes being dried
- The dairy sector produces powdered milk.
- A period dedicated to harvesting wood and timber.
- Textile-related industries for fabric drying, etc

This means that a number of strategies, including sun drying, can effectively use solar energy to meet human needs for food and energy. It is imperative to take the total cost of the system into account while building a solar dryer for agricultural use. Even at peak efficiency, a solar system won't be widely utilized until it offers a cheaper energy alternative than what is now available.

2.2 Details of Literature Review

Growing in acceptance is the idea that renewable energy might help farmers in developing countries raise their produce by providing them with access to more sophisticated technology. An energy-efficient substitute for agricultural purposes, solar thermal technology is gaining favor quickly. There are benefits to using it over other renewable energy sources like wind and shale due to its abundance, limitless supply, and little emissions.

Sunlight is used by inexpensive gadgets known as solar air heaters to heat the air. They require low to moderate temperatures, below 80 0C, for many of their applications, such as crop drying and space heating. Drying is a technique for removing moisture from materials by simultaneously transferring mass and heat. The preservation of agricultural products depends on this procedure. Two types of water are present in food products: chemically bound water and physically held water. During the drying process, only the water that is physically contained is removed. They are desirable because of their large selection, extended shelf life, and noticeable volume decrease of dried goods. Improvements in process applicability and product quality carry this further.

Reduced post-harvest losses can be achieved in developing countries while increasing food supply at the same time. In highly unfavorable conditions, these losses could exceed 80% of the total, but they are believed to be roughly 40% of the total. The majority of these losses can be attributed to improper handling and/or premature drying of foods, which includes cereal grains, legumes, potatoes, fish, and other products.

The method of food preservation that is most commonly used in developing countries is traditional drying, as it is the most straightforward and affordable. Conventional drying at ground level is typically conducted outside. There are a number of disadvantages to open-air drying, such as food exposure to dust and rain, infestation by insects, attacks by animals, and more, aside from the possibility that allergies could be caused by direct sunlight.

Over the last 20 years, solar dryers have gained a lot of attention as a way to improve traditional drying because of its capacity to greatly reduce the previously mentioned disadvantages of open-air drying. A wise choice would be a forced convection sun dryer. But the fans need power, and unhappily, there aren't enough power sources in a lot of remote locations. These potential dryer users have very little money; thus, they are unable to purchase electricity when it is offered. That is why many developing countries do not have a large usage of forced convection dryers. In naturally occurring convection dryers, drying air is distributed without the need for a fan. As a result, rural areas in developing countries are the best places to use them. Direct, indirect, and mixed solar drying are the three options available. In direct solar dryers, the grains are stored within an air warmer that lets them absorb solar radiation through a transparent cover. Conduction into the grain bed and radiation to the upper layers provide the majority of the heat needed for the drying process.

In an indirect drier, the grain bed is heated air from a separate solar collector while, at the same time, solar energy is directly absorbed by the drying cabinet through its transparent walls or roof. On the other hand, a dryer with a mixed mode concurrently absorbs solar energy directly into the drying cabinet. The aim of this project is to design a mixed-mode solar drier that will dry the grains simultaneously by allowing direct sunlight to enter through the transparent cabinet walls and roof and by circulating warm air from the solar collector. The dryer's performance was also evaluated Furthermore, farmers have not embraced the technique with much zeal. Roof structural modifications have been necessary for most solar air heaters developed in Thailand. While solar air heaters with or without glass coverings were found to be technically and economically feasible, their power output was found to be inferior to that of fuel oil.

For the purpose of sun-drying, or direct sun-drying, some fermented dairy products known as sikkak, Bahnasawy and Shenana (2004) developed a mathematical model. The drying system was composed of the latent heat of moisture evaporation, solar radiation, heating convection, and the primary sources of heat obtained or lost from the dryer bin wall. For the drying temperatures, the model may forecast a wide range of relative humidity levels. It can also predict how much moisture the product will lose under a variety of conditions, including temperature, air velocity, and relative humidity.

A parametric study on a solar air heater for solar drying applications with and without thermal storage was conducted by Aboul-Enein et al. and published in 2000. A flat-plate solar air heater was optimized both with and without thermal storage. Three different substances—water, stones, and sand—were employed to store heat. Its length and width return to normal as the air flows through the collector, and its average temperature rises. The airflow's exit temperature was shown to decrease with increasing airflow channel spacing and mass flow rate. The air heater operates more efficiently in terms of temperature when the proper storage materials are utilized. A range of agricultural goods can be dried by storing material with a thickness of approximately 0.12 m, as has been shown. When estimating the thermal performance of solar air heaters with and without thermal storage, the proposed mathematical model can also be utilized.

In 2022, Khajire et al. designed and tested a breakthrough convection sun dryer with an average temperature of between 50 and 55 0C. Studies show that this is the range of temperatures at which most fruits and vegetables—including grapes—dehydrate best. This gadget could generate enough naturally occurring hot air flow to expedite the drying process. The drying airflow rate increases with ambient temperature due to the thermal buoyancy of the collector. At mass flow rates of 0.0246 kg/s and 0.0126 kg/s of air, the collector efficiencies varied from 26% to 65%. To do this, the drying air just needed to be warmed. The grapes dried 43% faster than when they were left out to dry in the open.

A simple biomass burner was developed by Bena and Fuller (2002) for use in direct-type natural convection sun dryers. Small-scale producers of dried fruits and vegetables in underdeveloped countries without electricity were expected to find it a useful tool. It was found that 20–22 kg of freshly cut pineapple slices, with a thickness of one centimeter apiece, could fit within the dryer. The three most important parts of the biomass burner were found to be an internal baffle plate to extend the exhaust gas departure path, a variable air inlet valve, and the addition of thermal mass to the upper surface. Author 16 also suggested a number of changes to improve the efficiency of the dryer's solar and biomass components.

Ekechukwu & Norton carefully evaluate the various designs, building details, and operational principles for a variety of viable solar-energy drying systems (1999). All designs were evaluated to see if they would work well for emerging country rural farmers. Irtwange & Adebayo (2009) used simulations to study a simple, inexpensive solar batch dryer for agricultural products. Considering the drying procedure, they selected onions to be the dried product. Additionally, a suggestion was made to broaden the study's scope to cover other agricultural products and examine how solar dryers function all year round.

El-Sebaii & Shalaby (2013) evaluated a variety of products, including grapes, figs, onions, apples, tomatoes, and green peas, both theoretically and empirically, for drying using an indirect type natural convection solar. Based on the results of the experiment, the drying constants of the selected crops were calculated and connected with the drying product temperature. The drying constant and product temperature were found to have a linear relationship for the selected crops. Henderson's equation's empirical constants were determined for every substance used in the inquiry that isn't mentioned in any literature. It is possible that the drying kinetics of the selected crops can be accurately represented based on the empirical connection that is presented.

Research on a few dried fruits and vegetables (grapes, tomatoes, figs, and onions) was presented by Gallali (2000). In addition to chemical analysis (vitamin C, total reducing sugars, acidity, moisture content, and ash content), the analysis was based on sensory assessment data (color, flavor, and texture). Items dried by sun exposure naturally were compared to items dried using solar dryers. More precisely, the research indicates that in terms of drying time, solar dryers are superior to sun-drying methods.

The kinetics of sun and solar air-drying a few crops, including sultana grapes, currants, figs, plums, and apricots, were examined by Karathanos & Belessiotis (1997). Drying rates were established for both solar and industrial drying techniques. The air and product temperatures were monitored during the industrial drying process. Research revealed that the bulk of materials were dried during the phase of decreasing rate. Among them, the drying rate durations for jigs, plums, apricots, and currants were all different: one was characterized by a fruit's abrupt drying rate fall, and the other by a comparatively constant drying rate reduction. It was also shown that the industrial drying method produced superior outcomes than sun dehydration.

2.3 Techniques Based on Literature Review

A review of the evaluation techniques currently in use and the standard metrics for assessing solar food dryers were provided by Ms. Vaishnavi Bharat Chougule (2016). For these factors, the following categories are applicable:

a) physical features of the dryer
b) Thermal performance
c) Quality of dried product
d) Cost of dryer

a) Physical features of the dryer:
   Kind, form, and dimensions

   - The collector area and solar aperture
   - In kilograms per unit aperture area, the loading density to drying capacity ratio
   - The size and number of layers of the tray
   - The loading and unloading process is simple.
   - The duration required for loading and unloading
   - The simplicity of use, cleanliness, and upkeep; as well as the ease of construction

b) Thermal performance:

For products with a moisture content of up to 10% (d.b), the drying time and rate may differ.

- Efficient drying/drying efficiency up to 10% moisture content in the product (d.b).
- Initial drying effectiveness
- Temperature and relative humidity of drying air
- Peak drying temperature both without and with a load
- The drying air temperature was maintained at 10 0C above room temperature.
- Rate of air flow

c) Quality of dried product:

Taste, texture, scent, color, and flavor are examples of sensory qualities.

- Qualifiable nutritional features that allow for simple comparison
- Capacity for rehydration and presentation uniformity
- Consistency in drying

Chapter Three

RESEARCH/EXPERIMENTAL DESIGN

3.1 General Description for Domestic Passive Solar Food Dryer for home Use

The cabinet shape, which consists of hardwood boxes Featuring a glass cover, is the most often utilized design style. Some variations are even better, utilizing cardboard boxes and clear nylon or polyester.

The design under consideration is grounded in the theoretical concepts of the greenhouse effect and thermosiphon. A Vents or inlets enable the greenhouse effect to heat air entering the solar collector. A vent or outlet near the top of the shaded side allows the hot air to leave the drying chamber after rising through the trays and surrounding the food to remove moisture.(Oguntola & Nwaokocha, 2010).

Because heated air acts as the drying medium, removing and transporting moisture from products (or food) to the environment through free (natural) convection, the system is passive solar in nature, requiring no mechanical mechanism to control the dryer's air intake.

Solar food dryer was made up of two main chambers that are incorporated into one another:

i. Alternatively known as the air heater, this is the sun collecting container.
ii. Drying chamber was built to hold three trays with wooden frame and stainless-steel net (SS net), which are used to dry product or food.

3.2 Methodology

3.**2.1** Methodology for Design and Fabrication Flow Chart of the Project

This flow chart ensures a systematic approach to designing, and evaluating a domestic passive solar food dryer, covering all essential steps from inception to implementation and maintenance.

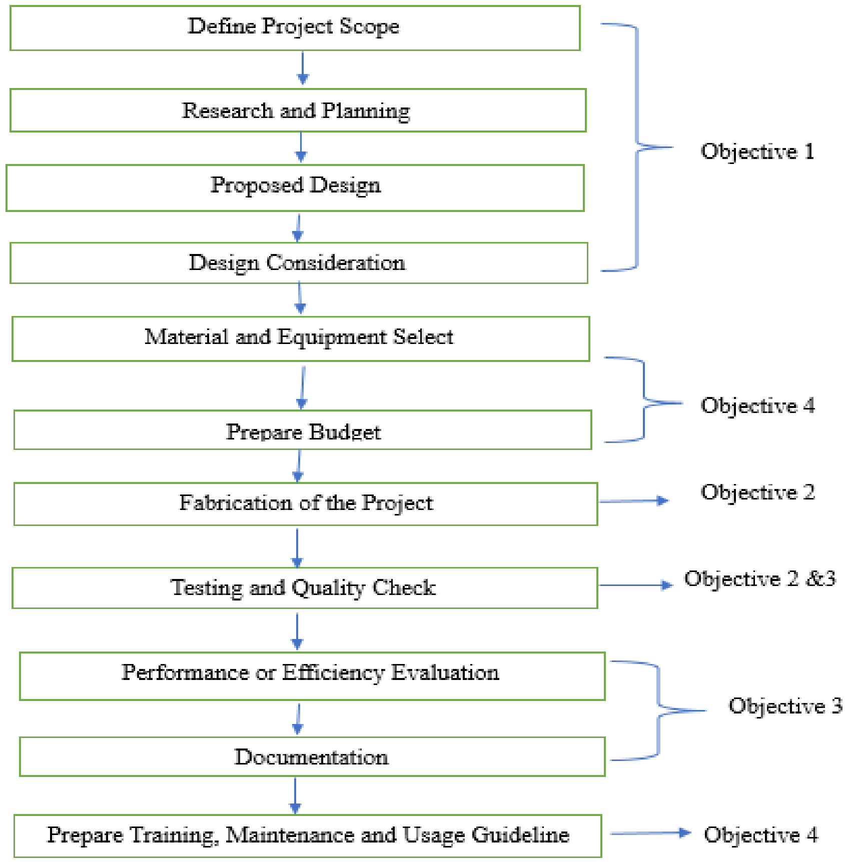

Figure 3.1 Flow Chart of the Project

3.2.2 Methodology and Material

When choosing engineering materials to fabricate the equipment, the following elements are considered:

i. The fabrication's cost.
ii. Mechanical characteristics of materials, such as creep, fatigue, and stress.
iii. Resistant against corrosion.
iv. Manufacturing simplicity (e.g. shaping, nailing, bending, cutting etc)
v. Need for services (Onigbogi et al., 2012).

Throughout the solar dryer's operational lifespan, consideration was also given to the most cost-effective materials that meet mechanical and process requirements and enable simple replacement, maintenance, and loosening. Lastly, it was confirmed that the chosen materials would be easily worked with and have enough strength.

3.2.3 Materials

The readily available components that were used to construct the home passive solar food dryer are found nearby. The domestic passive solar food dryer was constructed from Plastic wood, plain glass, mild steel Sheet (M.S Steel), Mild Steel Angle (M.S Angle), glue, nails, screws, hinges, paint (black) stainless-steel net (S.S net), fan/extractor, fiber wool, solar panel, inverter, battery, charge controller, and bulbs were the materials needed to build the effective solar dryer.

1. Plastic Wood: metals. Figure 3.2 shown the system's casing, or housing, was made of plastic wood as it's a cheap and effective insulator.

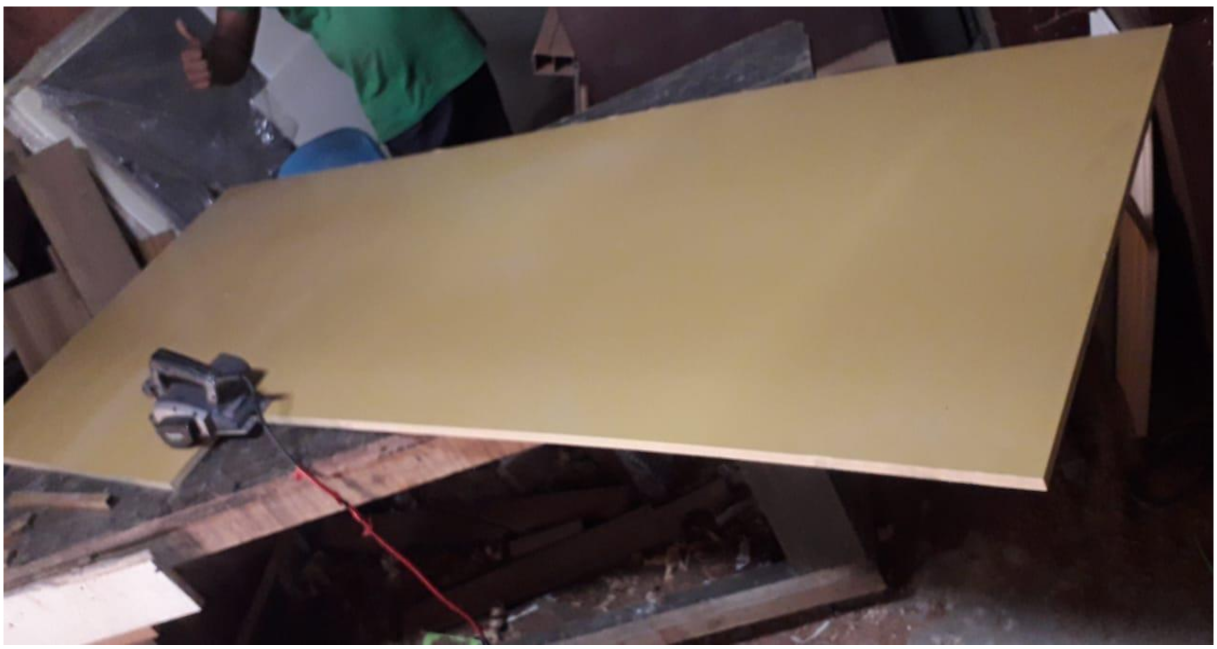

Figure 3.2: Plastic Wood for the Body Frame

2. Plain Glass: Figure 3.3 shown the solar collector and heating chamber covers. It stops heat energy from leaving the system while permitting heat energy from the sun to enter.

Figure 3.3: Plain Glass for Solar Collector

3. Mild Steel Metal Sheet: Figure 3.4 shown the mild steel metal sheet for the bottom plate and cover for the purpose of absorbing solar energy and bottom plate for solar collector, a mild steel sheet measuring 110 cm by 70 cm and with a thickness of 1mm will coat black using paint.

Figure 3.4: Mild Steel Metal Sheet for the bottom plate and cover

4. Wooden frames with stainless-steel net: Figure 3.5 shows the wooden frames with stainless-steel net were used in the tray construction to place any food stuffs loaded in the drying chamber.

Figure 3.5: Wooden frames and stainless-steel net for trays

5. Use screws and nails as fasteners.
6. Hinges were used for dryer doors.
7. Paint (black): Was used to paint the body of the dryer and the stand
8. Fiber wool was used for insulating the bottom and interior of the heating chamber and the bottom of drying chamber.
9. Mild Steel Angle was made for stand of the dryer.
10. A stainless still or (SS) net: Figure 1.6 show the SS net, which is used to stop insects from getting into the dryer, at the air intake and output.

3.3 Design Consideration

1. Temperature – Hence, 30 ^{0}C is the lowest and 60 ^{0}C is the highest temperature that can be used to dry food. Crop chips, crop seeds, and certain other crops can be dried at temperatures of 45 ^{0}C and above, which is regarded as ordinary and normal. An ideal temperature for the dryer was taken into consideration during design. The ambient temperature T1 = 30 ^{0}C (roughly the outside temperature) and the temperature of the air intake, T0 = 60 ^{0}C.
2. Geographical location: The country of Bangladesh is situated on the northern side of the Equator. Which is located between longitudes 93.40^{0} East and latitudes 23.70^{0} North on the line of equator.
3. Efficiency: This can be explained as the ratio of a device's input to its useful output.

4. Air Gap: It is suggested that for hot climate passive solar dryers, a gap of 50 by 15 cm will be created as air vent (inlet) and air passage.
5. Glass and Flat Plate Sheet: It recommended that the glass covering will have a thickness of 4mm transparent glass will used for this project. Additionally, we recommend that the thickness of the metal sheet will be 1.0 mm. The collector's glass cover will be 110 by 70 cm.
6. Dimension: It is advised that solar food dryer designs aim for a continuous air exchange and a large drying chamber. For this reason, the drying chamber was designed to be as large as possible, with an average size of 100 × 70 × 50 cm. Glass measuring 110 by 70 cm and angled at 45 degrees cover the heating chamber's roof. This is done to compensate for the glass's greenhouse impact by maintaining a reasonably consistent temperature inside the drying chamber.
7. Calculations: This includes all of the formulas and mathematical techniques applied to determine the dimensions.
8. Drawing: This displays the schematics of the machine that is currently being designed.
9. Fabrication: This is the finished structure that was created by combining the drawings and calculations.
10. Dryer Trays: The dryer trays was made of stainless-steel net to promote airflow throughout the drying chamber. Three trays with wooden frames were constructed. The 60 × 40 cm tray has a frame made of 2.5 × 2.5 cm wooden sticks. The food to be placed to protected from the sun by the trays by the dry chamber's design, which uses a slanted wall with wooden walls metal plate roof will tilt at both sides at the top of dry chamber. This is because direct sunlight usually destroys flavour, bleaches colour, and create uneven drying of the food.

3.**4** Proposed Design of Domestic Passive Solar Food Dryer

The dryer is divided into two main compartments: a heating chamber and a drying chamber shown in figure 3.6 and 3.7 below. This design leverages solar energy and four 100 watts bulbs to heat air and uses powered fans to enhance airflow and moisture removal, improving the efficiency and effectiveness of the food drying process.

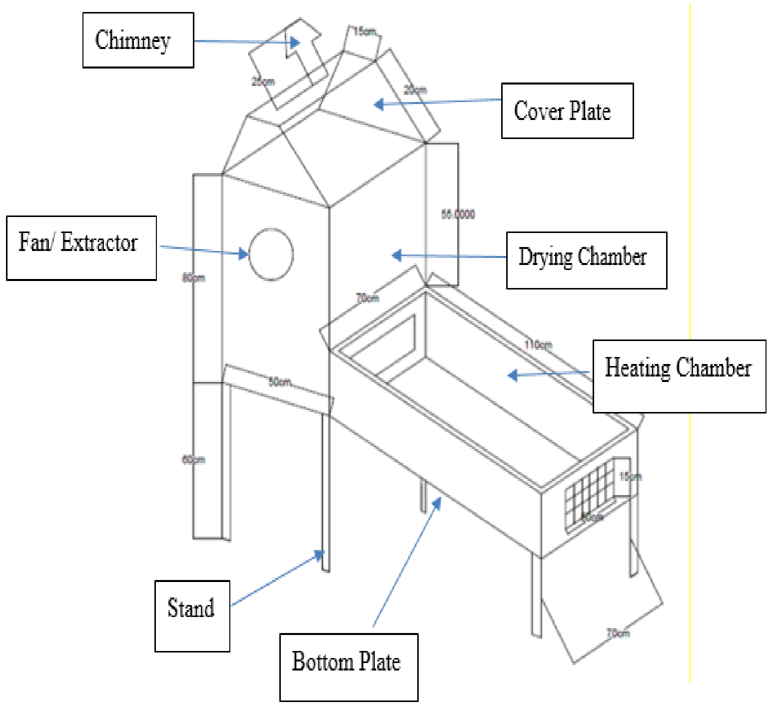

Figure 3.6: Proposed Design for Domestic Passive Solar Food Dryer

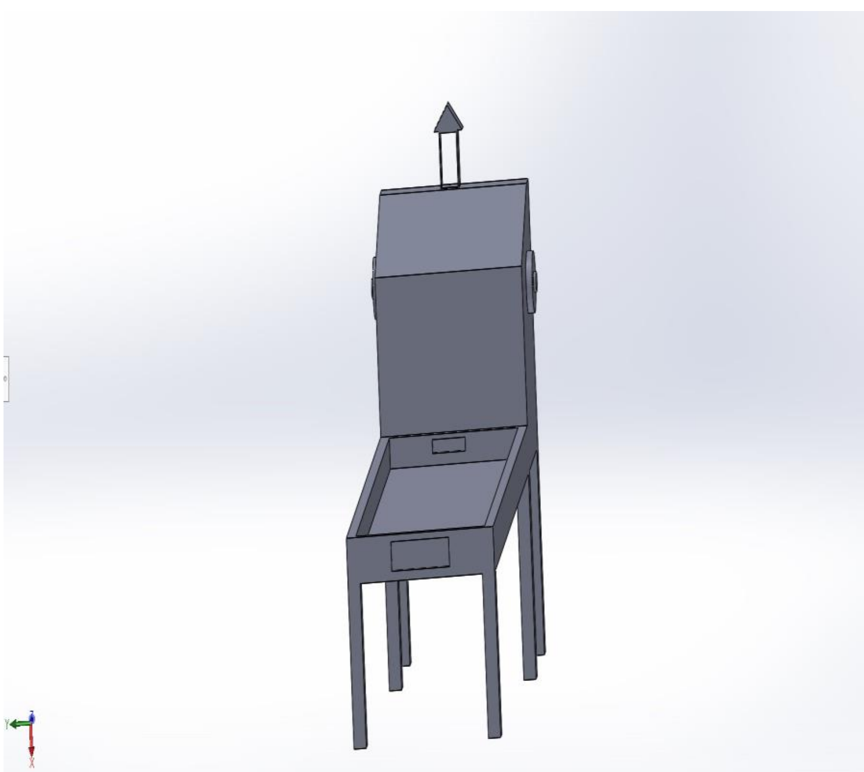

Figure 3.7: Solar Food Dryer Solid Work

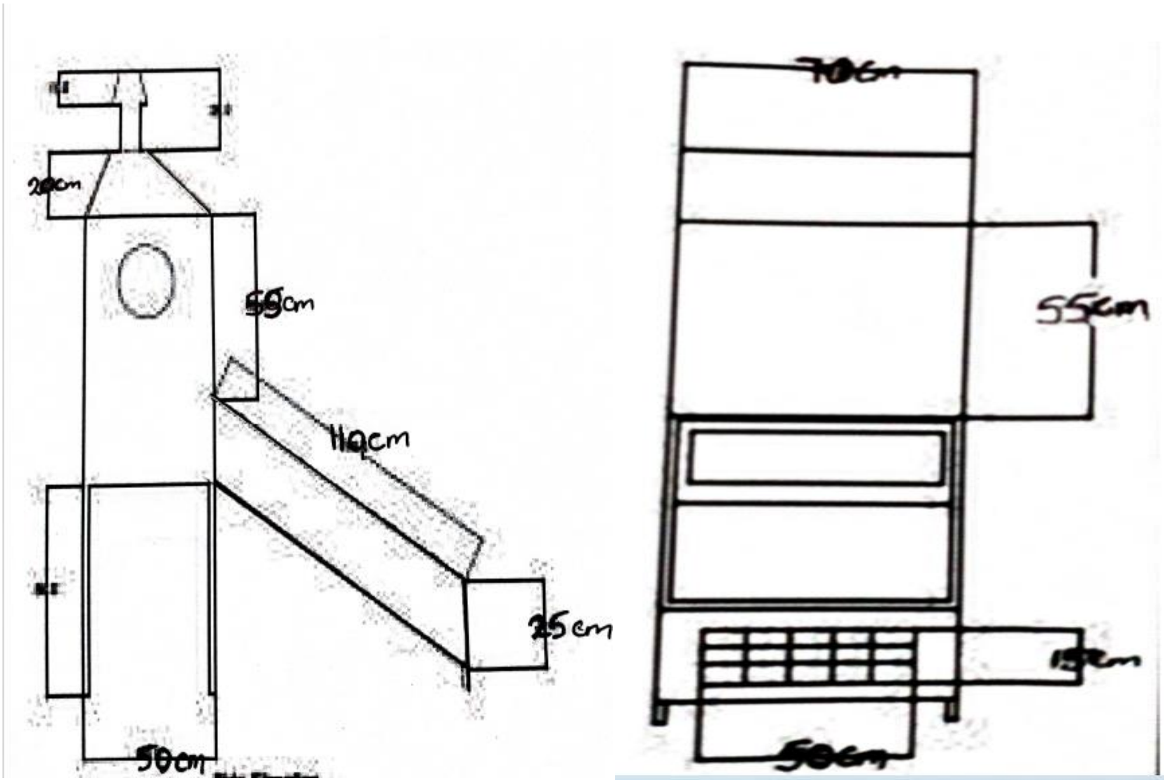

Figure 3.8: Side Elevation and Front Elevation

3.**5** Components of Domestic Passive Solar Food Dryer for Home Use

1. Drying Chamber: The drying chamber was constructed using three wood drying trays and a highly polished wood wish. Wood was selected for the drying chamber due to its low heat conductivity, flat surface, and reduced radiation-induced heat loss.
2. Cover Plate: This mild steel sheet is used to cover the absorber, keeping rain and dust away from it while also keeping heat from escaping. While metal plates are frequently used for cover materials, mild steel sheet metal was chosen for this project.
3. Absorber plate: This is a black-painted metal that is positioned beneath the cover to absorb incident solar radiation that is transmitted by the cover glass, heating the air between it and the cover. Mild steel plate is used to retain the absorbed solar radiation, and for quick absorption of solar radiation.
4. Heating Chamber: The air heater, also known as the sun collector compartment. Which is cover with a plain glass as a heat collector.

5. Insulation: This minimizes heat loss from the system; it is located beneath the absorber plate and the internal wall of the drying chamber and the heating chamber; it is fire resistant, resistant to out-of-going gasses, and susceptible to damage from moisture and insects; typically, insulating materials consist of fiber glass, mineral wool, Styrofoam, and urethanes, but in this case, Styrofoam was selected.
6. Solar Panel: Sun radiation is captured and transformed into electrical energy.
7. Charge Controller: Controls and guards against damage and overcharging of the battery. Assures long-term battery life and effective energy use.
8. Inverter: Transforms DC battery power that has been stored into AC power to lightbulbs.
9. Battery: To store more solar energy. Based on the preferred running time in the absence of sunlight.
10. Bulbs: When operating at night or in overcast conditions, add more heat.
11. Fan Extractor: Keeps the chamber's airflow constant, eliminating moisture and avoiding condensation. Expelling moist air and improving overall drying efficiency.

3.6 The Solar Collector's Orientation

Throughout the intended operating the flat-plate solar collector was consistently orientated and inclined in order to get the most solar energy possible. In the northern and eastern hemispheres, respectively, due east and due north are the ideal stationary orientations. The solar collector for this project is tilted 33.4^0 degrees to the horizontal, facing south. Roughly 20^0 North of the local geographical latitude (23.7^0 N) in Bangladesh, which is the position that a stationary absorber should be in the most. According to national geography. This inclination also facilitates easier water runoff and improves air circulation (Of & Dryer, 2011).

3.7 Project Network Diagram for Domestic Passive Solar Food Dryer for Home Use

A = Material preparation: cut plastic wood, MS sheet, and MS angle etc.

B= Heating and Drying chamber assembly

C= Fabricate the bottom and roof using mild steel plates.

D= Electrical wiring

E= Insulation material within the Heating and the drying chamber

F= Construct the stand for domestic food dryer mild steel angle iron (welded stand)

G= Install plain glass on the heating chamber

H= Install fan and bulb holder
I= Install solar panel, battery and its accessories

J= Electric connection

K= Painting

Table 3.1: Project Network Activity

Activity	Immediate predecessor Activity	Duration (Days)
A	_	2
B, C	A	3
D, E	B, C	3
F	A	2
G	C	1
H	G	1
I	F	2
J	H, I	1
K	J	1

3.8 The project network diagram

A project network diagram shown in Figure 3.9 for a domestic passive solar food dryer for home use, visually represents the sequence of activities required to complete the project, their dependencies, and the overall timeline. The diagrams shown in figure 3.9 and 3.2.1 would visually these activities with arrows indicating dependencies, and might use tools like Gantt charts to manage timeline and critical tasks.

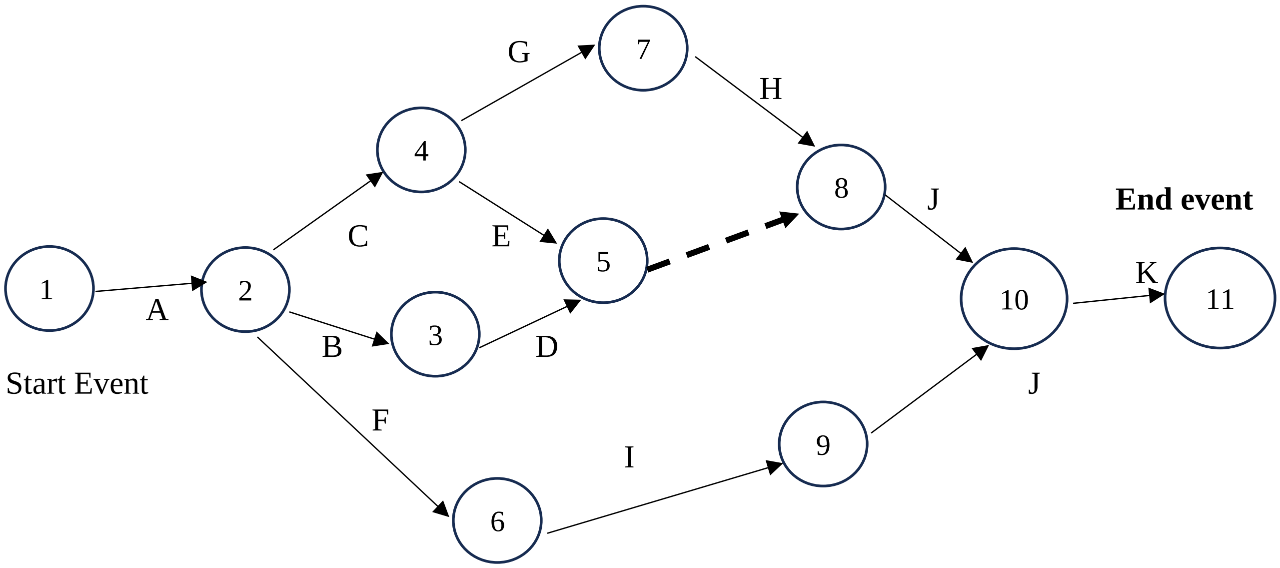

Figure 3.9:1 Project Network Diagram

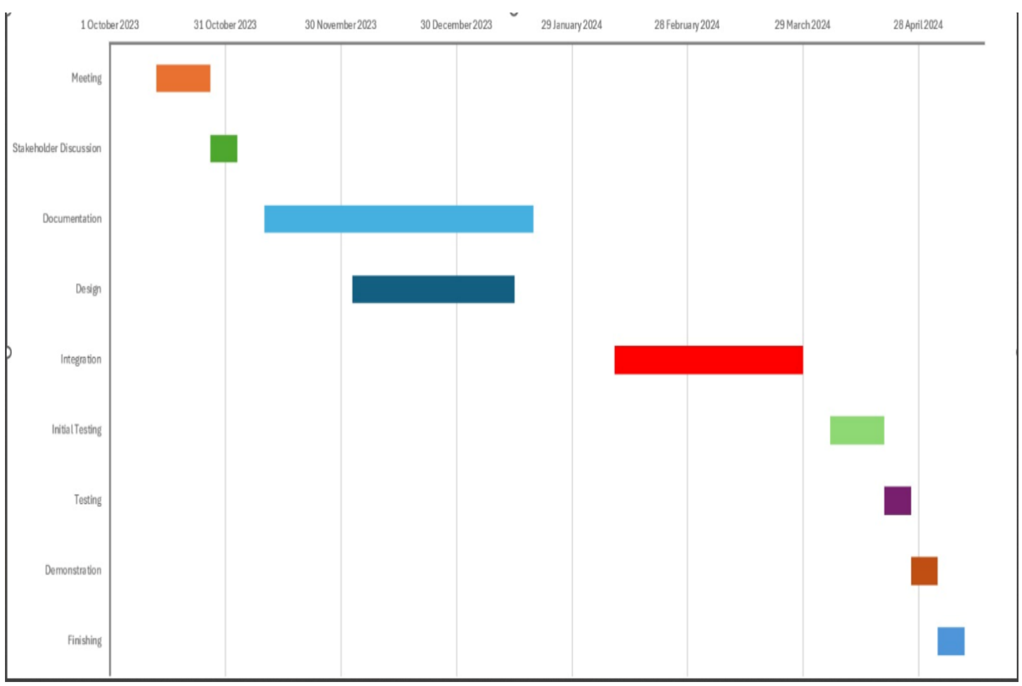

Figure 3.9.2 Gantt Chart

3.9 Cost of the project

Table 3.2 shown a detailed budget, that would itemize each component, providing specific cost estimates for each category, ensuring all aspects of the project are financially accounted for.

Table 3.2: Project Cost

No.	Name of Components	Description	Quantity	U – Price in Taka	Total Amount in Taka
1	Solar Pannel	150 watts – 18 volts	1	5,500	5,500
2	Charge Controller	10A – 30V - DC	1	1,000	1,000
3	Inverter	1000 watts – DC 12 volts to AC 220 volts	1	2,000	2,000
4	Battery	12 V – 60 Amp	1	7,000	7,000
5	Electrical Switches	Single gang	4	175	700
6	Bulb	100 watts -220 volts	4	250	1,000
7	Exhaust Fan	DC – 12V – 5W – 14 cm	2	200	400
8	M.S Sheet Cutting Disc	4′×8′×2mm 2	1 Sheets 8 pieces	5000 40	5,000 320
9	M.S Angle	$1\frac{1}{2}\times1\frac{1}{2}\times 3mm$ $1' \times 1' \times 2mm$	4 pcs 2 Ros	60 kg 20 kg	6,500 2,000
10	Welding Electrode		1 packet	1,000	1,000
11	Plastic Wood		1 piece	5,000	5,000
12	Plain Glass	6mm thickness	1 pc	700	700
13	Black Paint	Oil paint	2 Liters	1,500	3,000
14	Foil Paper	Aluminums	2 pcs	300	600
15	Electric wire	4.5 battery cable and 1.5 cable for fan and bulbs	2 pcs and 2 Rolls		1,000
16	Miscellaneous				3,000
17	Total Amount				45,720

3.9.1 Design Calculations

1. Ideal Angle of Tilt

We take IUT in Dhaka, Bangladesh, into consideration for testing. The Global Solar Atlas website provided the data pertaining to our region. Our site is located at 23.77^0 N and 90.38^0 E in latitude and longitude respectively.

The solar collector's/air heater's tilt angle (β).

According to this, the solar collector's tilt angle (β) should be

$\beta = lat\phi + 10$

Were $lat\phi$ is both the latitude in Bangladesh where the dryer was developed and the latitude at which the collector is situated 23^0 North

$\beta = 23^0 + 10$

2. Insolation within the surface area of the collection

The average daily radiation H on a horizontal surface of Bangladesh, as determined by study, is as follows:

$H = 978.69\ W/m^2$

The mean ratio of the tipped surface's solar energy to the horizontal surface's is represented by R.

$R = 1.0035$

The collector surface's insolation was therefore obtained as

$I_c = H_T = HR$

$I_c = 978.69 \times 1.0035$

$I_c = 982.11\ W/m^2$

3. Selecting the Collector's Dimension and Area

By calculating the average air speed, the mass flow rate of air Ma was found $V_a = 0.15$ m/s. The height of the air gap was measured as 15 cm = 0.15 m also the breadth of the collector 50 cm = 0.5 m.

Therefore, the air's volumetric flow rate $V'_a = V_a \times 0.15 \times 0.5$

$V'_a = 0.15 \times 0.15 \times 0.5$

$= 1.125 \times 10^{-2}\ m^3/s$

Therefore, the air's mass flow rate:

$a = V_a \rho_a$

We use 1.28 kg/m^3 as the air ρa density.

$M_a = 1.125 \times 10^{-2} \times 1.28$

$M_a = 1.44 \times 10^{-2}$

Thus, the collector's area (Ac)

$Ac = (1 \times 10^{-2} \times 1005 \times 30)/(0.5 \times 982.11)$

It was determined that the solar collector's length (L) was;

$L = A_c / B = 1.44 \times 10^{-2} / 0.6$

$L = 2.4 \times 10^{-2}$

The solar collector's estimated measurements were 1 m for length and 0.6 m for width.

Collecting area was so designated as $1\times 0.6 = 0.6$

4. Determination of Heat Losses from the Solar Collector (Air Heater). α

Total energy stored which is considered negligible therefore,

$$I_c A_c \tau\alpha = Q_u + Q_L + Q_s$$

Where Q_s is the energy stored which is considered negligible therefore,

$$I_c A_c \tau\alpha = Q_u + Q_L$$

Thus, Q_L is the heat energy losses

$$Q_L = I_c A_c \tau\alpha - Qu$$

Since

$$Q_u = m_a C_p (T_0 - T_i) = maC_p\Delta T$$

and

$$Q_L = U_L A_c \Delta T$$

Then

$$U_L A_c \Delta T = I_c A_c \tau\alpha - maCp\Delta T$$

$$U_L = (I_c A_c \tau\alpha - maCp\Delta T)/(A_c\Delta T)$$

α was taken as 0.9 and $\tau = 0.86$

$$T_a = 0.774$$

$$U_L = (982.11\times 0.6 \times 0.774 - 1.125\times 10^{-2}\times 1005 \times 30)/(0.6\times 30)$$

$$= (456.09 - 339.1875)/18 = 6.49\ W/m^{2\ 0}C$$

Therefore,

$$Q_L = 6.49\times 0.6 \times 30 = 116.82\ W$$

This heat loss includes the heat loss through the insulation from the sides and the cover glass.

5. Moisture Content (M.C): The moisture content is given as:

$$M.C = (M_i - M_f)/ M_i$$

Where M_i is the mass of the sample before drying and M_f is the mass of the sample after drying.

6. Moisture Loss ML: The Moisture Loss is given as:

ML = $(M_i - M_f)$ (g)

Where M_i is the mass of the sample before drying and M_f is the mass of the sample after drying.

7. Dryer Efficiency: is given as Ƞd

$$Ƞd = \frac{M \times L}{\mathrm{Ic} \times \mathrm{A} \times \mathrm{t}}$$

$$Ƞd = 0.158 \times 22.6 \times 10^5 / 235 \times 0.077 \times 13 \times 3600$$

$$Ƞd = 0.4216 \times 100$$

$$Ƞd = 42.2\ \%$$

8. Average drying rate = *M/t*

= *0.158/13*

= *0.0121 kg/h*

Chapter Four

GENERATING AND COLLECTING DATA, ANALYZING IT, AND HAVING DISCUSSIONS

4.1 Testing of Domestic Solar Food Dryer

In April and May, the dryer was tested open-air with the collector facing the sun. To obtain a sun beam that is roughly perpendicular, the collector and dryer are securely fastened at a 23.77^0 angle to the horizontal. Fish and potatoes, with an approximate weight of 46 g and 38 g and a thickness of 6 mm and 5 mm, respectively, were placed into the drying chamber.

Hourly temperature readings were taken without any load, from 9 a.m. to 5 p.m., of the collected chamber, the heated air inside the dryer, and the environment. There was also no hygrometer, thus used two thermometers to determine the proportionate humidity. In order to determine the dry bulb temperature, the normal temperature was taken from the sensor of the other thermometer, and the wet bulb temperature was determined by swirling the sensor of one thermometer with weak, contacting water in a beaker. Relative humidity was computed on the psychometric chart every hour between 9 a.m. and 5 p.m. using the temperature of the wet and dry bulbs.

Utilizing the DHG-9030 freshening oven, the moisture content was ascertained, and a dry bulb thermometer was used to record the solar dryer's temperature initially, an electronic scale was used to measure the variation in weight loss.

4.2 Daily Temperature Variation from 9:00 am to 17:00 pm

Figures 4.1 and 4.2 below, along with Tables 4.1 and 4.2, demonstrate the result obtained for measurement from the ambient, drying chamber, and heating chamber temperature. The temperature is in degree Celsius (^{0}C), and the time is recorded in 24- hour format.

Table 4.1: Test Results for Temperature in Day one

Time	Ambient Temperature	Heating Chamber Temperature	Drying Chamber Temperature
9:00 Am	35^0	57^0	45^0
10:00 Am	36^0	59^0	48^0
11:00 Am	36^0	65^0	56^0
12:00 Pm	37^0	68^0	58^0
13:00 Pm	38^0	70^0	59^0
14:00 Pm	38^0	71^0	59^0
15:00 Pm	36^0	69^0	58^0
16:00 Pm	36^0	68^0	58^0
17:00 Pm	35^0	66^0	55^0

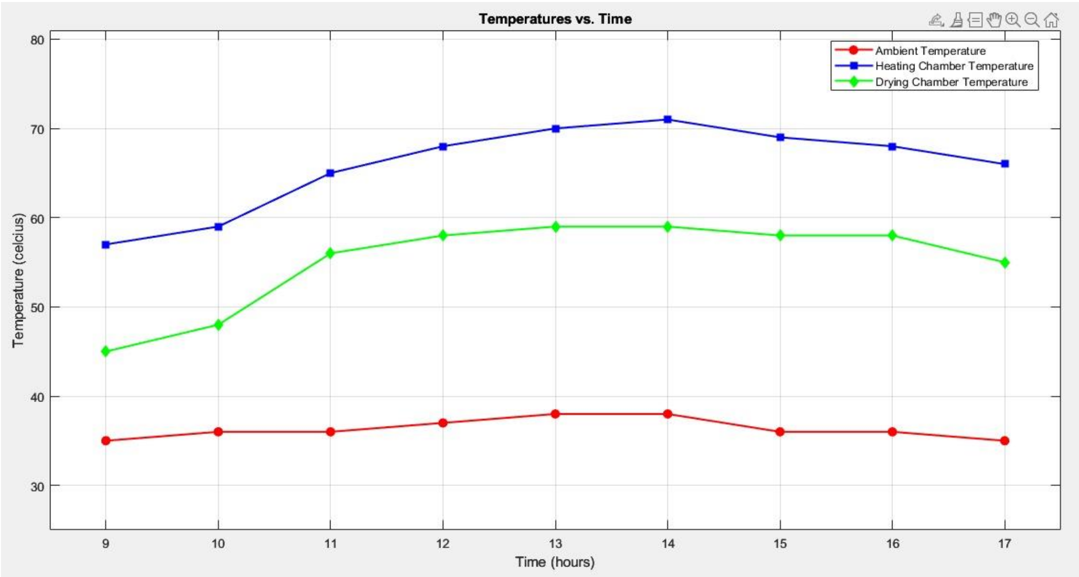

Figure 4.1: Test Results for Temperature in Day one

Table 4.2: Test Results Temperature in for Day Two

Time	Ambient Temperature	Heating Chamber Temperature	Drying Chamber Temperature
9:00 Am	33^0	55^0	41^0
10:00 Am	34^0	57^0	46^0
11:00 Am	36^0	57^0	45^0
12:00 Pm	36^0	59^0	48^0
13:00 Pm	37^0	60^0	50^0
14:00 Pm	37^0	60^0	49^0
15:00 Pm	35^0	59^0	48^0
16:00 Pm	34^0	58^0	48^0
17:00 Pm	34^0	56^0	46^0

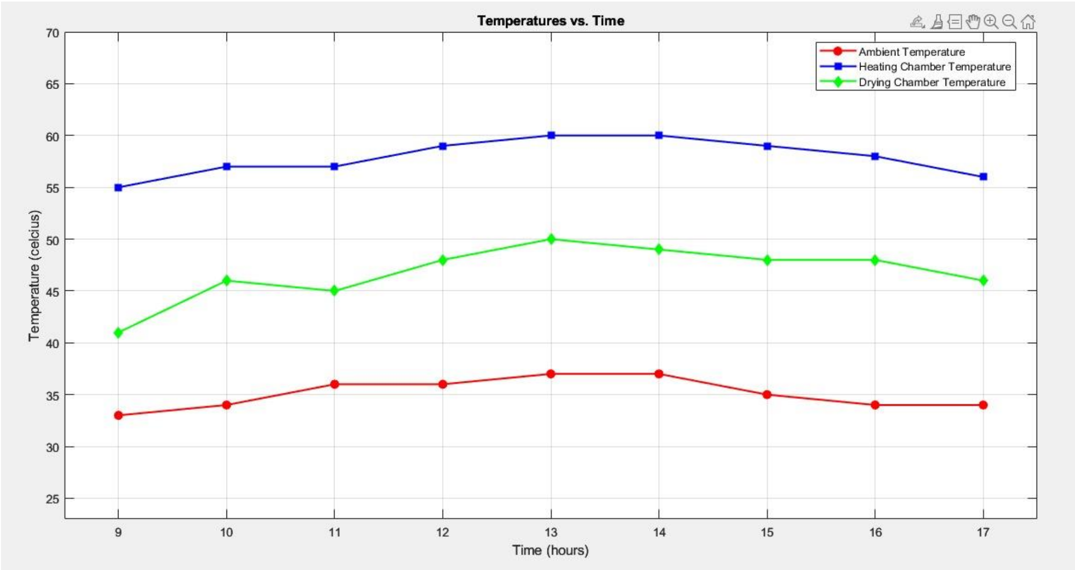

Figure 4.2: Test Results for Temperature in Day Two

Figure 4.3 and 4.4 shown the potatoes and fish on the trays in the drying chamber before drying and after drying respectively.

Figure 4.3: Before Drying the potatoes and fish

Figure 4.4: After drying the potatoes and fish

4.3 Test Results for Moisture Content in Potatoes and Fish

Table 4.3 and 4.4 as well as figure 4.3 below shows the result obtained for measurement from the Fish and Potato. The moisture content is in (%), and the time is recorded in 24- hour format.

Table 4.3: Hourly Moisture Loss and Moisture content for Potato

Time	M1 (g)	M2 (g)	M3 (g)	Av mass (g)	M loss (g)	M Content (%) d.b
9:00	48.0	46.2	44.9	46.9		57.2
10:00	44.5	42..8	41.3	42.9	3.5	54.9
11:00	38.5	37.3	36.0	37.4	9	35.0
12:00	35.1	34.1	32.9	34.0	12.4	22.7
13:00	31.8	30.0	29.6	30.5	15.9	10.1
14:00	29.8	27.7	27	28.2	18.2	1.8
15:00	29.5	27.2	26.5	27.7	18.5	

Table 4.4 Hourly Moisture Content and Moisture Loss for Fish

Time	M1 (g)	M2 (g)	M3 (g)	Av mass (g)	M loss (g)	M Content (%) d. b
9:00	275	273.8	271.9	273.56		58.32
10:00	267	265.4	263.1	265.16	8	56.40
11:00	256.5	254	253.1	254.53	18.5	54.61
12:00	250.1	248.9	242	247	24.9	53.45
13:00	230.1	228.6	225	227.9	44.9	49.41
14:00	200	199.2	197.8	199	75	41.8
15:00	167	165.3	162	164.76	108	30.29
16:00	148	144.2	140	144.26	126.4	21.35
17:00	126.5	125.9	125.1	125.83	148.5	7.98
18:00	125	124.6	124.3	124.63	150	6.88
19:00	123.4	123.0	122.9	123.1	151.9	5.67
20:00	118.2	118	118	118.3	156	1.52
21:00	117.9	117.2	116.4	116.5	158.5	

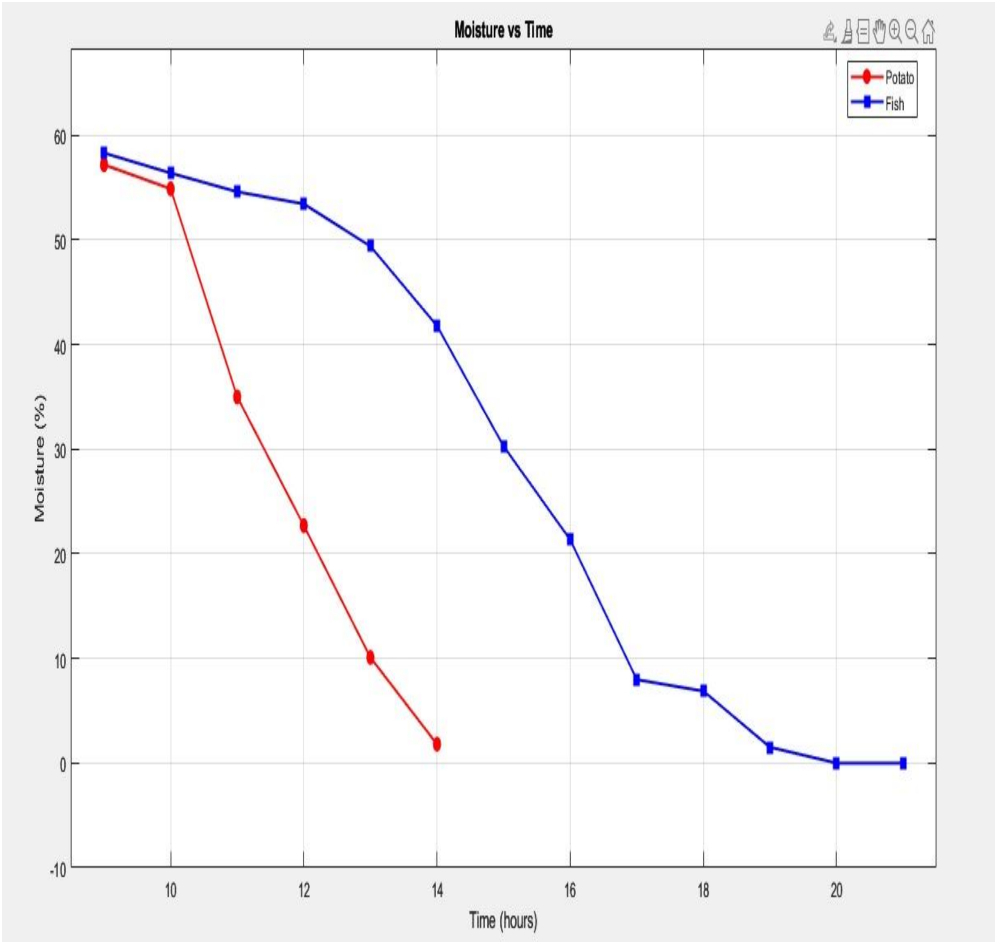

Figure 4.5 Hourly Moisture Content and Moisture Loss for Fish

Chapter Five

Conclusion and Recommendation

5.1 Conclusion

The system was designed to be compact as well as user-friendly, satisfying a variety of foods. It considered essential features such as humidity, ambient temperature, and air movement within the dryer to optimize performance. During testing the maximum temperature of heating chamber and drying chamber was 71 ^{0}C and 59 ^{0}C respectively.

The dryer was fabricated with the installation of a fan extractor to enhance air circulation. Performance testing was conducted by varying the air circulation to determine the drying efficiency was calculated as 42.2 % and average drying speed was 0.0121 kg/ h. Testing showed fan extractor significantly improved the air movement, leading to faster and more uniform drying

Throughout the drying process, the system ensured the preservation of food nutrients and flavors. This was achieved by carefully controlling the drying conditions, which prevented overheating and degradation of the food quality. The dryer effectively extended the shelf life of fresh foods, allowing them to last longer. This was evidenced by the reduced moisture content in the dried foods, which inhibits microbial growth and spoilage.

5.2 Recommendations

The device can accommodate a range of foods and was made to be small and simple to operate. In order to maximize performance, it took into account crucial elements like the dryer's internal air circulation, humidity, and ambient temperature. The heating chamber's and drying chamber's highest temperatures during testing were 71 ^{0}C and 50 ^{0}C, respectively.

To improve air circulation, a fan extractor was installed during fabrication of the dryer. Through performance testing, the average freshening rate was found to be 0.0121 kg/h, and the freshening efficiency was assessed to be 42.2 %. This was achieved by adjusting the air circulation.

The results of the testing demonstrated that the fan extractor greatly increased air flow, resulting in quicker and more even drying. The technique guaranteed that food nutrients and flavors would not be lost throughout the drying process. This was made possible by closely regulating the drying conditions, which stopped the food from scorching and degrading.
Fresh meals were able to survive longer because to the dryer's great shelf-life extension. The lower moisture level of the dried goods, which prevents microbial growth and spoiling, served as proof of this.

References

1. Aboul-Enein, S., El-Sebaii, A. A., Ramadan, M. R. I., & El-Gohary, H. G. (2000). Parametric study of a solar air heater with and without thermal storage for solar drying applications. *Renewable Energy*, *21*(3–4), 505–522. https://doi.org/10.1016/S0960-1481(00)00092-6
2. Al-Juamily, K. E. J., Khalifa, A. J. N., & Yassen, T. A. (2007). Testing of the performance of a fruit and vegetable solar drying system in Iraq. *Desalination*, *209*(1-3 SPEC. ISS.), 163–170. https://doi.org/10.1016/j.desal.2007.04.026
3. Bahnasawy, A. H., & Shenana, M. E. (2004). A mathematical model of direct sun and solar drying of some fermented dairy products (Kishk). *Journal of Food Engineering*, *61*(3), 309–319. https://doi.org/10.1016/S0260-8774(03)00134-1
4. Chen, H. H., Hernandez, C. E., & Huang, T. C. (2005). A study of the drying effect on lemon slices using a closed-type solar dryer. *Solar Energy*, *78*(1), 97–103. https://doi.org/10.1016/j.solener.2004.06.011
5. Ekechukwu, O. V., & Norton, B. (1999). Review of solar-energy drying systems II: An overview of solar drying technology. *Energy Conversion and Management*, *40*(6), 615–655. https://doi.org/10.1016/S0196-8904(98)00093-4
6. El-Sebaii, A. A., & Shalaby, S. M. (2013). Experimental investigation of an indirect-mode forced convection solar dryer for drying thymus and mint. *Energy Conversion and Management*, *74*, 109–116. https://doi.org/10.1016/j.enconman.2013.05.006
7. Harmain, N. B. (2012). *Development of Solar Dryer System for Food Drying Purposes*. *June*.
8. Irtwange, S. V, & Adebayo, S. (2009). Development and performance of a laboratory-scale passive solar grain dryer in a tropical environment. *Journal of Agricultural Extension and Rural Development*, *1*(2), 42–49.
9. Karathanos, V. T., & Belessiotis, V. G. (1997). Sun and artificial air drying kinetics of some agricultural products. *Journal of Food Engineering*, *31*(1), 35–46. https://doi.org/10.1016/S0260-8774(96)00050-7
10. Khajire, S., Birajdar, V., Nagulpelli, S., Bhegade, D., & Kamble, K. (2022). Experimental

Analysis of Solar Air Dryer Using PCM For Fruits Preservation. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4296837

11. Ms. Vaishnavi Bharat Chougule. (2016). Design and Fabrication of a Solar Drying System for. *Ms. Vaishnavi Bhara*, *March*, 1–10.
12. Of, T., & Dryer, A. S. (2011). Design , Construction and Testing of a Solar Dryer By the Department of Agricultural Engineering. *Sah Design*, *06*.
13. Oguntola, A., & Nwaokocha, C. (2010). Design and Construction of a Domestic Passive Solar Food Dryer. *Leonardo Journal of Sciences*, *March*. http://ljs.academicdirect.org/A16/071_082.htm
14. Onigbogi, I. O., Sobowale, S. S., & Ezekoma, O. S. (2012). Design, Construction and Evaluation of a Small Scale Solar Dryer. *Journal of Engineering and Applied Science*, *4*(June), 8–21. https://doi.org/10.13140/RG.2.1.3370.2886
15. Rahman, M. M., Rahman, M. M., & Salam, K. A. (2017). *Design , Construction and Performance Study of an Indirect Type Solar Dryer for Food Preservation*. *December 2017*, 1–76.