Solar Vegetables & Fruits dryer

SESSION: 2019 – 2023

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Approval Page

This is to clarify that the work contained in this thesis entitled "Advance Solar Vegetables and fruits Dryer" by my students "Shahbaz Khan", "Muhammad Usama", and "Muhammad Burhan" was carried under my supervision and in my opinion, is fully adequate in scope and quality for the degree of Bachelor of Sciences in Mechanical Engineering.

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Dedication

1) The Messenger of Allah, may God bless him and grant him peace, said: "Whoever sets out to acquire knowledge, he will be (numbered) in the way of Allah until he returns." (Sunan Tirmizi Hadees No # 2646)

2) The Holy Prophet (peace and blessings of Allah be upon him) said: "Whoever acquires knowledge, it will become an atonement for his past sins." (Sunan Tirmizi Hadees No # 2647)

Following the direction of Allah and Prophet Muhammad (PBUH), our dedication to work increases day by day. And we work with great enthusiasm every day.

We dedicate this work of ours to our loving parents, talented teachers and hardworking farmer

Copyright

"We the team members,

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Abstract

Farmers are suffering significant post-harvest losses as a result of the deterioration in the quality of their food brought on by the prohibitive transportation costs. The high summer temperatures and running cost mixed with this issue makes it even more challenging for them to command a premium price for their production. The range of food preservation is constrained by high costs and a lack of infrastructure. These variables combine to create a situation where farmers find it more cost-effective to discard some of their produce rather than incurring high transportation costs and receiving little in return.

Various types of solar dryers are used in many areas of the world for different purposes. Solar crop dryer, solar fish dryer, the five drying units inside the building containing the solar crop dryer, and the interior of the hut containing the drying bed of the solar fish dryer—these types of solar dryers are commercially installed in Ghana, West Africa. But these dryers use only one source of energy, i.e., solar energy, and when there is cloudy weather, these dryers become useless.

In our dehydrator, we overcame this issue and installed a secondary source of energy, i.e., electricity, that will provide heat when the temperature is low. We installed a 100-watt bulb in the dehydrator, which will maintain the required temperature level. Additionally, there is also polycarbonate glass instead of normal glass because it does not reflect back sun radiation. Another advantage of our dehydrator is that it has a temperature and humidity controller that controls both temperature and humidity levels based on different food items. Our dehydrator efficiently worked in Peshawar, Khyber Pakhtunkhwa, Pakistan, but it can also be extended to any area of the world by setting controller values.

Acknowledge

First and foremost, praises and thanks to the Allah Almighty, for His showers of blessings throughout our project. I am grateful to the Allah for good health and wellbeing that were necessary to complete this thesis.

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Secondly, we would like to thank our family for all the time support and encouragement throughout life. We also thank to our co-supervisor **Engr. Hashim Khan** lab supervisor of Mechanical Engineering who help us in software used in our FYP project.

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CHAPTER # 01

1 INTRODUCTION

1.1 Overview

The ongoing search for a substitute for fossil fuels was accelerated by its erratic increase and periodic scarcity. One of the clean and renewable energy sources that has drawn a sizable group of academics from all around the world is solar. This is mainly because it is available in both direct and indirect forms in abundance. So, the creation of effective and affordable equipment for the solar-powered drying of agricultural and marine products evolved, enhancing both the quality of the products and the quality of life. Solar dryers are used to dry a variety of agricultural products and come in a variety of sizes and designs. Farmers can choose from a variety of dryers to meet their demands; it has been discovered.

A continual application of relatively modest heat is typically required to dry agricultural items like coffee, tobacco, tea, fruit, cocoa beans, rice, nuts, and lumber. Crop drying has traditionally been done by open-air drying in filtered sunlight or by burning wood and fossil fuels in ovens. However, there are drawbacks to these approaches. The latter is vulnerable to the variety and unpredictability of the weather, while the former is expensive and harmful to the environment.

Agricultural items including grains, vegetables, and fruits are renowned for their high vitamin content, high moisture content, and low fat content. These crops are available mostly during the growing season because they are seasonal. Despite the growth, the expanding population's demand for veggies has not been satisfied. This is due to wastes produced by biological and biochemical processes that occur while the product is still fresh, unsuitable storage conditions, ineffective handling, inadequate transportation, inadequate post-harvest infrastructure, and subpar market outlets. In the majority of tropical and subtropical nations, sun drying is still the most popular technique for preserving agricultural items like grains and vegetables.

1.2 History of Food Preservation

Humans have been preserving food for thousands of years in an effort to keep food fresh, nutrient-dense, and delicious over time. Food was preserved for considerably longer periods of time using ancient techniques including drying, salting, and smoking. Modern food preservation techniques like pasteurization, refrigeration, vacuum-packing, and freezing are used today.

Drying was one of the first methods of food preservation. Ancient cultures like the Chinese and the Egyptians used drying to increase the shelf life of some foods. This technique was applied to preparing food for lengthy journeys as well as storing food for the winter. The sun, the smoke from fires, or heated ovens could all be used to dry fruits, vegetables, cereals, and meats. Foods that were dried were less likely to deteriorate and could be rehydrated when needed.

The Chinese were renowned for using salting to preserve food. Many different types of food, including fish and vegetables, were preserved using this technique. Food that has been brine-salted and stored in an earthenware vase or buried in sand can be kept from spoiling and remain edible for several weeks or months. Also, adding salt gave meals a distinct flavor that would be difficult to achieve otherwise.

Another crucial approach used in ancient preservation techniques was smoking. Several cultures utilized it to preserve the freshness of meat. Over a slow fire, fish and meats were hung to smoke, and flavor-enhancing fragrant wood was frequently added. As a result of the smoke's acidic environment and the interaction of heat, seasoning, and smoke compounds, dangerous bacteria's ability to proliferate was hampered.

A more contemporary method of food preservation is hoover packing. By removing air from a container, this technique creates an environment in which bacteria cannot survive. If correctly sealed, food stored in a vacuum bag can keep far longer than food stored in a conventional container.

Through the application of heat, the process of pasteurization is used to preserve some foods. Louis Pasteur invented it in 1864, and today it is primarily used to preserve dairy products, juices, and foods that are canned. Hot-fill pasteurization, in which a heated product is maintained at a given temperature for a predetermined amount of time, is the most used type of pasteurization.

Another way to preserve food is by canning. It entails placing food inside heated containers to seal and disinfect the contents. Nicolas Appert developed this technique in 1809, and it has completely changed how people store food. Foods in cans are safer and can last up too many years longer than food in the fresh state under optimal circumstances.

Another method of preserving food involves applying hot or low heat to it. Food can be frozen and kept for long periods of time with little nutritional loss. Similar to how it can prevent food from spoiling, heat treatment can kill hazardous bacteria.

Finally, germs and pathogens carried by food can be killed by irradiation. Food is subjected to gamma or electron beams during this process, which significantly lowers the risk of foodborne illness [1].

1.3 Ancient Time and Preservation Techniques

A sizable jar of honey was discovered in Egypt around 1800 by a group of archaeologists. Even though it was thousands of years old, they discovered when they opened it that the food tasted great. They noticed some hairs as they delved greedily into the jar, and as they dumped out the honey, they found the tiny baby's well preserved body.

The dead were frequently given a quantity of honey during burial rites to consume as they travelled to the afterlife. As honey was associated with immortality, many of the great men (and women) of the Aryan, Sumerian, Babylonian, and Cretan civilizations were interred in it beginning in the Neolithic period. When Alexander the Great passed away in Babylon in 323 B.C., he made the decision to be preserved in honey.

The preservation of the body and the supplies required for that voyage were taken extremely seriously by the Egyptians since they believed it to be the longest and most significant journey. Originally, the remains were dried in the hot, dry sands of the desert, but in later dynasties, the Egyptians wrapped the dead very securely in linen wraps due to the widespread idea that contact with air somehow induced putrefaction. Even though they had the right notion, until they attempted first removing the internal organs, this was not very successful.

At some point, they were able to comprehend the fundamental conditions necessary to keep a corpse adequately, if not always perfectly. The heart was left in place because it was thought to be the seat of understanding, according to Herodotus, who was writing in the fifth century B.C. Natron, a powdered salt that had been left in large quantities by evaporation near oasis in the Egyptian desert, was generously applied to the human cavity, both inside and out.

The abdominal cavity was dried after the salt removed the water from the tissues, and it was then filled with linen and stitched shut. It was thoroughly bandaged after being tested with ointments, herbs, and resins. Only the affluent and powerful could afford this complicated process. Furniture, chariots, priceless objects, significant items, and even stocks of onions and garlic that had been meticulously wrapped in bandages to resemble a guard of noxious little mummies were all placed inside their tombs.

The remains of a Han-era noblewoman were discovered in a tomb in China in 1972. (202B.C.-A.D. 220). The woman's body was remarkably preserved, and among the abundant burial remnants were copious supplies of food to sustain her and her husband—who was also interred with her—during their endless voyage. Rice, barley, red lentils, and millet were all preserved in various types of ceramic and bamboo containers. Along with lotus root, root ginger, and numerous spices, the site also contained fruits like pears, jujubes, and plums, as well as the remains of animals including hares, pigs, deer, sheep, and oxen, as well as duck, chicken, and pigeons.

Hundreds of written bamboo slips with instructions on cooking and methods for preserving food, like salting, sun-drying, and pickling, were also discovered by archaeologists. Whom was supposed to read these and cook some divine dinners is unknown.

Prehistoric insects that are thousands of years old have been found beautifully preserved in amber, and perfectly preserved mammoths have emerged from the permafrost, their tusks now being used as an alternative to elephant ivory. A Tungus hunter discovered the first mammoth that had been frozen in Siberia's ice in 1977, with its last meal of grass and pine cones still preserved in its stomach.

When William Buckland was dean of Westminster and an Oxford professor of mineralogy in the early nineteenth century, he once offered a dinner guest flesh from a frozen mammoth. You just consumed beef that is 1,000 years old, he said to his friends.

We've received other people and animals that have been preserved in a variety of ways. Men and women who had been offered as sacrifices have been discovered buried in mountain salt mines from the tenth century with their bodies completely preserved by salt. Their picks, salt blocks in knapsacks, and pottery pots for evaporating and shaping the salt into slabs were all found nearby. Recently, a frozen man emerged from a glacier carrying his "ploughman's lunch" in a skin bag. Lord Nelson arrived last but not least, if only for the duration of his journey from Trafalgar to a dignified burial. He was kept in a barrel of brandy.

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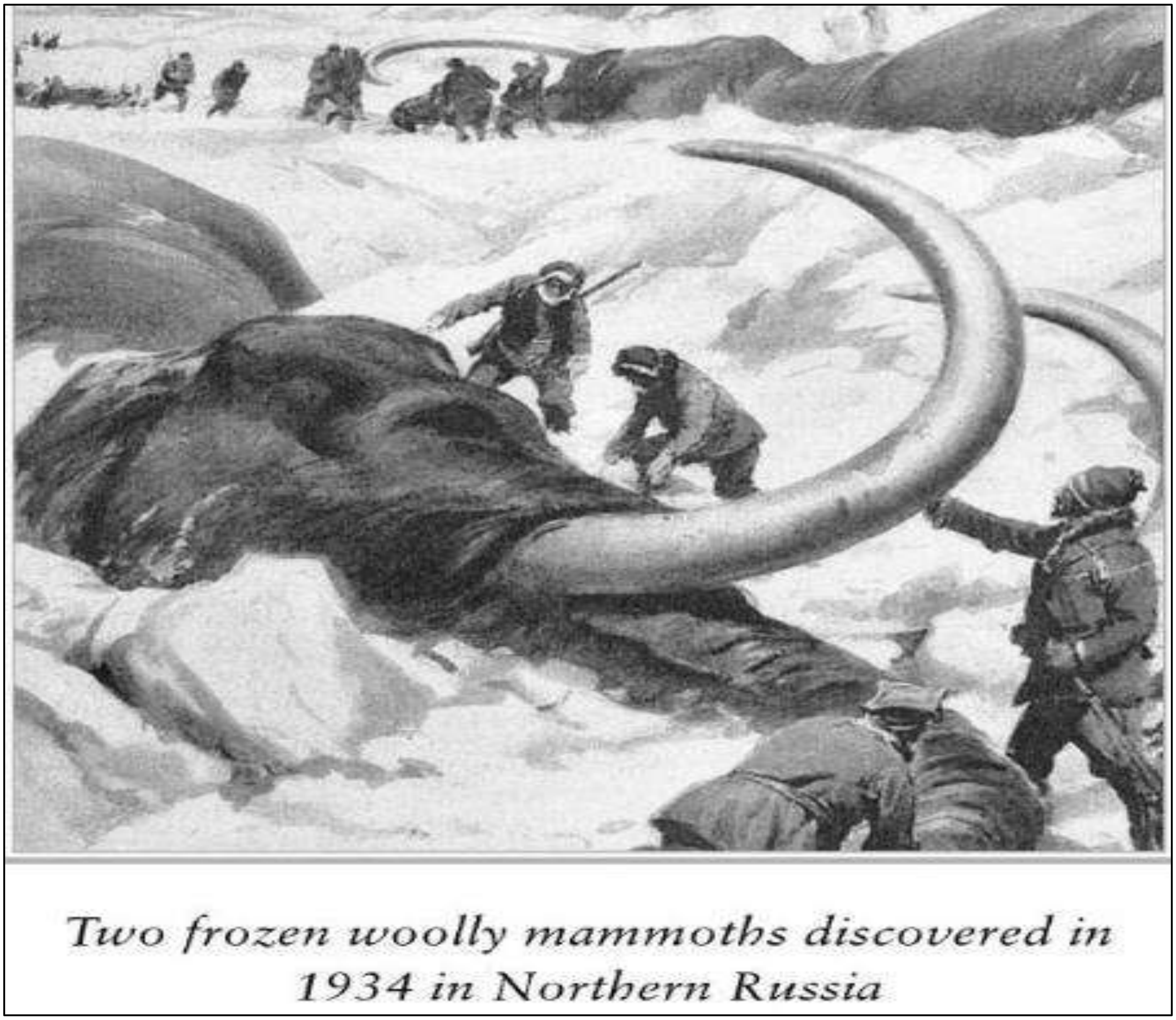


Figure 1-1: Two mammoths discovered in 1934

The word used in ancient Egypt to describe the technique of embalming mummies is also used to describe the preservation of fish through salting and drying. Each of these ancient traditions for preserving people and animals for the afterlife has a parallel in the principles of food preservation that are currently known, including drying with salts and spices, preserving in honey or brine, freezing, sealing in airtight wrappings or containers, or preserving in natural media like amber, alcohol, or formaldehyde, as well as burying in cool, wet bogs full of boric and other acids.

The ideas are remarkably straightforward, but the customs that have grown up around them—however sophisticated or simple—offer wonderful insights into the pasts, civilizations, and inventiveness of people in their struggle for survival and advancement.

1.4 Benefits of Food Preservation

Food preservation altered foods' texture and flavor as well as their safety for consumption, sometimes in disgusting ways to those who were not accustomed to them. Certain nations in Africa and the South Pacific Ocean valued the strong, acrid flavor of rotten, fermented foods. Around the world, various methods of food preservation have influenced the development of regional cuisines and palate preferences.

People from Scandinavia and Russia enjoy sour flavors, while vinegary flavors are more common in eastern Europe. Poor people around the world could manufacture very flavorful preserved sauces, pickles, and relishes to liven up their bland, monotonous diets of porridge. Moreover, preservation improved the taste of some meals and turned some noxious or even inedible plants into food that was safe for consumption.

The use of preservation techniques resulted in the development of intriguing new food varieties that became part of several cultures' traditional diets. They include chewy dried fruit that tastes like sunshine, jams and marmalade, and rich, sugared fruits and nuts. Other examples include juicy smoked hams, spicy dried sausages, and sweet cured bacon.

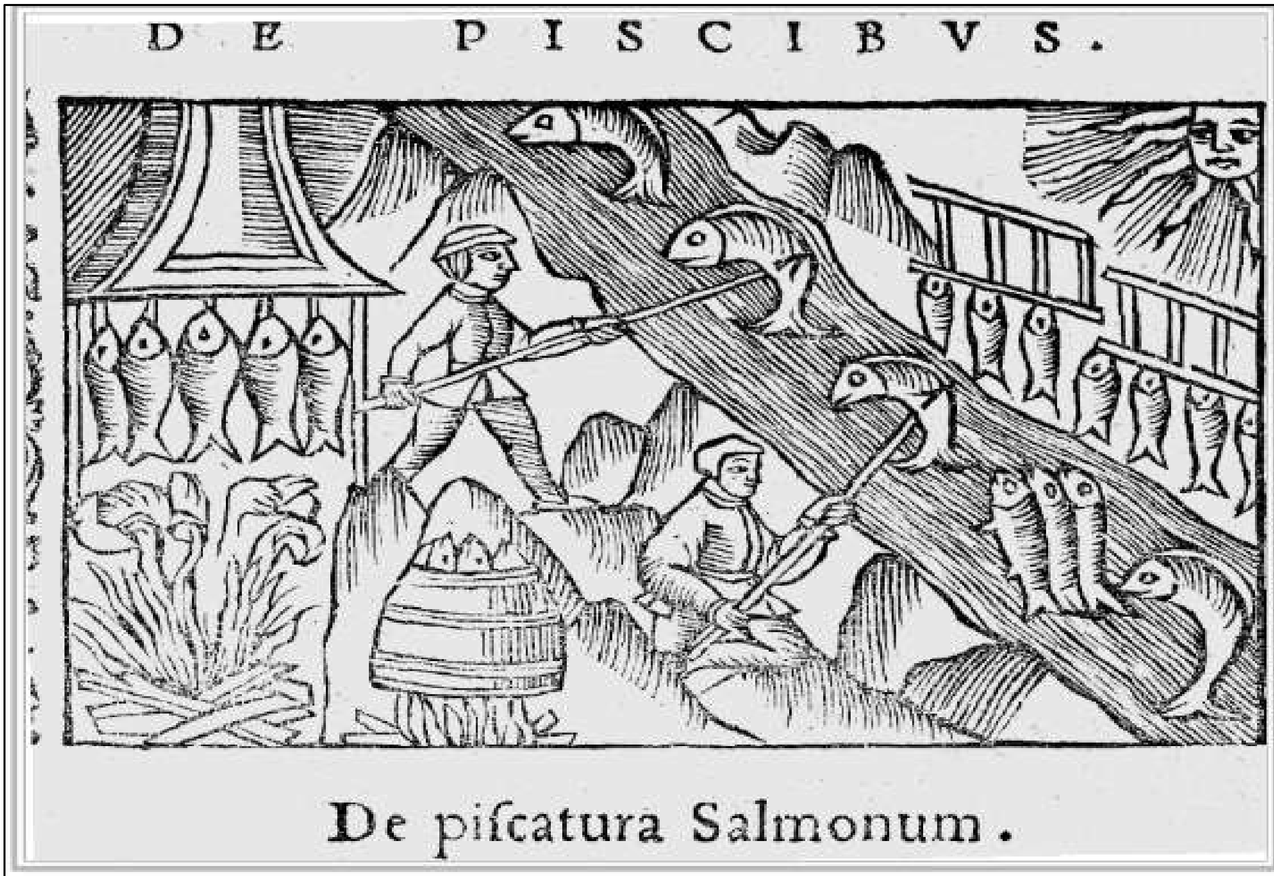
Milk was converted into a variety of matured cheeses and rich salted butter. For pairing with cheese and stewed meats, many types of dense, dry breads and biscuits were created. Salt cod, delicate gravlax, and pink smoked salmon were used to create traditional national dishes. Although while the necessity of food preservation for survival may no longer be as critical, our desire to consume food and experience the distinctive flavors it has given us is as strong as ever [1].

1.5 History of Food Drying Process

Mountain men—backwoodsmen, trappers, hunters, explorers, and adventurers—were leading their own extremely unique existence in the old Northwest long before immigration settlers and gold seekers had started to populate the America West in the middle of the nineteenth century. These wild, lonesome men who survived on their wits and travelled lightly are now characters of romance and legend.

Trappers who would spend months in the highlands and forests hunting beavers, whose tail hide was particularly precious, were among them. They would get together at the traders' fur marketplaces once a year, which were referred to as the "annual season of supply, trade, and saturnalia." Mangy hunters would tussle with keen-eyed traders and wary Indians at these wild fairs. The money from selling their skins was used to buy alcohol, resupply, and repair the trappers' wounds. The skins were exceedingly delicious and enjoyable to chew.

Dead snakes and locusts were discovered in the desert and were devoured. Some of the seasonal catch was buried beside lakes and along the coasts by the fisherman, who also hunted it up to dry. Unexpected discoveries became recurring practices, and as hunter-gatherers increasingly settled down to agrarian pursuits, they began to find means of making their extra food produce keep for when it was most required.



Catching, sun-drying, smoking, and curing salmon in northern Europe in 1555

Figure 1-2: Ancient Fish Preservation

Initially, dried meat, fish, and fruits would simply have been eaten uncooked and dry; saliva and chewing in the mouth would have moistened and softened the texture to enable swallowing and digestion. Dried foods could be soaked back to virtually its original state and utilized in stews, soups, compotes, and other increasingly complex recipes as soon as liquids could be contained in containers, such as skins, bladders, and later clay and iron cooking pots.

There is evidence that as early as 12,00 B.C., Egyptian tribes-people on the lower Nile dried fish and poultry using the hot desert sun. Areas with similar hot and dry climates found drying to be an effective method of reservation. The ancient Babylonians, whose culture reached its apogee in around 1690 B.C., made a concentrated paste from pounded dried fish that they crumbled up into their pottages.

The ability to preserve was essential for survival in some hostile areas. During his invasion from Macedonia to India in 334–323 B.C., Alexander the Great's commander observed how important drying was to the locals of Baluchistan, a coastal region in what is now Pakistan. A considerable portion of the fish catch was consumed raw, but the larger and rougher fish were ground into flour and used to create bread and cakes. The larger and tougher fish were dried in the sun until they were quite dry. Even their flocks are fed dried fish because there are no meadows or grasslands in the area [1].

1.6 Problem Statement

- Khyber Pakhtunkhwa's farmers are suffering significant post-harvest losses as a result of the deterioration in the quality of their food brought on by the prohibitive transportation costs. The high summer temperatures mixed with this issue makes it even more challenging for them to command a premium price for their production. The range of food preservation is constrained by high costs and a lack of infrastructure. These variables combine to create a situation where farmers find it more cost-effective to discard some of their produce rather than incurring high transportation costs and receiving little in return.
- All of this creates a vicious cycle for the local farmers, making it difficult for them to escape the grip of poverty and reducing their possibilities of advancement by obtaining high prices for their goods. Furthermore, because it is a source of greenhouse gas emissions, excessive fruit and vegetable waste has a negative effect on the environment.
- Only regions where the weather permits food to be dried right away after harvest in an average year are capable of sun drying.
- The items may, however, be significantly damaged by rain, wind, dust, damage from birds, insects, and other animals, and occasionally become inedible as a result. The resulting loss of food quality in the dried products may have negative economic effects on domestic and foreign markets.
- Certain fruits and vegetables lose quality (color and nutrient content) when exposed to direct sunlight. Also, as sun drying depends on outside circumstances, uniform and standardized product output is not anticipated.

1.7 Scope of Project

- By circulating heated air, food dehydrators significantly reduce the product's moisture content. By reducing the moisture content, microbial activity is inhibited, preventing food spoilage. The traditional method of sun drying, which helps preserve otherwise perishable food items like fruit and vegetables, has been upgraded by this technology. We plan to build a solar dehydrator that uses modern technology and an eco-design approach to ensure that the batch dries evenly. In contrast to other dehydrators now on the market, our dehydrator can prevent over drying by managing solar heat. Also, the end users will benefit from energy conservation and a shorter dehydration period.
- Briefly, upon successful completion of this project and subsequent commercialization will help the farmers of Khyber Pakhtunkhwa in particular to overcome the issues related to the high level of transportation charges and low market value of their produce because of the quality deterioration after the harvest. Further, the more the fruits and vegetables are consumed and preserved the lesser will be the wastage consequently the adversity on environment will be reduced as well.
- By using a solar dryer, some of the issues with open-air sun drying can be resolved. This solar dryer has the ability to work in any condition (hot summer days and cold winter days) because this solar dryer include temperature and humidity controller device which help to maintain the required temperature and humidity in the drying chamber.
- In addition, there is also three temperature and humidity measuring devices which will indicate inflow of temperature and humidity in air, temperature and humidity in ambient air and temperature and humidity in outflow of air. These values of temperature and humidity will then be used in numerical calculations.
- Also there is polycarbonate glass, which has the property to absorb solar radiations and does not allow to transmitted from it.

1.8 Objectives

1. Indigenously fabricated solar dehydrator.
2. Improvement in the livelihood of the farmers of KPK.
3. Reduction in food waste and greenhouse gases.
4. Conservation of Environment.
5. Better utilization of the produce of the fruits and vegetables of KPK.
6. Exports of fruits and vegetables will increase.
7. The scarcity of fruits and vegetables will decrease.

1.9 Components

Table 1-1: Material and Specification

MATERIAL	SPECIFICATION
Chamber	Imported wood (4ft Height × 3ft width)
Gate	Imported Wood (4ft Height × 3ft width)
Lower supporting Frame	Mild Steel (1.5ft Height) (2.5ft Length × 3ft Width) Thickness = 1 inch or 25.4 mm
Temperature/Humidity Controller	Temperature range = (0 — 80) °C Measuring Humidity range = (1 — 99) % RH Accuracy = $\pm$ 1° , 0.1 % RH
Temperature/Humidity Measuring Sensor	Temperature range = (-50 — 70) °C Measuring Humidity range = (10 — 99) % RH Humidity Accuracy = $\pm$ 1℃ , 5 % RH
Solar Radiation Collector Area	Area = 4×3 ft^2 Inclined = 216°
Polycarbonate glass	Area = 4×2.5 ft^2 Thickness = 5mm
Fan	12V, DC (Optional)
Trays	3 Quantity
Black Painted Iron Sheet	Thickness = 1.5 mm
Glass	In Gate Area = 3.5×3.5 ft^2 Thickness = 5mm
Weighing scale	0.1g to 500g

1.11 TECHNICAL SPECIFICATION

Table 1-2: Technical Specification

Prepared by:	The trailblazer	**Department:**	Mechanical Engineering
Purpose:	Final Year Project	**Batch:**	2019-2023

PROJECT SPECIFICATIONS			
Title:	Solar Vegetables and Fruits Dryer	**Location:**	Peshawar, Pakistan
Target Date:	1st June, 2023	**Budget:**	Rs 50,000

BASE EQUIPMENT	
Manufacturing Equipment	• Wood • Polycarbonate Glass • Black Painted Iron Sheet
Controlling Equipment	• Sun • Secondary Source • Temperature and Humidity Controller
Purpose	• Vegetables Drying • Fruits Drying
Use Scenario	
The dehydrator can be used for drying vegetables and fruits. This dryer has many features i-e secondary source which will provide temperature in cold climate, a temperature and humidity controller which have the ability to control both low and high ranges of temperature and humidity, and three temperature and humidity measuring sensor which will be located at different locations.	

1.12 Thesis Structure

1.12.1 Chapter: 01

Chapter: 01 is the brief introduction about the history of food preservation. In the history of food preservation, we get knowledge about how the process of food preservation came into being. After this we discuss about preservation techniques during ancient times. In this we get knowledge about how ancient preserve their food and bodies of themselves as well as their animals after death. Then there is benefits of food preservation. In this section, we get knowledge about what are the benefits of food preservations. Later, we discuss about history of food drying process briefly. Then we move toward our project problem statement and scope of our FYP project. At last we discuss about objectives, design specifications and flow chart.

1.12.2 Chapter: 02

Chapter 02 is the detailed literature review and available solar dryers in the market, i.e., domestic or industrial. Then we will move toward research gap identification and will discuss about research gap between solar dehydrator and environment of Pakistan. Later in this chapter we will propose concept generation and concept reduction.

1.12.3 Chapter: 03

Chapter 03 gives a summary of the research methods employed in the study. It will provide information on the study's participants, such as their identities, backgrounds, and the methods used to choose their samples.

1.12.4 Chapter: 04

This chapter will provide the design details that are necessary to build our product model. Layout drawings of the design will be offered to show the parts required to build a product. The section of the bill of materials that is allocated to it contains the component part list. In addition, we will discuss the benefits and engineering properties of our chosen material for our dehydrator.

1.12.5 Chapter: 05

In this chapter we will discuss briefly upon our prototype CAD modeling and their dimensions. And the we will also show them assemble and will discuss each and every components working mechanism.

1.12.6 Chapter: 06

In this chapter we will discuss Finite Element Analysis of our dehydrator. Finite element analysis (FEA), a method, is a computing approach that can be utilized to address challenging mechanical issues. The engineer can mimic reality regardless of the situation or complexity by choosing sound boundary conditions and loads. The mechanical behavior of products and structures can be investigated and optimized without the necessity for prototyping. Profits represent the quick returns in relation to the time and money invested during the design phase. Additionally, it improves your product's dependability.

1.12.7 Chapter: 07

In this chapter, we will discuss the fabrication of different components and their manufacturing processes. The fabrication process is done according to the design and specifications made in CAD.

1.12.8 Chapter: 08

This will be very important chapter of the thesis. In this chapter we will perform particle working and analysis of food drying process in our fabricated dehydrator. In this chapter, we will deal with graphs, tables and hurdle if any uncertainty happens during preservation process.

CHAPTER # 02

2 CONCEPT SYNTHESIS

2.1 Introduction

In this chapter, we will discuss:

- literature review in detail on solar dehydrator with different aspects. We will also discuss about available solar dehydrator in world.
- Then we will move toward research gap identification and will discuss about research gap between solar dehydrator and environment of Pakistan.
- Later in this chapter we will propose concept generation and concept reduction.

2.2 Literature Review

2.2.1 Book Title "How the Art and Science of Food Preserving Changed the World"

Originally published in Great Britain in 2000 by Headline Book Publishing Ltd.

Written by: SIMON & SCHUSTER PAPERBACKS

Edition: 2006

Designed by: Katy Riegel

This is very interesting and knowledgeable about the history of food preservation, ancient time and preservation techniques, benefits of food preservation, history of food drying process as discussed some information in chapter: 01. This book contains brief history about how concept of food preservation came into being and how ancient use different methods to preserve their food.

In the world, everything we eat was once an animal or plant, depending on the type. Our food begins to degrade as soon as it is killed or removed from the stalk, branch, or soil. Even while it may not be immediately hazardous to humans, this negatively impacts its value as food that is edible or nutritious. If we don't swiftly take advantage of food, something else will because the food chain is competitive. Many of the millions of tiny microorganisms that thrive in water, air, and soil are particularly drawn to food that benefits us.

When Louis Pasteur released his 1861 study demonstrating that germs were present in the air everywhere in the late nineteenth century, it was not until then that their significance was fully appreciated. He had taken some air from various locations and passed it through extremely fine guncotton filters. Little spores were discovered when the filters were later dissolved in an ether and alcohol solution. The air was then drawn into a flask holding a sterile infusion by Pasteur through a guncotton stopper. The infusion quickly turned bad when the plug, which was now covered in airborne spores, fell into the flask. Finally, Pasteur had demonstrated that airborne bacteria are what cause putrefaction.

Before that time, the general consensus was that decomposition was a natural occurrence brought on by exposure to air in an unknown manner. This critical error prevented the advancement of food preservation methods until the discovery of Pasteur. In actuality, microorganisms had been observed but were not completely understood sooner.

In 1665, Dutch optician Antonie van Leeuwenhoek used a home-made microscope to observe what he called "living animalcules." By heating food-borne microorganisms in a sealed flask in 1774, an Italian priest named Lazza Spallanzani attempted to refute the hypothesis of spontaneous degeneration. However, in a pattern seen throughout the history of food preservation, no one was really paying attention enough to draw the appropriate conclusions. As a result, people successfully prevented their food from going bad using empirical and, for the most part, scientifically sound methods without feeling the need to properly understand what they 've done it.

Despite not being able to see or understand microbes, humans have since the beginning of time been able to see the effects of their activities. They would have witnessed food go bad, so they started practicing a variety of efficient ways to rob these unidentified critters of their feast. They developed methods best suited to their unique habitat, employing the elements and natural compounds available.

Remarkably, they also learned how to cultivate particular microbes in a way that allowed them to be useful in preserving specific foods—bacteria for yoghurt (lactobacilli naturally found in milk) and yeast (from the grape bloom) for bread, beer, and wine—a process often known as fermenting.

The microbes that break down food come in many different varieties, but they all require the same basic conditions to thrive: a warm, moist environment that is somewhat acidic and an oxygen supply. (Anaerobes, a type of bacteria that can grow in the lack of oxygen, must be eliminated at all costs when food is being preserved. The most hazardous of them is Clostridium botulinum, which is the cause of botulism.

The majority of preservation techniques try to eliminate these elements in order to kill or inhibit the offending bacteria from returning to the processed food. Hence, it's also crucial that preserved goods are packaged and stored effectively.

To provide hazardous bacteria with a foreign environment, a wide range of approaches have been devised. People quickly started combining the many techniques, employing a variety of natural ingredients, and conserving media because there are only a few processes that can completely eliminate all the bacteriafriendly conditions. The heat of the sun, hot and cold breezes, hot sands, cooling coils, fire and smoke, salts, sweets, spices, herbs, acids, oils, airtight containers, or helpful yeasts were all used by people.

The technique of preservation most likely evolved over a protracted period of time through experimentation and taste. To produce a meal that would live longer than that generated by just one way, the idea of combining many procedures, such as drying, airtight packaging, and low temperature, would have been embraced. Perhaps a fortunate accident was the fact that they frequently worked well together or that one ingredient served to balance the bad effects of another. But it's no longer surprising how well our ancestors were able to watch, adapt to, and "game" nature [1].

2.2.2 Research Paper Title "Factors Affecting Household Food Security in Rural Northern Hinterland of Pakistan"

Publication date: April, 2019

Authors: Abdullah, Deyi Zhou, Tariq Shah, Sajjad Ali, Waqar Ahmad, Izhar Ud Din, Aasir Ilyas

Everyone faces a food availability issue, but the impoverished world is particularly affected. Food security refers to the availability and accessibility by each member of the household of food that is nutrient-sufficient, culturally acceptable, and obtained in a manner that promotes a healthy lifestyle. Contrarily, food insecurity refers to the uncertain or limited availability of safe, nutrient-dense food (Andersen, 1990, FAO, 2006). Because of the complex character of food security, it is difficult for policymakers to accurately measure and target their policies.

Food security, on the other hand, is defined as "reliable, constant availability to enough food for an active, healthy lifestyle" According to the FAO, "a scenario arises when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that fits their dietary needs and food preferences for an active and healthy life." is the definition of food security used in this study. There are four main components to this definition: availability, stability, accessibility, and utilization. When one or more of the four aspects of food security are uncertain and unstable, a food system is said to be susceptible. Food security, according to the FAO, is "a condition where all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that fits their dietary needs and food preferences for an A healthy and active existence.

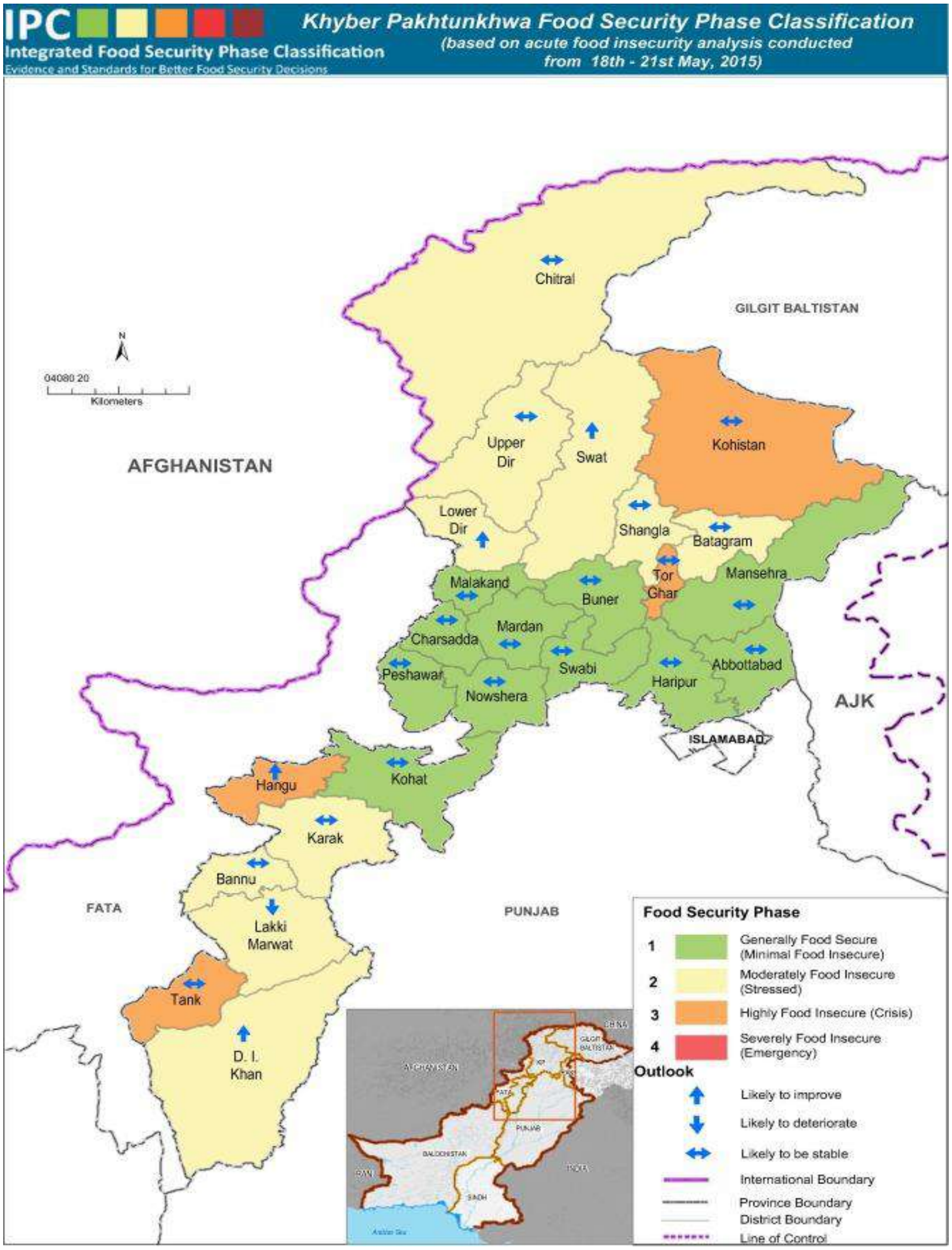
With a 2015 average per capita income of $1,512, Pakistan is one of the developing nations of south Asia. The government of Pakistan developed a number of contemporary, scientific procedures and strategies to strengthen the agricultural industry. Amounts contributed by agriculture to GDP and employment total roughly 20.88% and 43.5%, respectively. The agriculture sector is vital to the nation's socioeconomic development and has both mediated and unmediated ties to other economic sectors. Pakistan now ranks sixth in terms of population, with a population of an estimated 191.71 million and a growth rate of 1.92%. In 2015, 116.52 million people lived in rural areas, while 75.19 million lived in urban areas.

In one year, the percentage of people living in rural areas dropped from 61.4% to 60.8%, while that in urban areas rose from 38.5% to 39.2 by 2015. The rural population depends on agriculture for a living, either directly or indirectly. "All people, at all times, have physical and economic access to sufficient, safe and nutritious food to suit their dietary needs and food preferences for an active and healthy life," states Pakistan Vision 2025 .

Pakistan has been impacted by food insecurity for many years. This is the result of a number of historically significant events, including the war on terror, military operations in residential areas, catastrophic floods that wrecked infrastructure and crops, and most recently, the earthquake. The Global Hunger Index (GHI), which illustrates how persistent the issue has been, makes this very obvious. Although Pakistan's score on the World Hunger Index dropped from 43.6 to 33.9 between 1990 and 2015, the situation remained the same as Pakistan continues to be classified as "very worrying," ranking 93 out of 104 countries.

In Khyber Pakhtunkhwa (KPK), food security is a major issue because the province can't produce enough food to meet demand and must import food from other provinces that receive subsidies. To close the gap between the supply and demand of food, it is imperative to raise the production of various crops by implementing cutting-edge techniques and technologies. The province of KPK is categorized as moderately food insecure by the Integrated Food Security Phase Classification as four districts are very food insecure, ten districts are moderately food insecure, and eleven districts, along with district Malakand, are generally food secure.

Figure 2-1: Khyber Pakhtunkhwa Food Security Phase Classification.



2.2.2.1 *Result and Conclusion*

The purpose of this study is to investigate the variables affecting household food insecurity in Pakistan's rural north. 294 households provided quantitative data between June 2016 and July 2016 for collection. The data collected includes the respondents' demographics as well as a wide range of other elements that are thought to influence household food insecurity. To investigate the state of food security in Pakistan's north, descriptive statistics were used. Furthermore, logistic regression analysis was used to determine the variables affecting the food security of households.

Using a standardised questionnaire and a basic random sampling technique, the data was gathered. Due to the high incidence of illiteracy in the study area, the questionnaire was pre-tested before the real survey and then it was provided verbally to the majority of the participant. In this study, 294 households in total were examined. According to the size of their populations—339,442 in Tehsil Batkhela and 228,139 in Tehsil Dargai—approximately 196 and 98 respondents, respectively, were chosen from each.

Also, the performance of agriculture is significantly changed by the contribution of productive resources like agricultural technology. The use of agricultural technologies could lessen food insecurity. Improved seeds, for instance, can result in increased yield, and irrigation can lower the risk of crop failure. The survey used in this study helped identify a number of important factors contributing to food insecurity in Pakistan's northern region [2].

2.2.3 Research Paper Title "Economic Analysis of Food Security in Peshawar, Pakistan"

Publication date: 15th, Nov, 2020

Authors: Sundais Hussain, Hina Hussain, Muhammad Nisar, Seema Zubair

This research is based on the District Peshawar, Khyber Pakhtunkhwa, 300 residents were questioned in order to analyze and explore the situation with regard to food security. Food insecurity is one of Pakistan's most difficult problems. According to the 2017 edition of the World Food Program, 56% of the population of Pakistan, only in the province of KP, suffers from food insecurity. Although food is available in Pakistan, the majority of the population still experiences food scarcity, including famine, as a result of inadequate access to food. The main cause of this condition is poverty, as impoverished people are unable to purchase an adequate amount of nutritious diet.

Because these households have few economic prospects and little to no access to agricultural land, they are more likely to migrate, which is why the issue of food security for vulnerable families is directly tied to migration. Due to the detrimental consequences of floods, which frequently occur as a result of climate change, food safety issues are becoming more and more prevalent in the modern world. Food insecurity is related to inadequate food availability, food scarcity, and food purchasing power.

In KP, there was a shortage of wheat output in nearly 24 districts in 2009. Due to the supply of wheat to Afghanistan and the Federally Administrated Tribal Territory, the KP is increasingly vulnerable to food instability (FATA). The KP faces a cereal deficit as a result of small landholdings, a lack of arable land, and a higher population density. Peshawar, Kohat, Karak, Lakki Marwat, Tank, Bannu, Abbottabad, Nowshera, Lower Dir, Hangu, and Upper Dir are the districts with the lowest production of cereals. Out of 24 districts, 23 struggle with a lack of crop-based food; only D. I. Khan manages to meet its own needs. The districts with the severe crop-based food shortages are Peshawar, Kohistan, Karak, Abbottabad, Lakki Marwat, Hangu, Bannu, Lower Dir, Shangla, Upper Dir, Chitral, Nowshera, and Battagram. The majority of districts (83%) have extremely limited access to food goods. Food security is a serious issue in KP that is negatively affecting the population.

2.2.3.1 Result and Conclusion

For the purpose of gathering information about the state of food security in KP, the district of Peshawar is taken into account. Because of the time and resource constraints, a small population size is taken into consideration for this study. Peshawar is a city that is quickly expanding, with a population of 1,970,042 in 2017 compared to 982,816 in 1998 and 566,248 in 1981. In Peshawar, 300 residents (of both sexes) are chosen at random. Lower, middle, and upper classes of citizens are all represented.

It is imperative to address and resolve the "food insecurity" situation that KP is currently experiencing as soon as feasible. The most affected group is the poor, who are unable to afford even the most basic food supplies. Due to this wretched scenario, there is severe social unrest/stress, including destructive demonstrations, starvation, malnutrition, rising crime rates, and poverty. Political, social, and economic instability in the KP are all results of food shortages. Timely protective actions must be performed. The study's findings are used to draw the subsequent conclusions.

I. Food security and the rate of population expansion are strongly correlated and negatively correlated. People therefore experience food insecurity when population expansion is vigorous, prompt, and rapid.
II. Food security and the boom in biofuel production are strongly correlated and negatively correlated. People therefore experience food insecurity when biofuel production increases intensely, forcibly, and quickly.
III. Food security and the increase of poverty are strongly and negatively correlated. People therefore experience food insecurity when poverty rises aggressively, excessively, and quickly. When basic food items are so costly, poor people suffer badly.

IV. Food security and the increase in social instability are strongly correlated and negatively correlated. Consequently, social discontent increases when there is acute, lively, and severe food insecurity. Khyber Pakhtunkhwa is completely at risk of societal upheaval because of the shortage and deficiency of food items and massive food prices. Food insecurity has raised the rates of crime, suicide, and terrorism. As a result, there will likely be constant, determined, and escalating societal unrest and disruption if food costs stay high [3].

2.2.4 Research Paper Title "Quality Deterioration of Postharvest Fruits and Vegetables in Developing Country Pakistan: A Mini Overview"

Publication date: 2, April 2021

Authors: Khurshid Ahmad, Mahideen Afridi, Nasir Ali Khan, , Azeem Sarwar

Pakistan has a competitive advantage in a variety of vegetable and fruit crops because of its affordable labor, favorable environment, and access to export markets including the Middle East and Asia. Even still, the production of fruits and vegetables is much less advanced than that of grains. Since postharvest control of fruits and vegetables has not received adequate attention, significant loss occurs throughout the harvest and postharvest stages, and the majority of postharvest losses for horticulture produce are difficult to measure. Although the horticultural industry in Pakistan is expanding, there has been little and insufficient support indicated for enhancing and lowering postharvest loss and improving the quality of horticultural commodities. According to reports, Pakistani horticultural crop losses following harvest are estimated to be between 35 and 40 percent.

Because these harvest-related losses have a direct impact on the livelihood and economy of the nation, they are a significant source of food loss that can be seen from the viewpoints of reducing poverty and ensuring global food security. According to several researches, inadequate packaging, rough handling, incorrect temperature and cooling control, and lack of processing to remove pre-storage flaws are the most frequent causes of postharvest losses.

Nearly 58% of the world's total vegetable production and 45% of the fruit that is harvested are produced in Pakistan, a developing nation. Fruits and vegetables in Pakistan contribute significantly to economic growth as they account for 12% of the country's agricultural GDP.

Guava, mango, and oranges are the fruits produced in Pakistan at rates of 7%, 27%, and 31%, respectively. Agro climatic conditions in Pakistan ranged from tropical to mild, where 40 different kinds of vegetables and 20 different kinds of fruits were grown. Pakistan is included on the list of underdeveloped nations where numerous fruits and vegetables were lost owing to the use of outdated instruments, techniques, and procedures. These kinds of losses are extremely rare in industrialized nations.

Although Pakistan produced over 13.764 million tons of fruits and vegetables overall, as indicated in below table, it is believed that 35 to 40 percent of those fruits and vegetables were discarded after harvest.

Table 2-1: Losses of Crops, Fruits, and Vegetables in Pakistan

Crops/Fruits/Vegetables	Percentage of losses
Harvested crop	15-20% loss at time management
Rice	15%
Wheat	10%
Fruit/vegetables	10-12% loss at transport
Tomato	20%
Harvesting fruit/vegetables	5-8%
Almond, walnuts	6%
Peach	23%
Banana	28.84%
Mulberry, mango, apples, apricots, cherry	50 %

2.2.4.1 Handling, Shipping, Carrying and Storage Problem in KPK Pakistan

It is crucial to use smooth, ventilated, and secure cans for packing in order to reduce crop losses throughout processing, distribution, transportation, and storage. Only 31.1 percent of stores, according to a study, stored rotten and physically damaged fruits separately in the Swat fruit management assessment. As a result, when handling horticultural products after harvest, the transportation system placed them one on top of the other, putting them at risk of harm and lowering their period of storage.

Mixed loads of bulk commodities are a severe worry once more because the products react differently to transpiration, temperature, ethylene, transportation, and dehydration, all of which affect the durability of the commodities by increasing mechanical, chemical, physiological, and biological losses. In the Swat areas of Pakistan's northern KPK region, 3.98 percent of postharvest potato loss was documented during transport, and 10.08 percent occurred during storage. In Pakistan, quality decline and post-harvest loss of vegetables and fruit were attributed to transportation, insufficient packaging, and poor storage facilities.

When harvesting different items from fields, different containers including baskets, sacks, wooden crates, and plastic materials are utilized carelessly, increasing the level of damage the production causes. In order to prevent structural changes, packages must be ventilated and strong enough. Open baskets and bags are not protective of the contents when piled, so if things are packed for convenience of handling, waxed cartons, hard plastic containers, or wooden boxes are suggested. Overfilling containers and combining dissimilar products have been significant postharvest issues. Most traders combine healthy and damaged food with **regular produce and subsequently incur losses.**

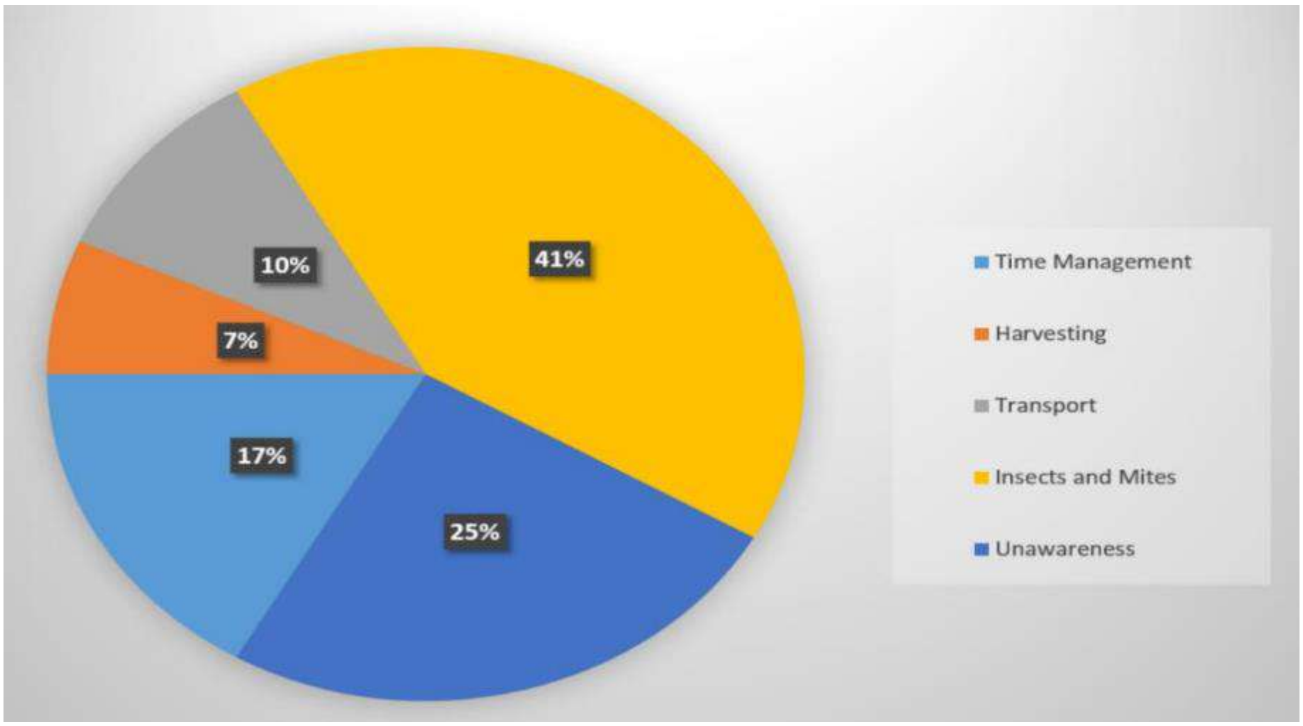


Figure 2-2:Postharvest Losses of Fruits and Vegetables through various Percentage in Pakistan (Dawn, 2001)

2.2.4.2 Conclusion

From the field to the fork, there are quality declines and postharvest losses, and even pre-harvest practices and activities have a significant influence on the magnitude of subsequent losses. They could also come about through exploiting crucial storage facilities. So, one of the best ways to minimize post-harvest losses in the field and during storage could be through training and educational activities. The effects and problems of postharvest loss should be thoroughly understood by horticulturists, extension specialists, and development agents who should also be involved in teaching farmers how to manage the losses. With the help of government postharvest handling programs and government extension, postharvest methods from other nations could typically be adapted for commercially significant perishable horticulture commodities [4].

2.2.5 Research Paper Title "Review on Solar Dryer for Grains, Vegetables and Fruits"

ISSN: 2278—0181

Publication date: Vol.02 Issue 1, January — 2013

Authors: Atul H Patel, Prof. S A Shah, Prof. Hitesh Bhargav

An analysis of the solar dryer is provided in this study. Almost 6 billion people live on the planet, and 20–25 percent of them do not have enough food to eat. According to estimates, the globe as a whole loses more than 25 to 30 percent of its food grains and 50 to 60 percent of its fruits, vegetables, and other produce before it reaches consumers. Many ways of preserving are employed to combat the spoiling issues that arise with fruits, vegetables, and food grains; renewable sources are preferable for this purpose because they allow us to conserve energy while maintaining the product's unique taste.

An enclosed device called a solar dryer is used to dry agricultural produce. Also, the food must be protected from harm, birds, insects, and unexpected downpours. Through the years, people have used solar dryers, also referred to as dehydrators, to preserve grains, vegetables, and fruits by eliminating moisture. Solar dryers may be produced locally in any size and capacity, and they are cost-effective for drying cash crops. The different solar dryer designs that have been described in the literature to date are presented.

Agricultural items including grains, vegetables, and fruits are renowned for their high vitamin content, high moisture content, and low fat content. These crops are available mostly during the growing season because they are seasonal. Despite the growth, the expanding population's demand for veggies has not been satisfied. This is due to wastes produced by biological and biochemical processes that occur when the fresh product is being produced, unsuitable storage conditions, ineffective handling, inadequate transportation, inadequate post-harvest infrastructure, and subpar market outlets. In the majority of tropical and subtropical nations, sun drying remains the most popular technique for preserving agricultural items like grains and vegetables.

Low initial and ongoing expenditures as well as the lack of specialized knowledge are the primary benefits of sun drying. Only regions where the weather permits food to be dried right away after harvest in an average year are capable of sun drying. However, as they are not covered from rain, wind, dust, damage from birds, insects, and other animals, the items may suffer substantial degradation to the point that they are occasionally rendered inedible. The resulting loss of food quality in the dried products may have negative economic impacts on both the national and international markets.

Certain fruits and vegetables lose quality (color and nutrient content) when exposed to direct sunlight. Also, as sun drying depends on outside circumstances, uniform and standardized product output is not anticipated.

Using a solar dryer, which consists of a collector, a drying chamber, and occasionally a chimney, can help overcome some of the issues with open-air sun drying (Madhlopa et al., 2002).

Tropical countries' climates make solar energy drying food both environmentally responsible and practically appealing. In order to increase shelf life, product variety, and huge volume reduction, dryers have been developed and are used to dry agricultural products. The majority of these either combine solar energy with another type of energy or employ an expensive energy source, like power generation (El-Shiatry et al., 1991). (Sesay and Stenning, 1996). The majority of these projects have not been taken up by small farmers, either as a result of the final design and data collection techniques generally being ineffective or because of the cost remaining out of reach.

2.2.5.1 Types of Solar Drying System

2.2.5.1.1 2.2.2.1.1 Direct Type Dryers

The agricultural produce is arranged in shallow layers in a blackened enclosure with a clear cover in direct or natural convection dryers. The product itself immediately absorbs the sun radiations. By means of natural convection and circulation, the food product is heated, evaporating its moisture and dissipating it.

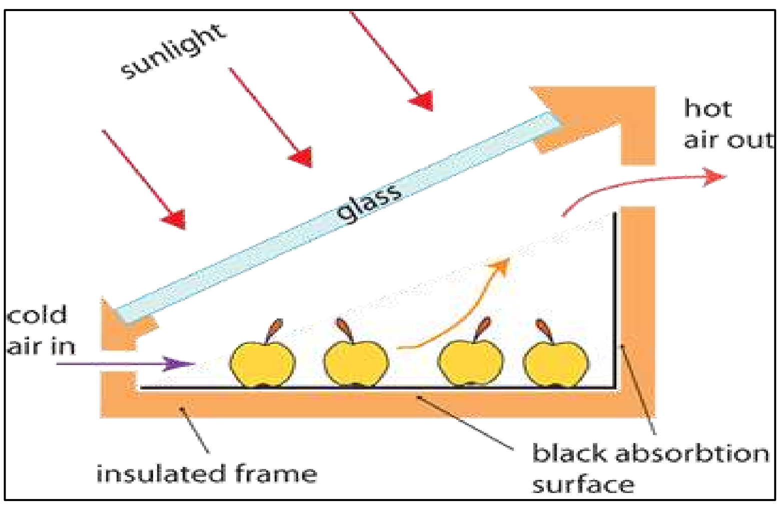


Figure 2-3: Direct Drying

2.2.5.1.2 <u>Indirect Type Dryers</u>

The food product is put into one of these dryers' drying chambers. Solar air heaters heat the air, which is then blasted into the drying chamber. In some of the systems, dryers get heated air via solar air heaters in addition to direct sun radiation. These dryers allow some degree of temperature, humidity, and drying rate modification.

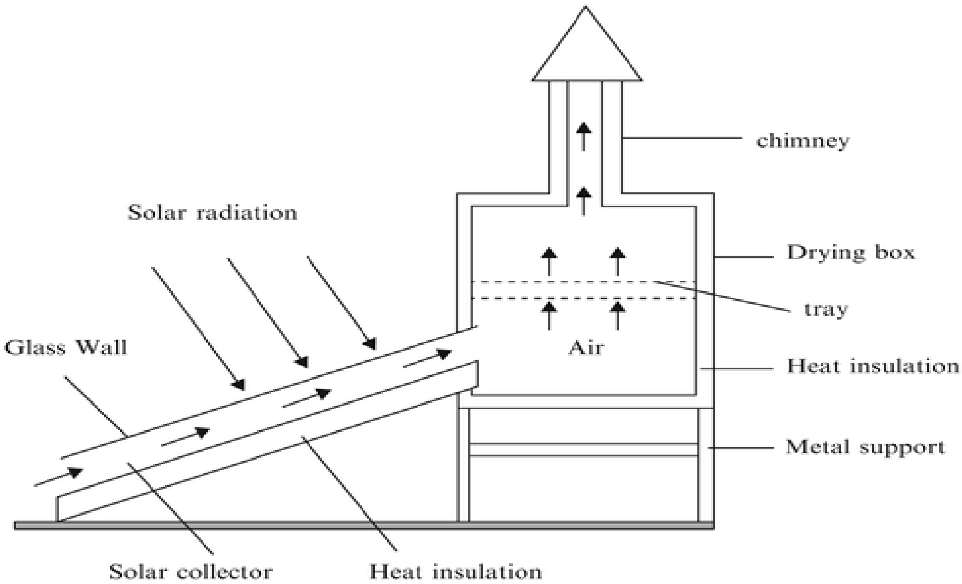


Figure 2-4:Indirect Type Dryer

Our final year project is based on indirect solar dryer. Ambient air contact with sun radiation which is absorbed by black painted iron sheet. Then due to convection heat transfer occurs and fresh air become warm and humid. This warm and humid air is then passed through first temperature and humidity measuring sensor, which will indicate available humidity and temperature of the inlet air in the drying chamber. This air is then passed through temperature and humidity controlling device, this controller controls the required temperature and humidity required for drying of that food item. When air comes in contact with food item, it will absorb water vapors from it and will evaporate through exhaust.

2.2.5.1.3 <u>Forced Circulation Type Dryers</u>

Hot air is continuously pushed over the food product in these dryers. The food products themselves are constantly or sporadically loaded or unloaded. These dryers can be used to dry huge agricultural products and are faster and more thermodynamically efficient than other types. These dryers may belong to either cross-flow, concurrent flow, or counter-flow varieties.

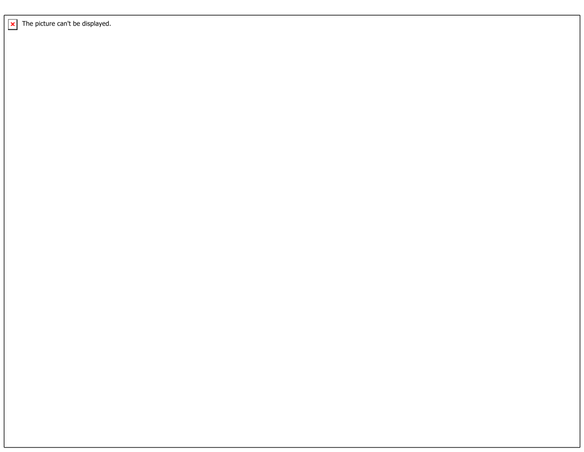


Figure 2-5:Forced Circulation Type Dryer

2.2.5.1.4 Conclusion of this Research Paper

In this analysis, the objective of this research is to demonstrates that employing a solar dryer led to a major decrease in drying time when compared to traditional sun drying, and the products dried using this dryer were of higher quality than those produced with traditional sun drying. The parameters of drying materials, such as moisture content, size, form, and geometry, as well as ambient conditions, such as solar radiation and temperature, relative humidity, velocity, and atmospheric conditions of ambient air, have an impact on the effectiveness of sun drying systems [5].

2.2.6 Research Paper Title "Design and Performance Evaluation of a Solar Dryer"

Publication date: 2019

Authors: O. Kilanko, T.A. Ilori, R.O. Leramo, P.O. Babalola, S.E. Eluwa

Introduction

In impoverished countries, inadequate storage facilities and a lack of infrastructure are two of the main reasons for post-harvest losses. In hot temperatures, fresh food and fruit products deteriorate or decay since there are insufficient setups for keeping goods preserved between harvest and market. For long life cycles and increased sales of perishable items, goods must be preserved. To stop damage, loss, or degradation of objects, preservation employs a variety of techniques. It entails reducing or eliminating bacterial deterioration to lengthen the shelf life of perishable commodities. Any technique used to keep food from going bad is a preservation technique.

In this day and age, where "out of season" goods are always expected and people will consume less and fewer foods grown on their own lands, food preservation has become increasingly important. Dehydration, cooling, refrigeration, cure, smoked, pickles, sugar scrub, preserving, and sealing are some of the classic ways of preservation.

The sun is the source of more than 99.99% of all energy in the globe. The sun's light and heat energy are used for solar drying. Nigeria is fortunate to have a lot of solar energy since we're located in a tropical area. Since solar energy is a clean, renewable source of energy and has a great capacity when harnessed, it is being employed as a substitute for non-renewable forms of energy, particularly fossil fuel energy. If energy can be renewed over a person's lifetime, it is seen as renewable. Using renewable energy sources, like solar, minimizes operational expenses compared to using fossil fuels [6].

2.2.6.1 Conclusion of this Research Paper

The agricultural industry is becoming increasingly interested in using solar dryers to preserve various crops, which is especially helpful for smallholder farmers in regions with strong solar insolation like North Central and Northern Nigeria. This process yields higher-quality food that has a longer shelf life and a higher selling price. Scotch bonnet peppers used in this experiment weighed 200g, and after three weeks, the peppers had lost an average of 81.3% of their weight in moisture. The drying chamber's temperature was higher than the surrounding air's temperature for the majority of the day, just as previous dryers described in literature. Average drying efficiency for solar collectors made of galvanized steel is 28.4%.

2.2.7 Research Paper Title “Identification of Barriers and Drivers to implementation of Solar Drying Technologies”

Publication date: 22, Oct,2022

Authors: Varun Goel, Suvanjan Bhattacharyya, Rajneesh Kumar, Sudhir Kumar Pathak, V. V. Tyagi & R. P. Saini

The need for energy is growing every day, and when the fossil fuel sources run out, there will be a number of environmental hazards. Utilizing technology based on fossil fuels, drying procedures are being utilized in industries, the agricultural sector, and household activities. Solar drying can be applied in these industries for a variety of useful purposes, such as product drying, crop drying, and lumber drying, to reduce the Green House Gases (GHG) emission contributions. Although there is a lot of work being done in this area to enhance the effectiveness of sun drying systems, practical deployment of such an arrangement has not yet shown much promise.

In order to improve the application of solar drying systems, an effort has been made to identify several barriers classed as political barriers, economic barriers, technical or institutional barriers, and social and environmental barriers. This research provides a comprehensive understanding of the causes of the low smallholder ownership of commercially accessible solar dryers in light of this. Additionally, a number of potential motivating elements have been presented in order to assure a greater use of drying technology based on solar energy and help society develop sustainably [8].

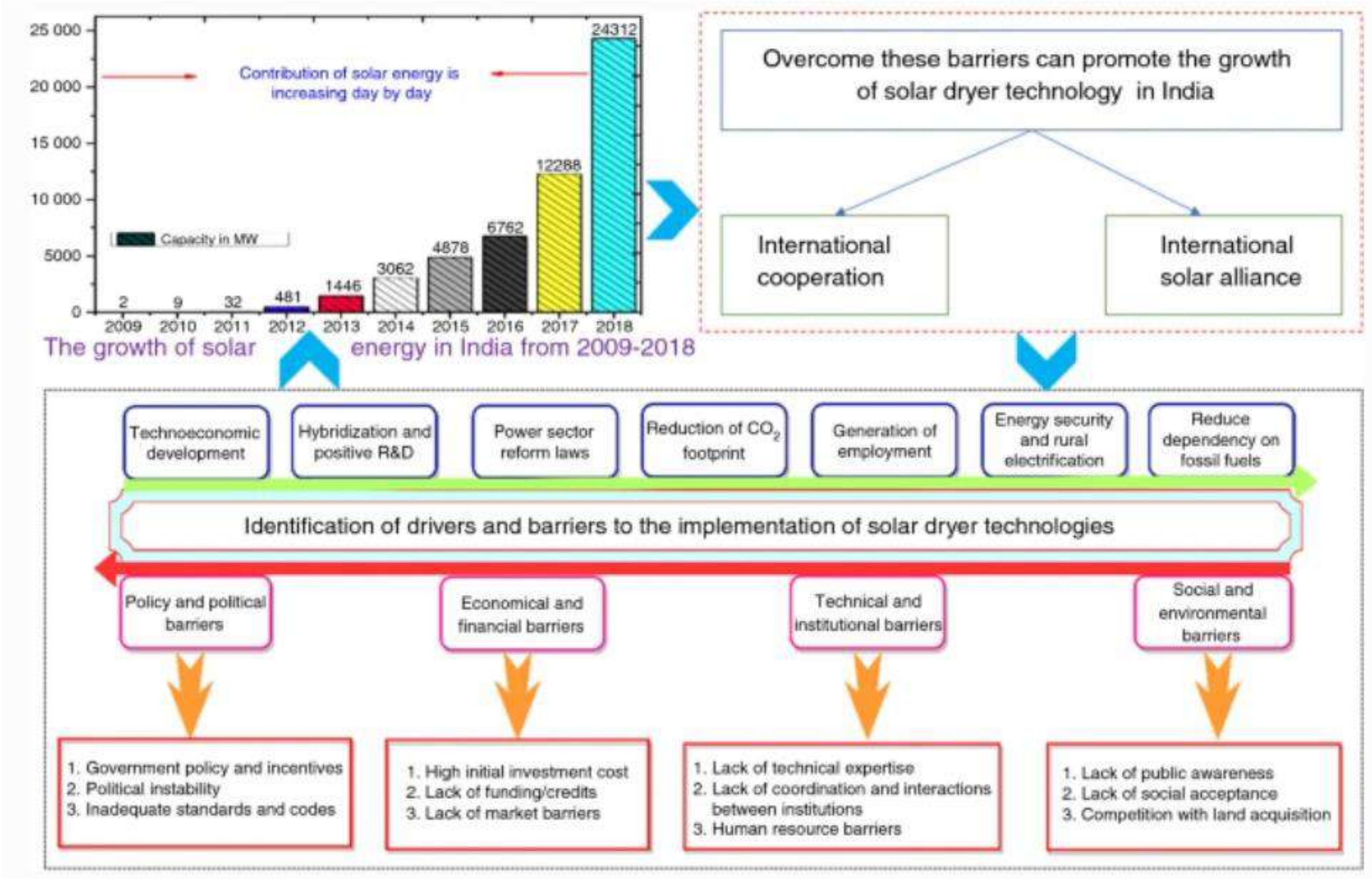


Figure 2-6:Barriers and Drivers

2.2.8 Research Paper Title "Performance Assessment and Modeling Techniques for Domestic Solar Dryers"

Published in: 31st / Jan/ 2023

Authors: Shimpy, Mahesh Kumar, Anil Kumar

One of the most alluring methods of food preservation utilized historically all across the world is drying. Due to the decreased weight, it not only helps with food nutrition preservation but also with easy and lengthy storage and transit. Researchers have been forced to look into alternatives to conventional energy needs due to the rising costs and scarcity of fossil fuels as well as climate change brought on by the emission of greenhouse gases (GHGs). Drying is a costly procedure that accounts for 30% of the total cost for preserving vegetables and fruit.

Food that is produced but not eaten accounts for approximately 17% of all food available for purchase at retail, food services, and consumer levels, or 8–10% of all GHG emissions. The UN's Food and Agriculture

Organization (FAO) also predicted that 3 billion more people will go hungry after the COVID-19 pandemic, bringing the total number of hungry people worldwide in 2019 to 690 million.

One of the most appealing alternatives to conventionally powered dryers has emerged: solar drying. In addition to reducing food loss or wastage, solar dryers are unaffected by the issues of rising prices and fuel shortages. One of the main factors contributing to solar dryers' appeal among many academics is their eco-friendliness.

In general, the flow of the drying fluid inside the dryer and the mechanisms of heat transfer to the drying commodity are used to classify solar dryers. In the past 20 years, a new category of solar dryers known as "Hybrid solar dryers" has also arisen and gained appeal among numerous academics.

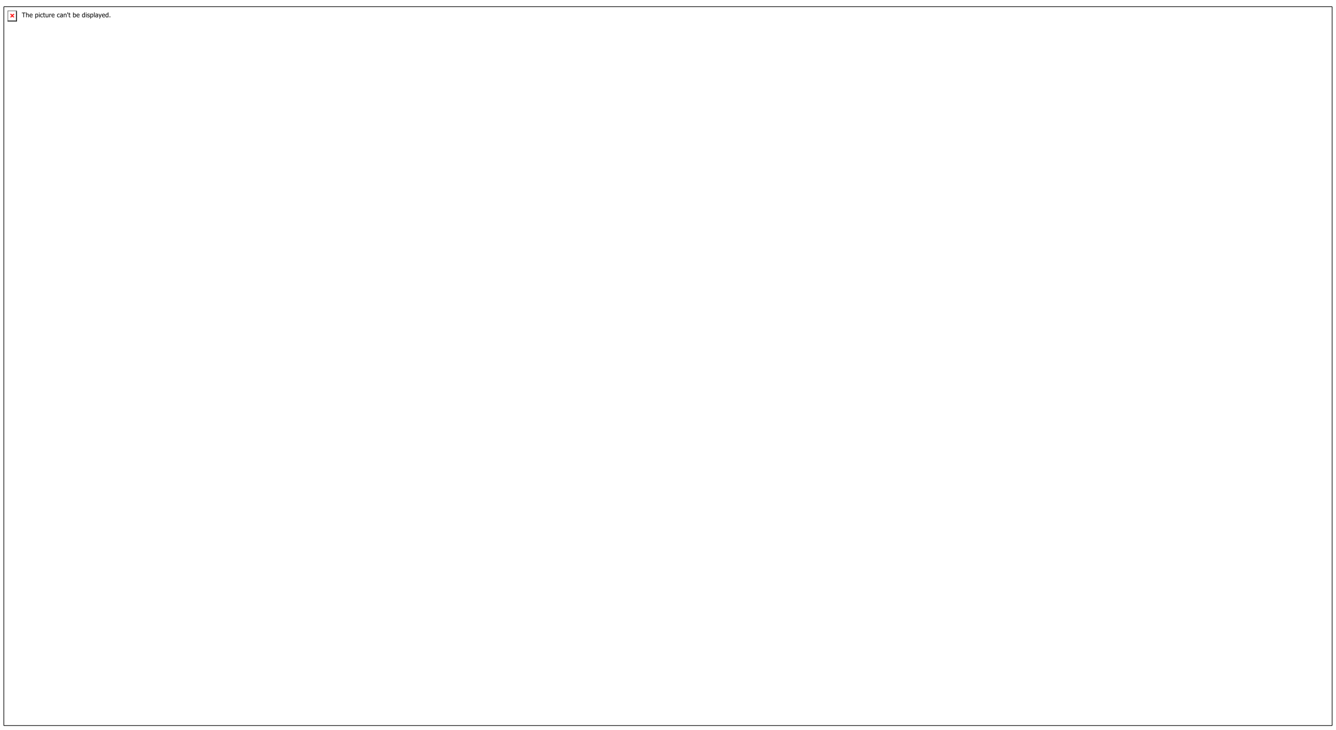


Figure 2-7:Categorization of Solar Dryer

The primary source of energy—the "Sun"—provides the power needed to run a solar dryer. There are three techniques to increase the temperature of the food item using solar energy. The first is the direct method, in which sun light directly hits the product and is absorbed, raising its temperature and causing moisture to evaporate. The second method involves heating a drying fluid separately with solar radiation before using that heated fluid to remove moisture from a commodity that is stored in a properly insulated drying chamber.

The mixed-mode kind of solar drying is the third method, which combines direct and indirect heat transmission. Natural air currents caused by the buoyancy effect are known as "natural convection," while external sources of air circulation such fans and blowers are known as "forced convection" can be used to remove the evaporated moisture from the drying product from the drying system.

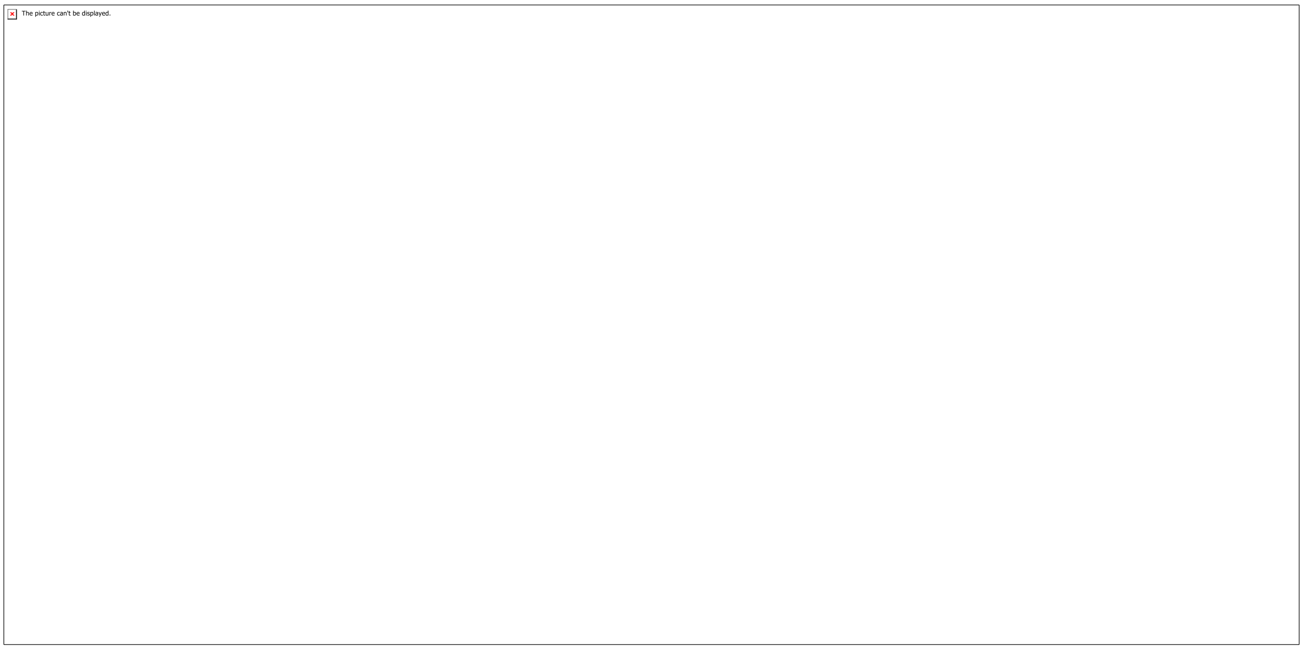


Figure 2-8:Natural convection direct solar dryer

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Figure 2-9:Forced convection indirect solar dryer

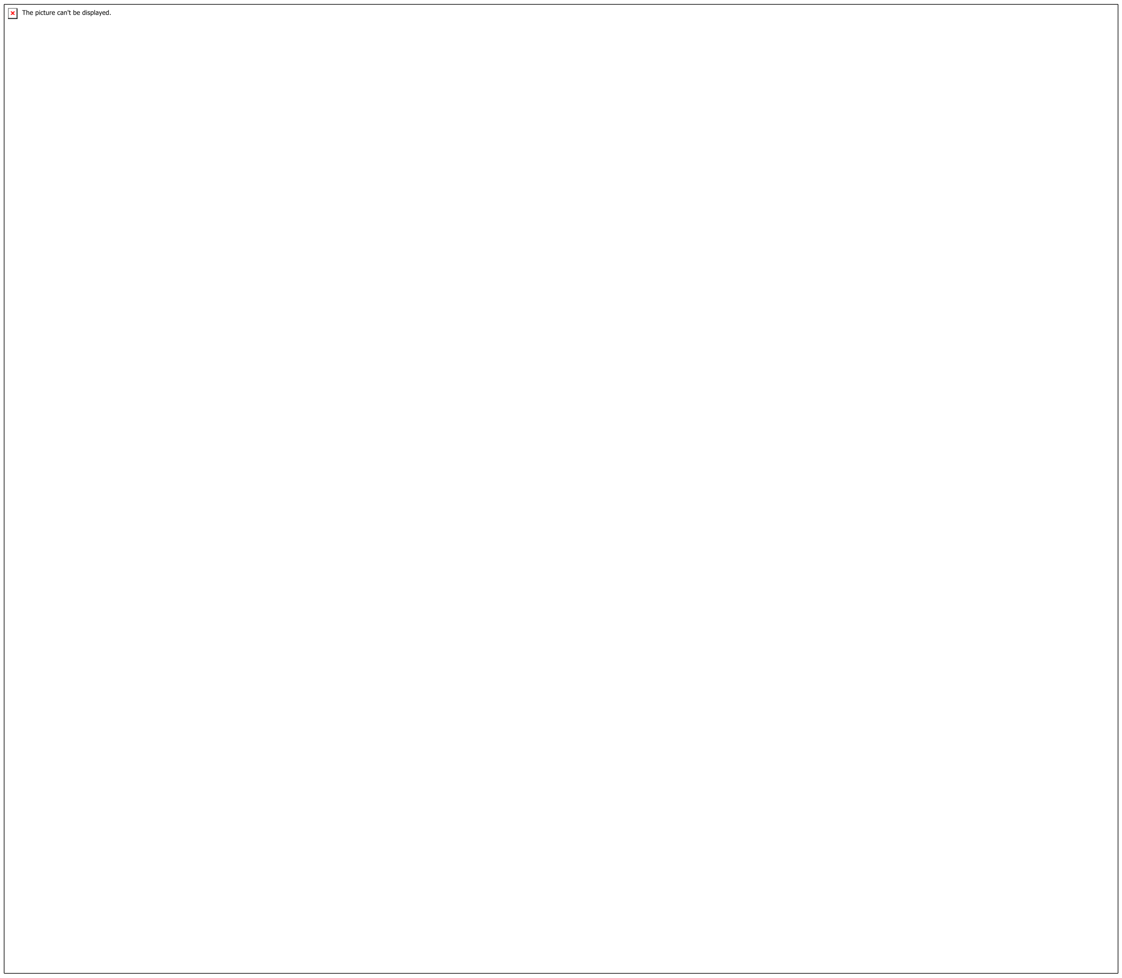

Figure 2-10:hybrid solar dryer

2.2.8.1 CFD Analysis of Solar Dryer

One of the most popular computer assisted process engineering methods for analyzing and researching sun drying systems is computational fluid dynamics (CFD). Based on the laws of conservation of mass, momentum, and energy, it can generate quantitative predictions regarding the behavior of the fluid flow inside the drying chamber. Used ANSYS software for CFD analysis to forecast the velocity, temperature, and pressure distributions inside a forced convection indirect solar dryer. The flow chart of the CFD simulation procedure is depicted in the accompanying fig. The results of CFD analysis were compared to those of an artificial neural network-based model and found to be significantly more accurate.

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Figure 2-11: Flow chart for CFD simulation

2.2.8.2 *Discussion, Implications and Recommendations*

According to the current research, the effectiveness of a sun drying system may be assessed based on thermal, drying kinetic, environmental, economic, and quality factors for dried goods. It has been noted that there isn't a study in the literature that fully evaluates the performance of a household solar dryer. Some of the most frequently reported performance parameters include thermal efficiency, moisture content, drying time, cost, and payback period.

Different domestic solar dryers were found to have thermal efficiency values ranging from 3.74 to 67.78%, which can be further improved by using various design modifications (including the incorporation of solar collectors for higher energy collection, heat storage arrangements for continuous and fluctuation-free operation, better insulation for reduced heat losses, and adequate ventilations for easy moisture removal and least energy losses) and processes (including the use of heat transfer fluids, such as steam, to name a few).

In areas with low solar insolation, hybridizing solar dryers may be an effective way to speed up drying. Researchers have used environmental impact assessment extensively for various solar technologies, and it is now more important than ever because climate change is thought to be the biggest threat to human life on the planet. Domestic solar dryers' environmental effect assessment hasn't been covered too much in the literature. Different residential solar dryers were found to have start-up costs and payback times that fell between \$3.61 and \$500 and 0.25 and 3.26 years, respectively. Using locally available materials can lower the cost of a household solar dryer, and operating at peak efficiency can shorten the payback period [9].

2.2.9 Research Paper Title "Recent Advancements in Design, Application, and Simulation Studies of Hybrid Solar Drying Technology"

Published in: 01st / Sep/ 2020

Authors: Aprajeeta Jha, P.P. Tripathy

A cost- and energy-efficient alternative to the highly energy-intensive thermal dryers used in the agri-food processing chain is hybrid sun drying technology for food products. In this, "only solar dryer" is combined with a number of additional energy-harvesting technologies, including biogas, heat pumps, electricity, and thermal storage materials. This essay examines the value of hybrid solar dryers in terms of their ability to endure a range of climatic conditions and uncontrollable environmental factors, as well as their effect on the drying properties of food products. According to the evaluation, heat pump hybrid solar dryers are more effective, have a wide range of drying temperatures, and are suited for products that are sensitive to heat.

The benefits of a biomass hybrid solar dryer, on the other hand, come from its capacity to use inexpensive local resources to help with energy requirements and from its affordability during construction. The state of the art revealed that, despite this, more research has to be done on the hygienic benefits of solar drying. The review that is being provided additionally examines the research situation for pertinent virtual platforms that may be used to simulate dryer design and drying parameters. Discussion also includes significant findings on thick layer drying of food products in solar dryers and modeling aspects of dryer design. The profitability indicators and equipment cost of the hybrid solar dryers that are currently on the market were competitive.

Furthermore, it is recommended to set a baseline for drying applications in the food processing industries in order to promote energy-efficient hybrid solar dryers and their environmental benefits in the future [10].

2.2.10 Research Paper Title "DESIGN AND DEVELOPMENT OF A HYBRID SOLAR-ELECTRIC DRYER FOR SLICED VEGETABLE CROPS"

Published in: Sep, 2017

Authors: N.R. Nwakuba, S.N. Asoegwa, K.N. Nwaigwe, C.O. Chukwuezie

Vegetables are seasonal crops distinguished by their high vitamin content, high moisture content (often above 70% wet basis), and low fat contents, particularly during harvest. Because of this, drying it requires a significant amount of energy to reduce the high moisture content to a safe storage level, which is typically 5 to 15% at temperatures between 35 and 65°C.Up to 50% of the fruit and vegetable harvest in Nigeria alone is lost to spoilage each year, which results in seasonal shortages and changes in availability and pricing. In order to efficiently dry vegetables, their moisture level must be decreased.

Using a dependable heat source, increasing airflow around the product, slicing and spreading the product to increase its surface area to hot convective air, insulating the areas not exposed to the same heat source to prevent heat loss, avoiding direct heating because it degrades the product's quality and appearance, and safeguarding the dried goods against contamination all help to speed up the drying process for vegetables.

By heating air in a separate solar collector, which is then circulated through drying racks where it draws moisture from the crop, indirect heating is accomplished. Due to sporadic sun radiation throughout the day, agricultural products can be continuously dried using a mixed-mode system that combines solar and non-solar heating sources with biomass or electricity. The design of a hybrid dryer is influenced by this.

2.2.10.1 Description of the hybrid sliced vegetable crop dryer

The air heater unit (solar collector) and the dying chamber with two layers of wire mesh drying racks on which the sliced crops are placed for drying are the two main essential parts of the hybrid vegetable drier. The dryer system also includes the following additional parts: a solar panel (80W, 12V), a DC battery (75Amps, 12V), a control unit, a liquid crystal display (LCD), an inverter system, inlet and exhaust fans, plain glass (4mm thick), temperature and relative humidity sensors (LM-35 transducers), weighing balances, weight sensors, a heating element, a frame support, and rollers.

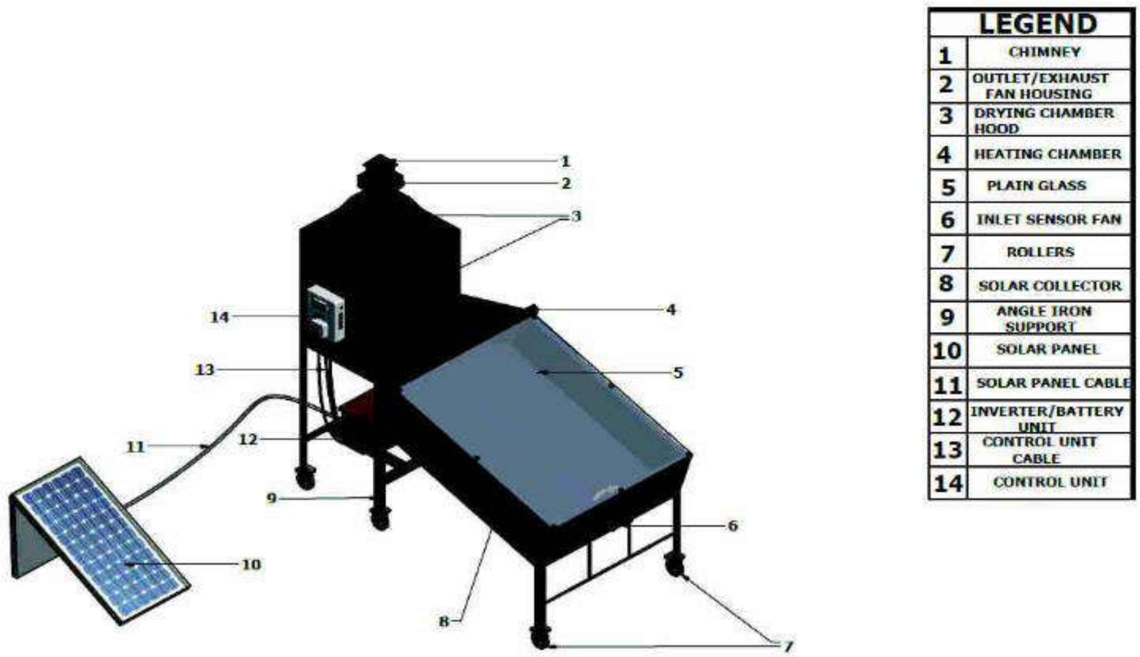


Figure 2-12:Isometric view of the hybrid sliced vegetable crop dryer

The Arduino microprocessor is the brains of the dryer. It manages system wide operations and automates processes like temperature and humidity regulation, sample weight reduction, and electrical energy consumption (from AC and DC sources). A main heating element that is powered by alternating current (AC) from the Public Power Supply or an electricity producing unit is also a part of the system. The chimney, two drying racks, solar collector, and inlet fan are the five strategically placed transducers on the hybrid dryer that record temperature and relative humidity. Measurements are taken automatically by the microprocessor unit and displayed on the LCD as shown in the below figure.

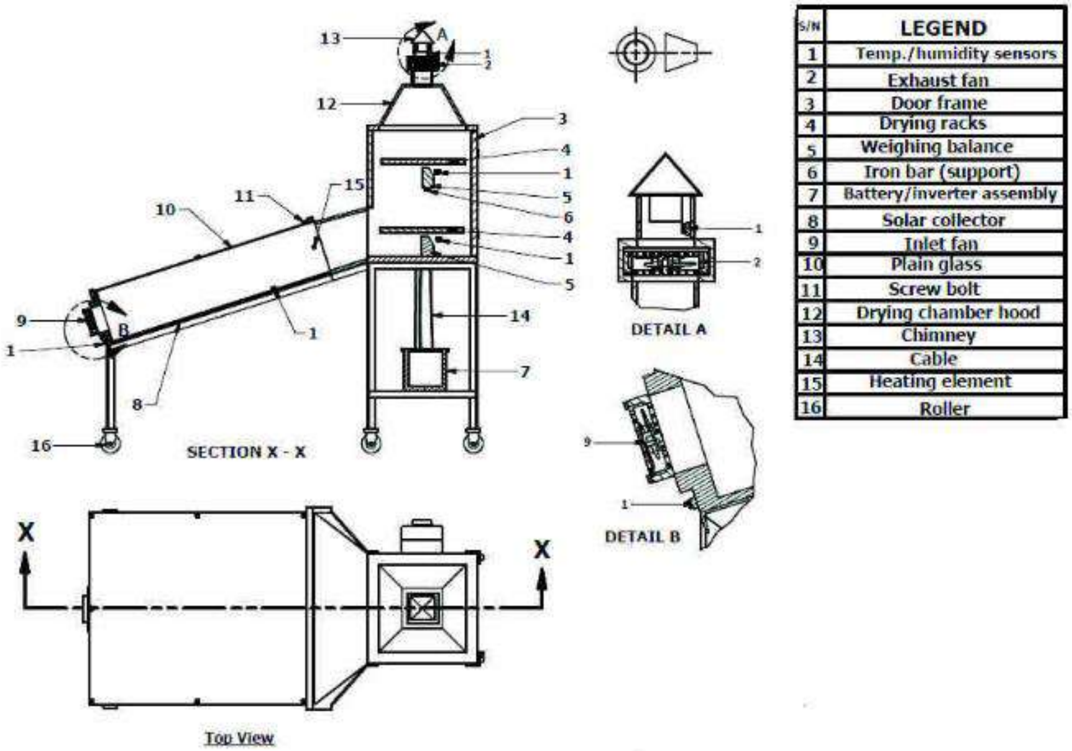


Figure 2-13:Sectional view of the hybrid dryer.

2.2.10.2 Conclusion of This Paper

For drying sliced vegetable crops, a hybrid solar-electric crop dryer has been successfully constructed. Given the ideal drying temperatures of the crops to be handled, the dryer was built for a maximum batch size of 25kg of freshly sliced vegetables and a maximum temperature of 70°C. Given the moisture-laden nature of the crops to be processed, results of no-load tests collected show that the drier displayed high heat generation in the hybrid mode. The energy development and drying chamber heat-up times of the hybrid heat source were excellent. At a temperature and air velocity of 70°C and 2m/s, respectively, the hybrid heat source needed a minimum heat-up time of 5.2 minutes.

The dryer heat-up time and drying tray temperatures were found to be significantly influenced by both the drying temperature and air velocity. Due to changes in solar heat on an hourly basis, drying time has a considerable impact on the dryer's energy usage. The peak energy usage was noted at 4 PM, which roughly corresponds to the peak solar heat flux. Given its high heat generation and effective temperature control, the hybrid drier has the potential to dry a variety of freshly picked vegetables, roots, and tubers as well as fish products and other crops to any desired final moisture level.

A steady optimum drying temperature at a moderately high air velocity more than or equal to 2ms-1 should be maintained in order to reduce the hybrid dryer's energy consumption [11].

2.3 Research Gape Identification

After studying and analyzing so many research papers, which are included above and which are not, and observing Pakistan's agriculture conditions, we decided to make a dehydrator that is used for both fruits and vegetables. This dehydrator will be beneficial for farmers to preserve their food, solve Pakistan's agriculture problems, and also export to other countries, thereby strengthening Pakistan's economy. By reducing the food problem, our country will not import food from other countries, and the dollar requirement will be reduced. We select hybrid solar dryers, which use the sun as a primary source and electricity as a secondary source. This technology is common, and we can implement it in Pakistan without any harmful effects.

2.4 Concept Generation

After viewing the different available dehydrators, each has different methods of preserving food. Different solar dryers were made with the aim of increasing the efficiency of their dehydrator and preserving food efficiently. So among the existing solar dryers, there were temperature issues in the cold area. So a new technology was developed in these dehydrators to provide the required temperature from secondary sources, i.e., fossil fuels, electricity, biomass, etc.

So we select electricity as a secondary source for our dehydrator. A 100-watt bulb generates an approximate 3,52,800 watts of heat in one hour, which will solve the temperature problem in cold areas. Additionally, we also select polycarbonate glass instead of normal glass because it does not reflect back sun radiation. We generate the idea of our dehydrator by mixing many components of different dehydrators at once.

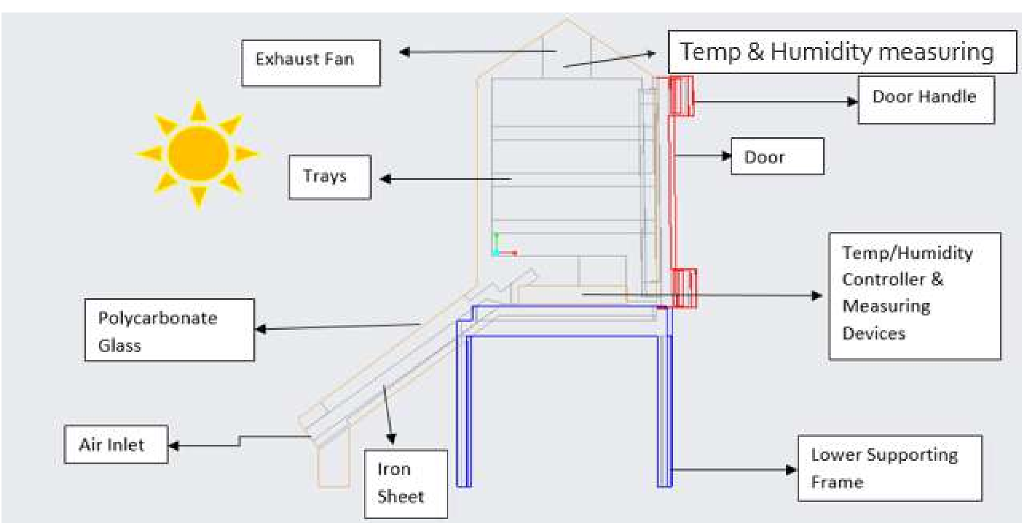


Figure 2-14: Concept Generation

2.5 Concept Reduction

2.5.1 Use of 100W bulb instead of electric heater

2.5.1.1 For Electric Heater

The maximum quantity of heat produced by the resistance wire per hour is given as

$\mathbf{Q_E = I \times V \times T}$ ……………………..Eq (01)

Where

I = Current (Amp), V = Applied Voltage (220 V), T = Time (Hrs)

Power rated of the heater, P = 2000W. So

Q_E = (4.6 Amps) × (220V) × (1 Hr)

Q_E = 1012 W- Hr = 1.012 kW-Hr = 3.64 MJ

Q_E = 3643.2 kJ

2.5.1.2 For 100W Bulb

The 100W let's assume convert 2W to light energy and 98W is released as heat. So the formula for Heat(H) is

H=Power × Time …………………… Eq (02)

Where H is the heat produced

Power is in Watts

Time is in seconds

H= 98W × 1 Hr

H= 98$\frac{J}{sec}$ × 3600 sec

H= 352800 J

H = 352.8 kJ

2.5.1.3 Conclusion

An electric heater generates extreme heat as compared to a 100-watt bulb. But we prefer bulb because we target Peshawar, KPK, for our dehydrator, where the temperature is not extremely cold in winter. And also, a 100-watt bulb is cheaper to replace than an electric heater in case of damage.

2.5.2 Installation Temperature and Humidity controller instead of Arduino Microprocessor

We prefer a dual digital temperature and humidity controller over an Arduino microprocessor because this controller has the following features over the Arduino microprocessor:

- Easy installation.
- No programming requirement.
- Ability to control temperature as well as humidity at same time.
- No extra components or wiring required.
- Adjustment of upper and lower limit of temperature and humidity can be easily set.

2.6 Summary

In this chapter, we briefly discussed different research papers on food scarcity problems, food preservation techniques, the importance of solar dryers in food preservation, and new technologies in solar dryers. After studying all factors and similar food loss problems in Pakistan and available materials in the local market, we selected the newly unique design of our dehydrator. We also discussed the advantages and disadvantages of food preservation in a solar dryer. We then compare the installation of an electric heater with a 100-watt bulb and prefer to use the bulb in the drying chamber. We also compare temperature and humidity controllers with Arduino microprocessors and select the controller best suited for our project.

CHAPTER # 03

3 RESEARCH

METHODOLOGY

3.1 Introduction

In this chapter, a summary of the research methods employed in the study is given. It provides information on the study's participants, such as their identities, backgrounds, and the methods used to choose their samples.

Methodology are divided into two categories:

1. Flow Chart
2. Software

3.2 Flow Chart

There are two types of flow chart:

1) Hardware Flow Chart
2) Working Mechanism Flow Chart

3.2.1 Hardware Flow Chart

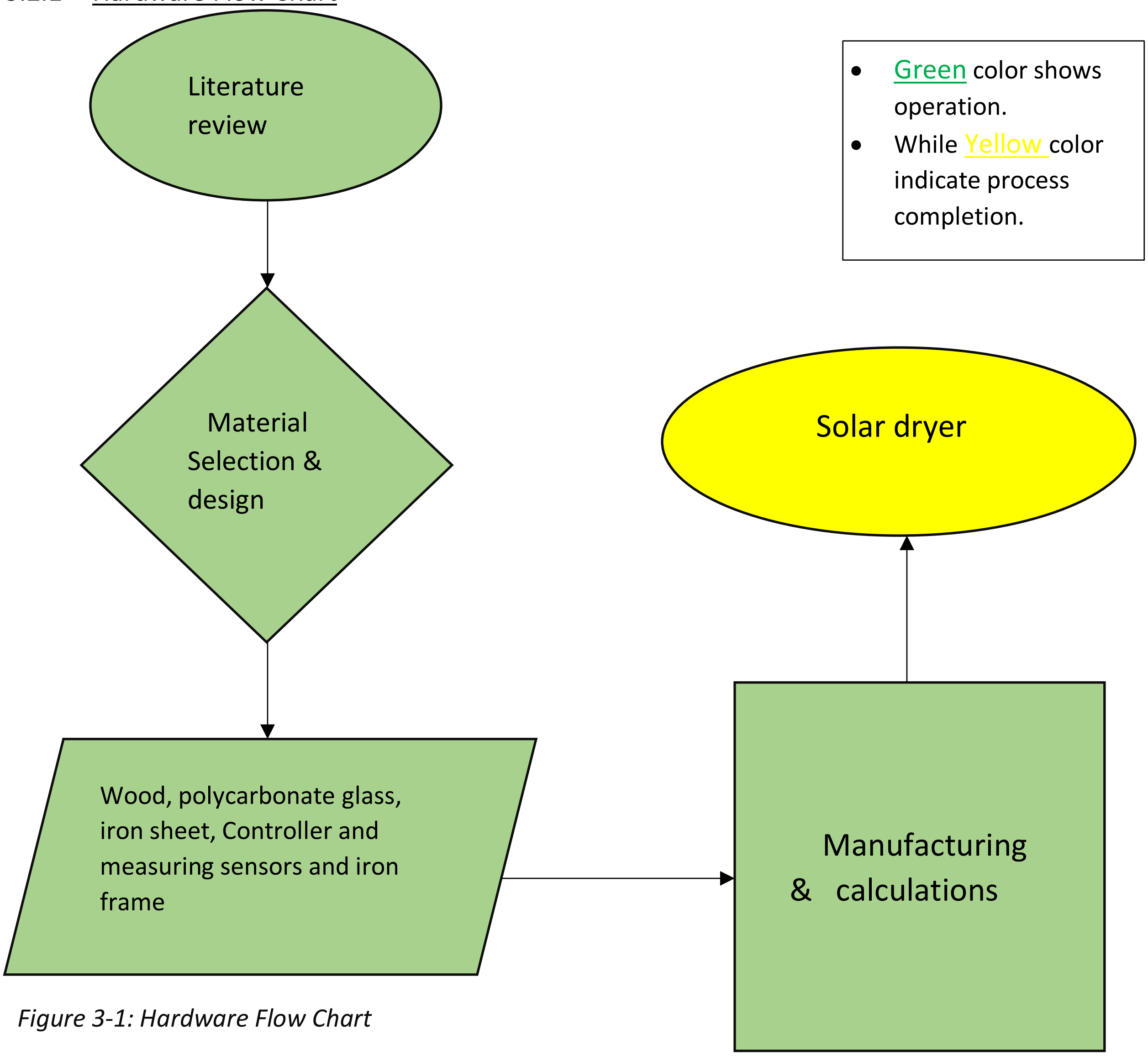


Figure 3-1: Hardware Flow Chart

The hardware flow chart indicates the manufacturing procedure and material details. Generate idea after literature review with some changes and modification by our brainstorming ability. Then select best and efficient components for our dehydrator. After selection, we provide components as an input for manufacturing process and do calculations. And thus the journey of our dehydrator is completed.

3.2.2 Working Mechanism Flow Chart

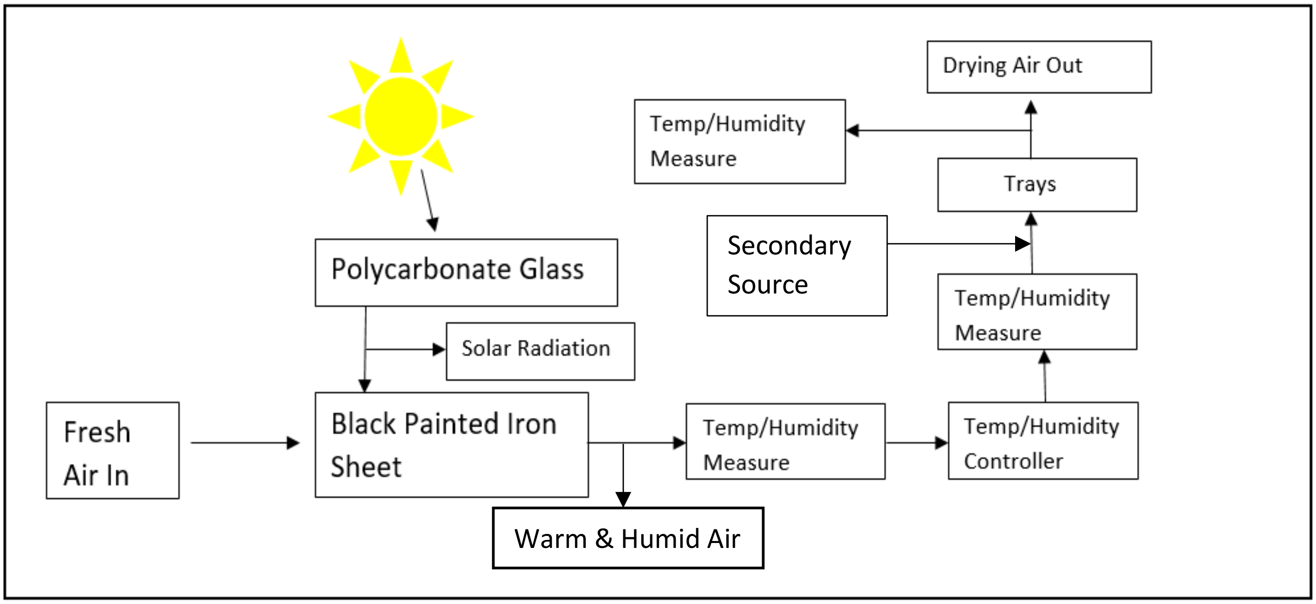


Figure 3-2:Working Mechanism Flow Chart

3.3 Software

Two main software's were used in design and manufacturing of solar dryer:

1) Pro-e-creo
2) ANSYS Workbench

3.3.1 Pro-e-creo

Pro-E-Creo is a 3D CAD software used to design and manufacture products. It is used by engineers and designers to create 3D models, enabling them to design complex parts and assemblies quickly and accurately. The main advantages of Pro-E-Creo are its robust modeling capabilities, its intuitive user interface, and its high-quality output capabilities. The main disadvantages of Pro-E-Creo include the cost of the software, its reliance on hardware for 3D performance, and the difficulty of learning the software. Pro-E-Creo is used in a variety of industries, such as automotive, aerospace, defense, and medical.

We use Creo 8.0.4.0 for designing our project. Creo 8.0.4.0 is a scalable suite of interoperable, right-sized design applications for users across the enterprise to more easily participate in and contribute to the product design process. With these applications, companies can bring better products to market faster by improving processes such as concept design, detailed design, and verification and validation.

3.3.2 ANSYS Workbench

Real life occurs all at once. You require tests that provide real-world scenarios in order to validate your design concepts. Additionally, physics doesn't rotate in the real world. To produce more accurate models more quickly, you can combine data from engineering simulations using the Ansys Workbench platform.

Ansys Workbench organizes all of your simulation data in one location, making it simpler to make more informed design decisions.

- Easily manage data across all your Ansys products
- Integrate multiple analyses within a single interface
- Save time with automated data transfer
- Create higher fidelity models

There are many simulations performed in ANSYS Workbench, but we use ANSYS Mechanical side i-e static structure load analysis of lower frame and ANSYS Fluent i-e CFD analysis of our dryer.

3.3.2.1 ANSYS Mechanical

You may use Ansys Mechanical to tackle challenging structural engineering issues and make wiser, quicker design choices. You can parameterize your finite element analysis (FEA) solvers to assess various design scenarios and personalize and automate solutions for your structural mechanics' challenges. A dynamic tool with a full complement of analytical tools is Ansys Mechanical.

- Multipurpose, Simple-to-Use Tool
- Integrated, Dynamic Platform
- Consistent, Reliable, Accurate Solver Technology
- Effective Linear and Nonlinear Solvers

3.3.2.2 ANSYS Fluent (Optional)

You have more time with Ansys Fluent to innovate and improve the performance of your products. Trust the findings of your simulation to software that has been thoroughly proven in a variety of applications. With

Ansys Fluent, you can build complex physics models and analyze a range of fluid phenomena in a programmable and user-friendly environment.

- An intuitive interface
- Top-notch Physics Models
- Single-window, efficient workflow
- Parallel Meshing and Solving Capabilities

3.4 Summary

In this chapter we gain knowledge about our project in terms of designing in Pro-e-creo, analysis in ANSYS, manufacturing process and working mechanism of solar vegetables and food dryer. We also install secondary source to obtain required temperature for drying food.

CHAPTER # 04

4 DETAILED

DESIGN

4.1 Introduction

This chapter will provide the design details that are necessary to build our product model. Layout drawings of the design will be offered to show the parts required to build a product. The section of the bill of materials that is allocated to it contains the component part list. In addition, we will discuss the benefits and engineering properties of our chosen material for our dehydrator.

4.2 Engineering Analysis: Mechanical Design Analysis

All engineering analysis used in the design process will be presented and discussed in this section. All formulae, presumptions, and full information about the materials utilized, including their physical and mechanical characteristics, will be presented.

4.2.1 Engineering Drawing Set

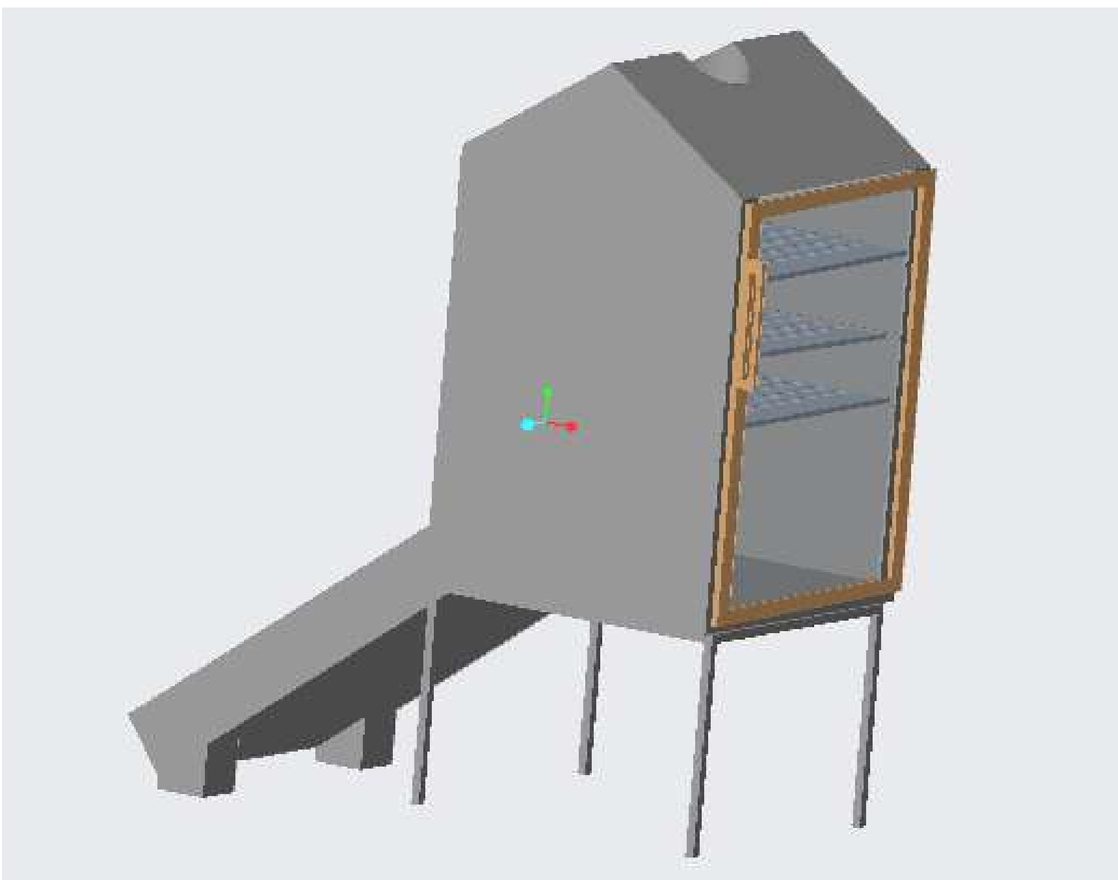


Figure 4-1: Assembly of Engineering Drawing Set

4.2.2 Analytical Design

As discussed in section 2.5 Concept Reduction

4.2.2.1 For Electric Heater

The maximum quantity of heat produced by the resistance wire per hour is given as

Q_E = I×V×T ……………………Eq (01)

Where

I = Current (Amp), V = Applied Voltage (220 V), T = Time (Hrs)

Power rated of the heater, P = 2000W. So

Q_E = (4.6 Amps) × (220V) × (1 Hr)

Q_E = 1012 W- Hr = 1.012 kW-Hr = 3.64 MJ

Q_E = 3643.2 kJ

4.2.2.2 For 100W Bulb

The 100W let's assume convert 2W to light energy and 98W is released as heat. So the formula for Heat(H) is

H=Power × Time …………………. Eq (02)

Where H is the heat produced

Power is in Watts

Time is in seconds

H= 98W × 1 Hr

H= $98\frac{J}{sec}$ × 3600 sec

H= 352800 J

H = 352.8 kJ

4.2.2.3 Conclusion

An electric heater generates extreme heat as compared to a 100-watt bulb. But we prefer bulb because we target Peshawar, KPK, for our dehydrator, where the temperature is not extremely cold in winter. And also, a 100-watt bulb is cheaper to replace than an electric heater in case of damage.

4.3 Material Used

4.3.1 Wood

Compared to materials like metals, marble, glass, and concrete, wood has a low thermal conductivity (high heat-insulating ability). Light, dry woods are superior insulators because thermal conductivity is highest in the axial direction and increases with density and moisture content. A natural insulator, wood is 15 times better than masonry, 400 times better than steel, and 1,770 times better than aluminum due to the air pockets that exist inside its cellular structure [12].

We select wood because if we use another material like iron, aluminum, etc., then we will do insulation after installation to block heat transfer from the wall of the chamber. And also we pick imported wood because it is cheaper and have high strength.

4.3.2 Polycarbonate Glass

Nearly all UV rays are nearly blocked by polycarbonate, which also absorbs UVA and UVB rays and does not permit any UVR transmission. Due to its UVR-blocking properties, polycarbonate is a well-liked material for roofing in both commercial and residential construction. It provides the best protection from the sun's harmful rays [13].

Following are the benefits of polycarbonate glass:

1) **Light Weight:** Due to its less weight than glass, polycarbonate can be shipped, handled, and installed more easily.
2) **Durable:** Due to its near indestructibility, polycarbonate is a fantastic material to use as a weatherproofing material.
3) **UVR Protection:** While providing light transmission qualities that are similar to glass, polycarbonate does not permit any UVR transmission.

By using polycarbonate glass to allow and contact sun radiation with black painted iron sheet, the efficiency of black painted iron sheet will increase in terms of thermal conductivity, and contact between air and sun radiation will be more effective when sun radiation does not reflect back.

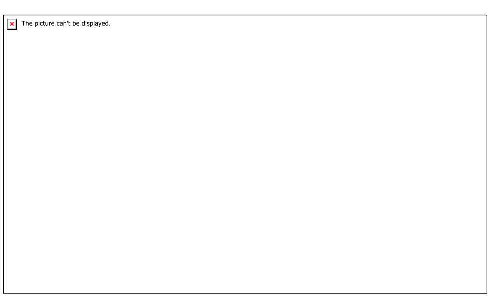


Figure 4-2: Polycarbonate Glass

4.3.3 Temperature and Humidity Controller

This type of controller, controls both temperature and humidity required levels which was set manually.

4.3.3.1 For Temperature Controlling

The high and low ranges of the temperature have been set manually. And the connection has been made in such a way that when the temperature exceeds the given high range, the exhaust fan starts on and brings the drying chamber into the required temperature range. And when the temperature is below the required range, then the temperature has been provided from a secondary source. Here we select a 100-watt bulb to provide the required amount of temperature.

4.3.3.2 For Humidity Controlling

The high and low ranges of the humidity have been set manually. And the connection has been made in such a way that when the humidity exceeds the given high range, the same exhaust fan starts on and brings the drying chamber into the required humidity range. And when the humidity is low in the air, it will absorb more water content from food, and food will take less time to dry.

Figure 4-3: Temperature & Humidity Controller

4.3.3.3 Reason for Selecting 110-220V Controller

Among 12V, 24V, and 110–220V, we select 110–220V because Pakistan's electricity range is 220-240V. So we can easily get secondary energy sources. And one more benefit is that for 12V and 24V, we will then install batteries, and then their maintenance and running costs will affect farmers.

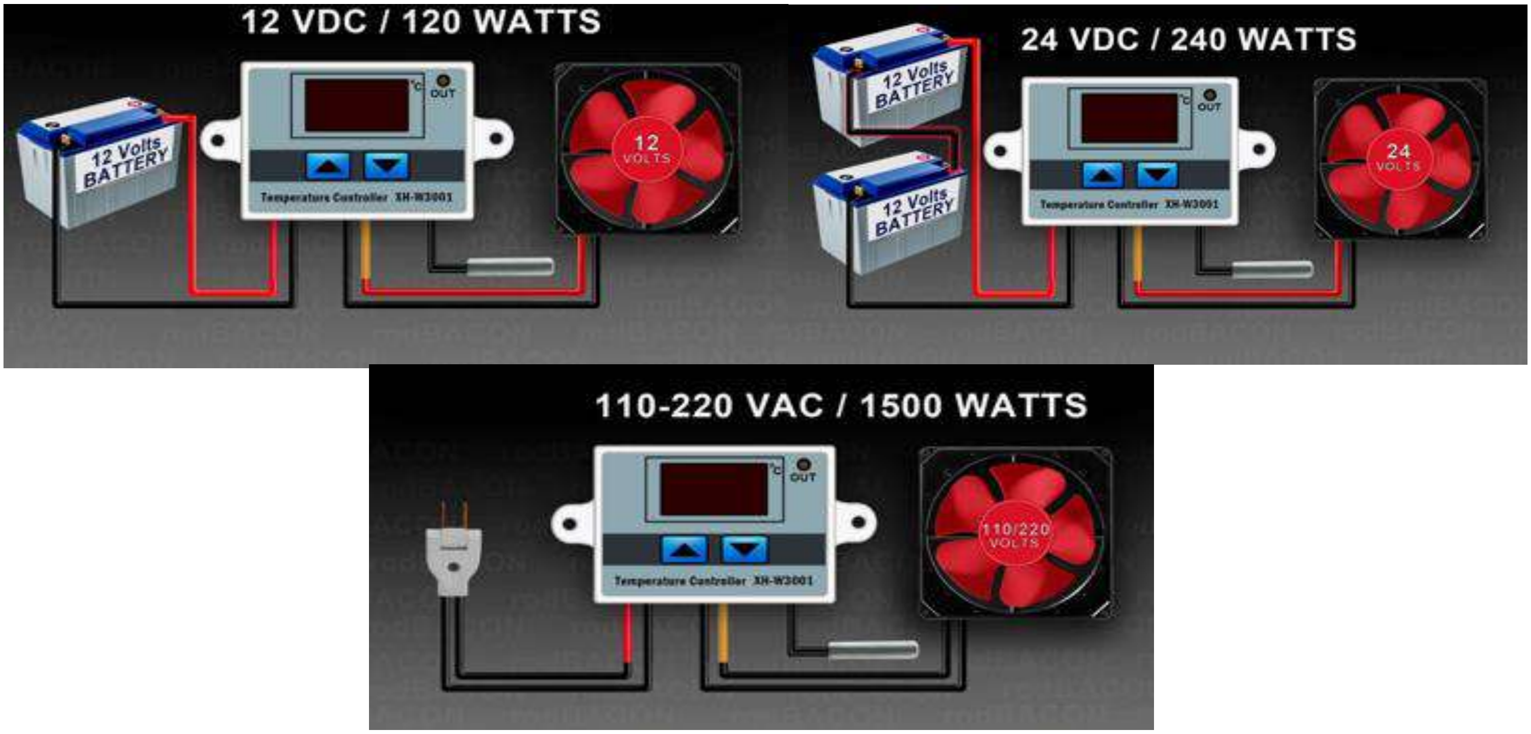


Figure 4-4: Connection Diagram of Temperature Controller

4.3.4 Temperature and humidity measuring sensor

In order to quickly measure temperature and humidity, temperature and humidity sensors (also known as RH-temp sensors) are devices that can convert temperature and humidity into electrical impulses. Market-available temperature and relative humidity transmitters typically measure the air's temperature and relative humidity, convert it into electrical signals or other signal types in accordance with predetermined rules, and output the data to an instrument or software to satisfy users' needs for environmental monitoring. We will install 3 RH-temp sensors at different locations for different purposes.

1) Outside the dryer for measuring ambient air temperature and relative humidity.
2) At the entrance of wet and dry air from the inlet portion to the drying chamber, which will indicate the entrance air temperature and humidity, a temperature and humidity controller will be set.
3) At the exhaust location, which will indicate the leaving air's temperature and humidity presence.

Figure 4-5: Temperature and Humidity Measuring Sensor

4.3.4.1 Details

- Measuring Humidity Range: 10%RH ~ 99%RH
- Humidity Accuracy: +5/-5%
- Humidity Display Resolution: 1%RH
- Measuring Temperature Range: -50℃~70℃
- Temperature Accuracy: +1/-1℃
- Temperature Display Resolution: 0.1℃
- Operation Voltage: 1.5v, one button cell size LR44
- Dimension: approx.48mm*9mm*15mm
- LCD Dimension: approx.46mm*27mm
- Power source: 2 x LR44 button cell (included)
- Probe cable length: 1.5m

4.3.5 220V Exhaust Fan

The cheapest option is a 6 Inch 220V Exhaust Fan. This exhaust fan is used to control the temperature inside an electrical enclosure with moderately low humidity and ambient temperatures. This exhaust fan's compact design guarantees adaptability and dependability. In comparison to air conditioners, the costs of purchasing and operating enclosure cooling fans are significantly cheaper. The fan wire setting can be done technically so that it will operate on both temperature and humidity values when they exceed the required amount.

Figure 4-6: Exhaust Fan

4.3.5.1 Details

- Current: 0.21 ampere.
- Speed: 2500 RPM.
- Frequency: 50Hz.

4.3.6 Ordinary Glass in Gate

We installed ordinary glass in gate for two reason:

1) To have a clear view of the drying process.
2) For getting readings of inner installed Temperature and humidity measuring sensors.

4.4 Installation of Displays of Controller and Sensors

We installed controller and all three sensors displaces outside the chamber for some reason:

1) For easy observation of readings
2) For easy setting of ranges.
3) For an easy reaction when something gets wrong.

4.5 Cost Analysis

4.5.1 Prototype Cost

Table 4-1: Cost Analysis

MATERIAL	**Approximate Cost**
Wood	Rs 22,000
Lower supporting Frame	Rs 4500
Temperature/Humidity Controller	Rs 2000
Temperature/Humidity Measuring Sensor	500/piece =1500
Polycarbonate glass	Rs 5000
Fan	Rs 700
Trays	Rs 1900
Mild Steel	Rs 1400
Glass	In Gate Rs 1900
Handle, Screws and Joints	Rs 600
Hardware	Rs 2000
Paint	Rs 2300
Weighing scale	Rs 700

Labor Cost = Rs 8000

Delivery from manufacturing place = Rs 2000

Total Approximate Cost = Rs 56,000

4.5.2 Lifetime Cost

As this dehydrator uses the sun as its primary source, and sun energy is a category of sustainable energy, it doesn't involve any running costs except the use of a secondary source, i.e., electricity. We use imported wood, which has the ability to stay in the rain and not get damaged.

4.6 Hazard and Failure Analysis

Solar vegetable and fruit dryers are a great way to preserve food without using energy from fossil fuels. They use solar energy, which is renewable and carbon-free, to dehydrate the food. However, these systems can have a negative environmental impact if not properly managed. For instance, the use of large amounts of plastic for drying trays can create plastic waste, and the inefficient use of energy can lead to the emission of greenhouse gases. Additionally, the use of pesticides and fertilizers can cause contamination of groundwater and the air. Finally, the use of large amounts of water for washing the vegetables and fruits can place strain on agricultural water resources. Following are the hazards and failure analyses that can happen in this dryer:

1) Due to the electricity shortage problem in Pakistan, controller work will be affected.
2) There will be 220-240 volts of electricity in the wire, which is hazardous for living things.
3) By wrongly connecting the controller with a bulb or fan, it will not work and will display LLL or HHH instead of numbers.
4) Changing the value of the controller will affect the drying process.

4.7 Summary

In this chapter, we briefly discussed our dehydrator engineering drawing and its analytical design for choosing bulbs. And then we briefly discuss material uses for the manufacturing of dehydrators and their benefits and preferences over other alternatives. We explained the advantages of the materials. After that, we discuss the cost of our dehydrator, i.e., the prototype cost and the lifetime cost. At the end, we discussed hazards and failure analysis in our project.

CHAPTER # 05

5 CAD

MODELING

5.1 Introduction

In this chapter we will discuss briefly upon our prototype CAD modeling and their dimensions. And the we will also show them assemble and will discuss each and every components working mechanism.

5.2 CAD Modeling of Components

5.2.1 Component: 01 (Drying Chamber)

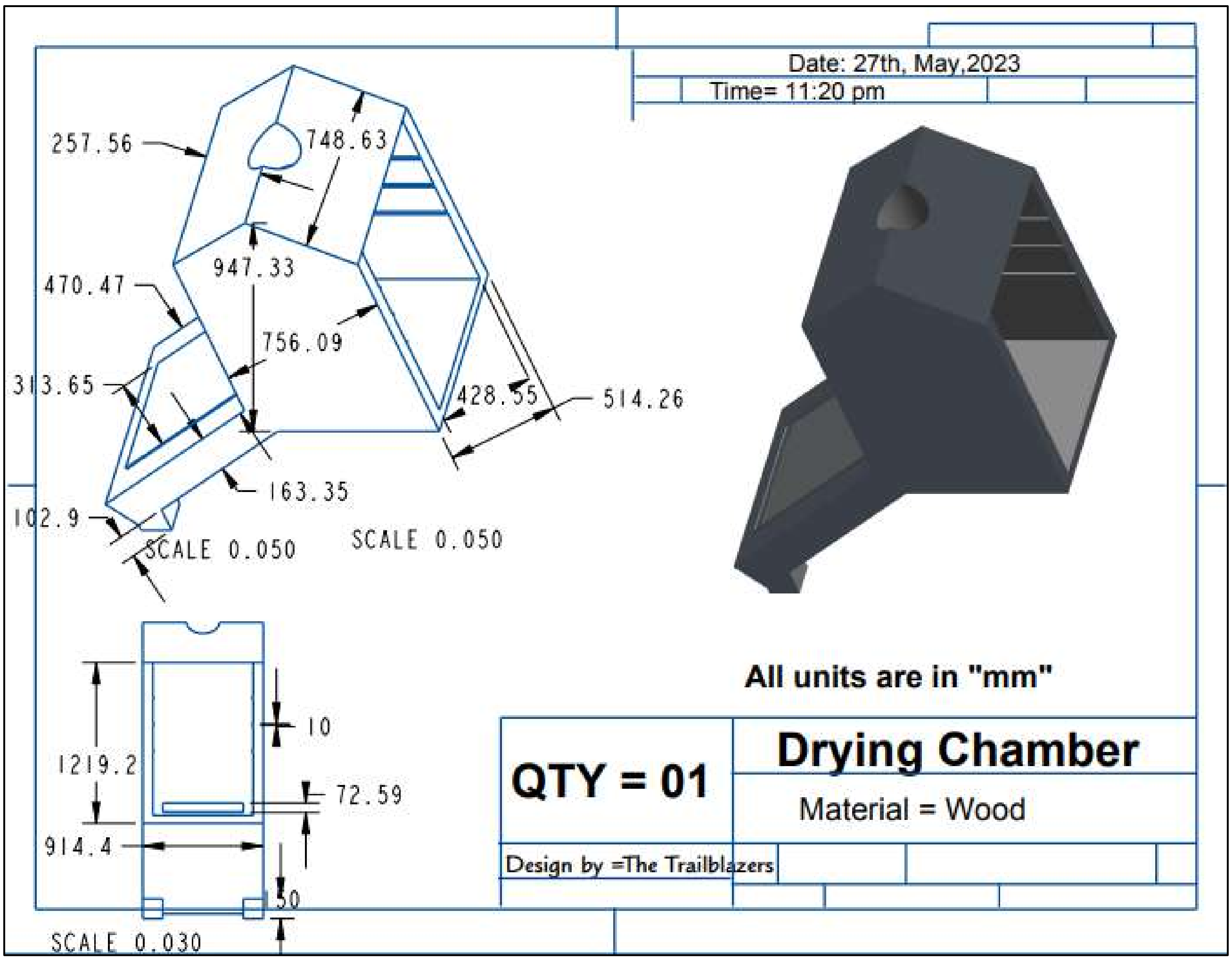


Figure 5-1: Drying Chamber

5.2.2 Component: 02 (Gate)

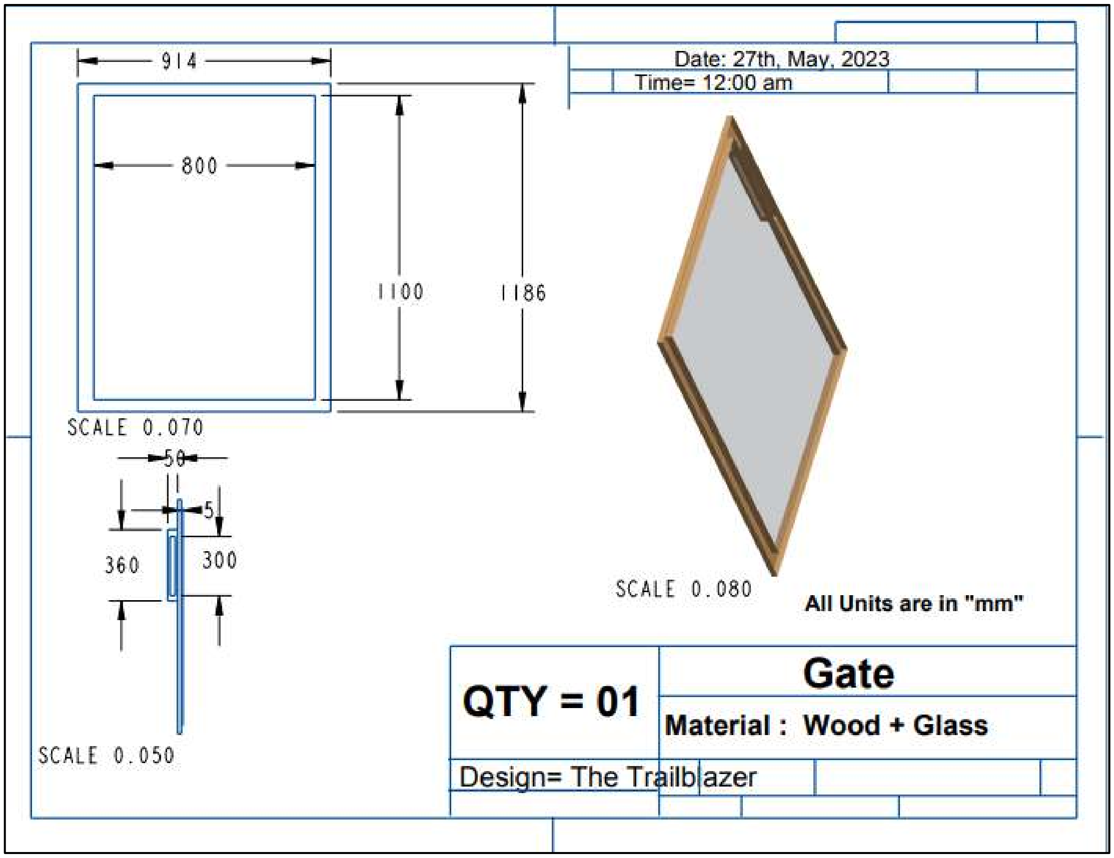


Figure 5-3:Gate

5.2.3 Component: 03 (Lower Frame)

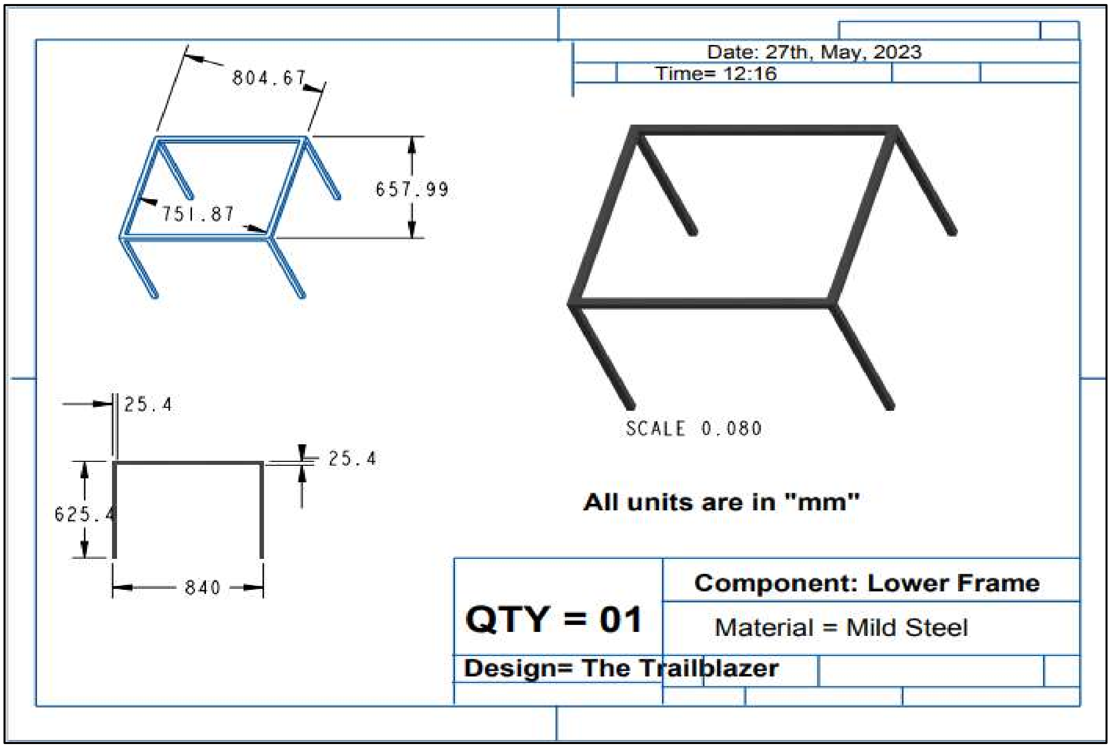


Figure 5-4: Lower Frame

5.2.4 Assembly

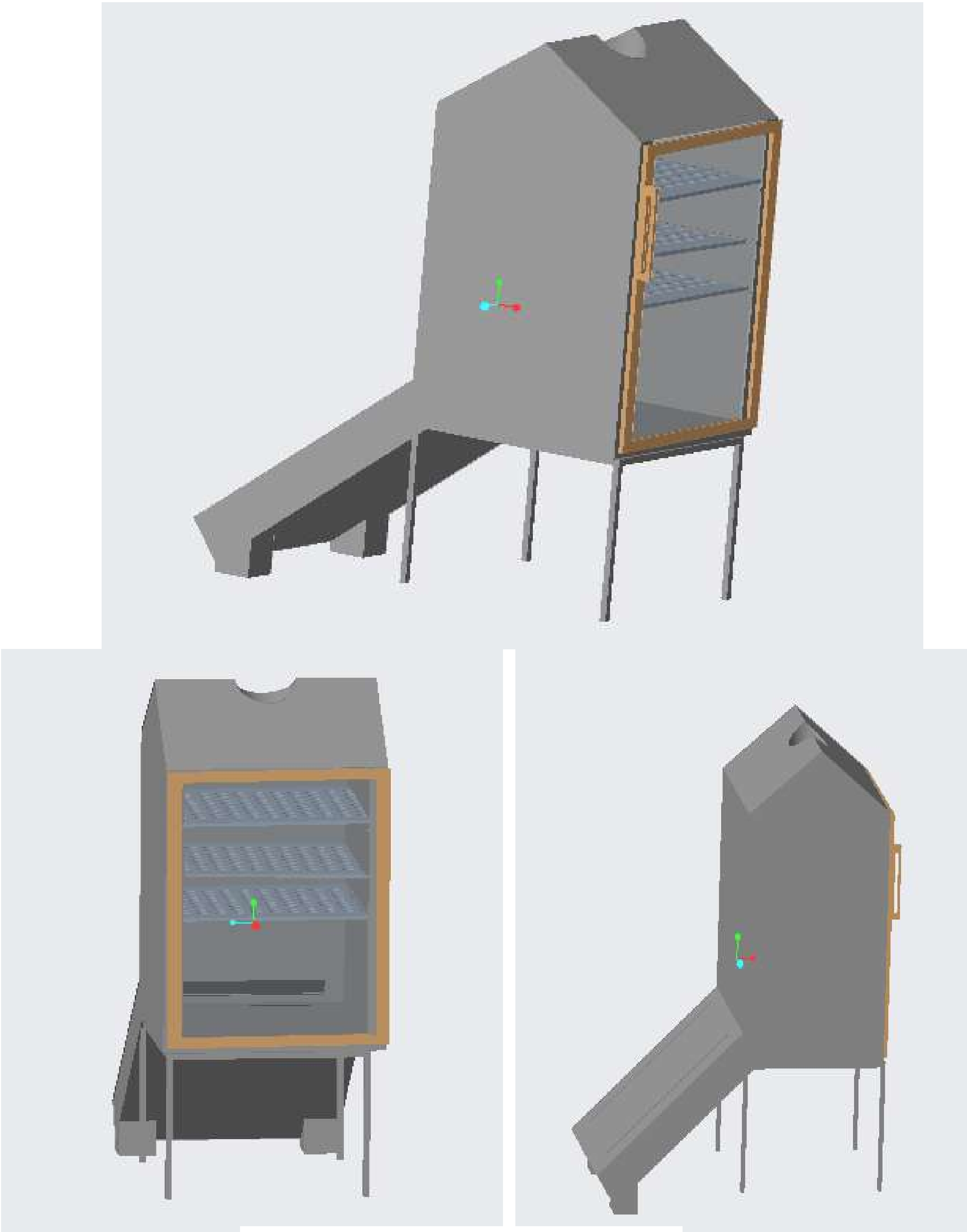


Figure 5-5: Assembly of CAD Model (Closed Gate)

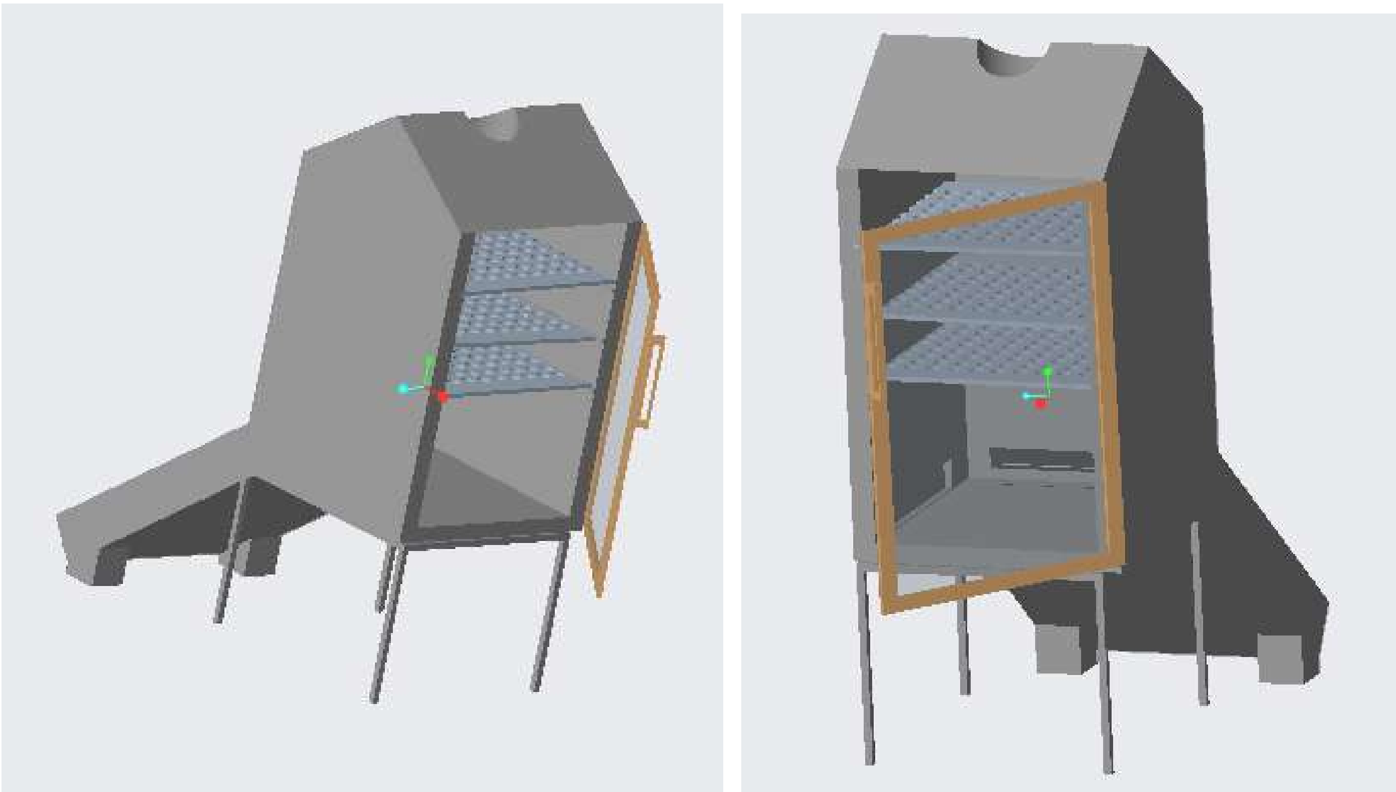


Figure 5-6:Assembly of CAD Model (Open Gate)

5.3 Working Methodology

1) Assemble all the components of the dryer.
2) Face the dehydrator's front view towards the south.
3) Keep different food items, i.e., fruits or vegetable slices, in the trays.
4) Keep the same food items on each tray.
5) Select a sample of placed fruits or vegetables for reading measurement.
6) Measure the sample's initial weight.
7) Set the required values for temperature and humidity in the controller.
8) When the sun rises, the radiation will be absorbed by polycarbonate glass.
9) The radiation is grabbed by black-painted mild steel, and a warm environment is produced.
10) The fresh air will enter from the inlet, and due to convection, heat transfer will occur.
11) Now the fresh air becomes warm and humid, depending on the ambient air condition.
12) This air enters the drying chamber.
13) The measuring sensor will provide the air temperature and humidity level.
14) The controller will indicate the air temperature and humidity and take action if required.
15) This air then comes into contact with food items.

16) Again, due to convection, heat transfer phenomena occur, and the air will absorb moisture content from these foods and evaporate from exhaust.
17) The process continues until the food item gets dry.
18) When there is less radiation, the bulb will provide the required amount of temperature in the form of heat.
19) And when the humidity is high in the ambient air, the controller will turn on the exhaust fan and increase the rate of evaporation.
20) Measure the weight of the selected food item after each hour of drying.

5.4 Summary

In this chapter, we observe the CAD modeling of different parts of our dehydrator and their specifications. We also observe the assembly of different components in our dehydrator. Then we briefly explain the real working mechanism of our dehydrator and its procedure. The upcoming chapter is a detailed knowledge of finite element analysis and will observe static structure analysis of the lower frame.

CHAPTER # 06

6 Finite

Element

Analysis

6.1 Introduction

Finite element analysis (FEA), a method, is a computing approach that can be utilized to address challenging mechanical issues. The engineer can mimic reality regardless of the situation or complexity by choosing sound boundary conditions and loads. The mechanical behavior of products and structures can be investigated and optimized without the necessity for prototyping. Profits represent the quick returns in relation to the time and money invested during the design phase. Additionally, it improves your product's dependability.

6.2 Importance of Finite Element Analysis (FEA)

Engineers can learn about a system's physical reaction anywhere by using finite element analysis, which enables the safe modeling of potentially harmful or destructive load conditions and failure modes. Other advantages are:

- ❖ The study of any physical stress that might have an impact on the design has increased precision.
- ❖ Enhanced design as a result of the ability to see how stresses in one element may impact the materials in a related piece.
- ❖ Testing earlier on during the development phase. Instead of taking days or weeks to construct physical prototypes, virtual prototyping enables designers to quickly simulate a variety of ideas and materials.
- ❖ Because FEA software enables developers to manufacture higher quality products in a quicker design cycle while also utilizing less material, there is an increase in productivity and income.
- ❖ Improved understanding of crucial design factors as a result of being able to simulate both the interior and exterior of the design. This enables designers to assess the overall impact of crucial elements on the structure as well as the potential causes and locations of breakdowns.
- ❖ Optimum use of models since multiple failure types or physical occurrences may be tested using a single, generic model.
- ❖ Quick calculation times and inexpensive investment.
- ❖ Having access to previously conducted experiments that can be used to inform the parametric assessments of newly developed models [14].

6.3 Basics of FEA

The term "finite elements analysis" is abbreviated as "FEA." It is a method based on the finite element method (FEM) that use computers to forecast the behavior of numerous physical systems, including the deformation of solids, heat conduction, and fluid movement. Because it makes it possible to accurately, creatively, and practically apply physical rules to real-world situations, FEA software, also known as FEM software, is a very popular tool used by engineers and [15].

6.3.1 Working

The finite element method (FEM) is applied to real-world issues through finite element analysis (FEA). The finite element method is a mathematical technique for estimating approximate differential equation solutions. The objective of this process is to convert the differential equations into a set of linear equations that can subsequently be solved automatically by a computer.

Due to the fact that differential equations are the language used to define physical principles, they are crucial and present in many engineering situations. They link alterations in an object's internal variables—such as displacement, temperature, or pressure—and their relationship with the geometry, physical characteristics, and external forces at play.

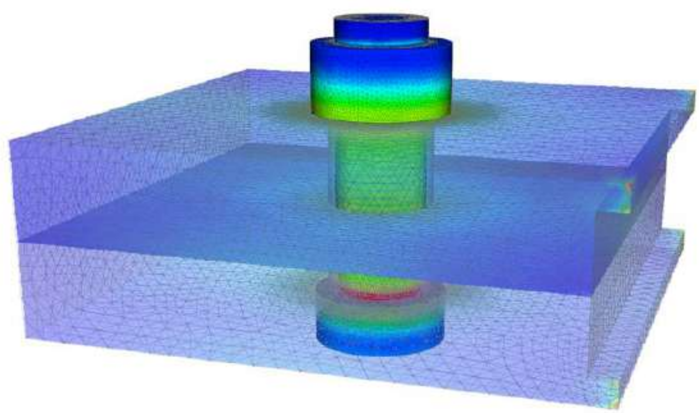


Figure 6-1:Simulation of Bolt Connection

The specifics of how this physical law is changed into a series of linear equations are outside the purview of this article, but the overall procedure is as follows:

1) Differential equations represent the physical principles that must be applied to the well specified physical situation.
2) The domain and boundary of the thing to be investigated are terms used to describe its geometry. The domain is the area that the object occupies, while the boundary is the surface that surrounds it.
3) External forces, pressures, temperatures, or heat sources operating on the border or domain are also clearly described. They are referred to as "boundary conditions."

4) The object's "initial conditions" are clearly described as well. The beginning values of all internal variables, such as the initial velocities, pre-stresses, or starting temperature distribution, are the set of values that were present at the start of the problem.
5) The realm is then divided into discrete, fundamental shapes called "elements." The term "mesh" refers to the collection of all pieces. 'Nodes' is another name for the locations where neighboring elements converge. The accuracy of the approximation will depend on the element sizes, with smaller being preferable. The demand for computing resources like memory and processing time will rise with a bigger number of elements utilized.
6) The final step involves "projecting" all equations and boundary conditions into the nodes, which generates a finite—but frequently significant—number of linear equations.
7) The set of variables that are generated for each node and element after the computer has solved the linear equations has been saved to directories.
8) Decisions regarding design, visualization, and numerical analysis are made using the collected data.

6.3.2 Applications Area of FEA

The structural analysis of solids is the finite element method's primary area of application, despite the fact that it is not restricted to a specific class of physical problems. Although structural analysis may consider several situations and types of loading, its fundamental objective is to determine if a given part or structure is capable of withstanding the forces being applied to it.

According to the notion of material resistance, this is accomplished by examining the part's stress and strain state. To determine whether the maximum values produced using any approach (for instance, FEM) are within the safety range, they are compared to the permissible values. The majority of the time, a design code, such as ASCE, ASME, Euro code, etc., specifies these permissible values. The following are some typical use cases for FEA software:

1) For use in buildings and other civil purposes, such as load lifting, steel or reinforced concrete constructions are available.
2) Industrial tools including rotating machinery, boilers, pipelines, pressure vessels, etc.
3) Tools used in manufacturing, such as mills, molds, and tooling.
4) Especially for virtual crash tests, transport structures such as cars, planes, or other vehicles.

6.3.3 Stress

Internal forces created within the material counteract external forces in a way that seeks to oppose the elongation effect, creating the equilibrium condition. These internal forces, or the "stress" of the material, are the outcome of cohesive forces at the molecular level. The amount of stress that the material develops will depend on how active the external force is. Limit stresses are the foundation of failure theories; in other words, failure of the element is anticipated to happen when stress levels exceed a certain level.

6.3.4 Strain

The elongation of elements was found to be an inconsistent measure when Hooke's law was attempted to be expressed in terms of material stress. The stiffness constant did not generalize for a particular material if the geometry of a test specimen was altered (for a uniaxial test, for example). It was noted that a unique measure of deformation should be taken into account. This is referred to as the "material strain" and can be described in a number of ways, including as "true stress" or "engineering stress." Using a measurement of the material rigidity known as Young's modulus, these definitions enabled the assertion of a relationship between the material's stress and strain.

Even while stress and deformation are the primary calculations used in FEA, it's crucial to keep in mind that there are other significant predictions that may be produced using the method. With FEA, additional extremely helpful data for a specific structural system can be discovered, such as:

1) The amplitudes and modes of natural vibration
2) Harmonic response to forced vibration
3) Limits and types of buckling for thin structures
4) Modalities of fracture propagation and fatigue life

6.4 Key Industries Using FEA

6.4.1 Automotive

FEA software simulations are used in the automotive industry to evaluate the structural safety of designed components including chassis, anchors, suspension, bodyworks, etc. Virtual crash testing is one of the most intriguing applications, where a dynamical simulation is carried out to foretell deformations and energy absorption against crash impact.

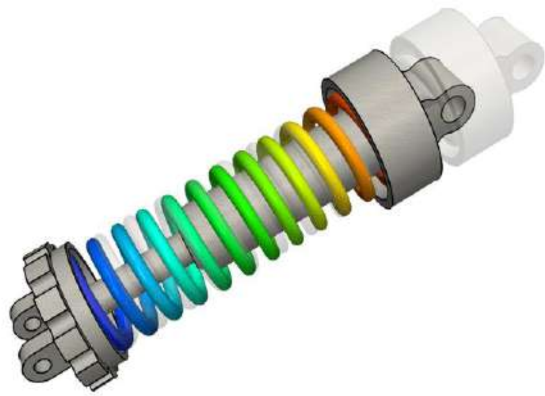


Figure 6-2: Structure Analysis of a Car Suspension

6.4.2 Industrial Equipment

Finite element analysis software is commonly used for the design and engineering of industrial equipment. For instance, pressure and heat loads are used in the processing sector to forecast the levels of stress in pipes, pressure vessels, tanks, and similar equipment. The modeling of forging operations for mills, benders, and stampers in order to gauge the amount of stress and spring-back in forged components is another potential application for the sector.

6.4.3 Civil Engineering and Structural Design

FEA software has unleashed the power of quick and accurate analysis for civil engineering and structural design, with the ability to automatically apply code load combos and verify compliance. Static loading, equivalent static loading, dynamic performance in seismic situations, natural vibration modes, and frequency computation are examples of common analysis scenarios. Using a steel construction as an example, consider the following project:

Figure 6-3: Von-Mises stresses of a Structure

6.5 Assumption During FEA Analysis and Generalized Processing Steps

Numerous assumptions or simplifications must frequently be made in order to have a final workable model while trying to achieve results in a limited amount of time. Workable simply implies that the FEA model must provide the computation of the desired results with adequate accuracy and within a reasonable amount of time and resources. The computers used for these investigations are both located in open labs and have specific amounts of RAM, hard drive space, and processing power allotted to them, therefore the last two have emerged as crucial factors to take into account.

The user must make a number of assumptions in order to simplify the model. One such presumption is that the materials used in the model are homogeneous, isotropic, and free of internal flaws or defects. Another presumption is to overlook features of the geometry that are unlikely to have an impact on the outcomes, like the part's chamfered edges on the outside. Often, the first set of assumptions used to simplify a model ignores visual characteristics and assumes homogenous materials are typical in industry.

The model can be referred to as a simplified physical model after such presumptions are made. Making more assumptions would be the next step in developing a mathematical model. The idealized loading conditions and linear material qualities are part of this set of presumptions. The loading must be steady and positioned on completely set locations in order for the loading circumstances to be excellent. In order to represent the variation in attributes inside the model's borders, the model is now transformed into one or more differential equations.

Making a FEA model from the mathematical model is the next stage. Here, one or more differential equations are transformed into an equal number of concurrent linear algebraic equations. A run processor, which is a FEA engine, actually implements the solution to the stated issue. It will employ specialized numerical techniques and algorithms to exploit different characteristics inside the system of equations. The output can be graphically shown, highlighting essential elements such the displacement form, stress distribution, mode shapes, and many more.

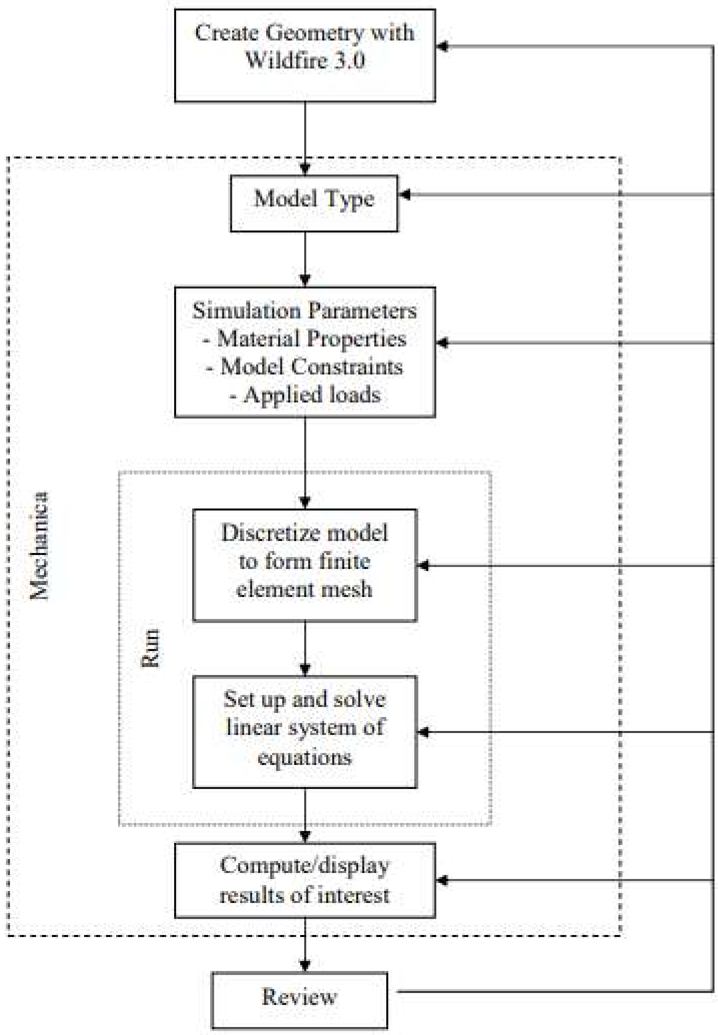


Figure 6-4: Processing Steps

6.6 FEA Analysis of Lower Frame

6.6.1 Material

These data are taken from [16].

Table 6-1:Mild Steel Properties

Generic Data :

Technical Name	Mild Steel 1018
Process	CNC Machining
Accuracy	(+/-) 125µm
Maximum Build size	300 x 300 x 200 mm

Material Data Sheet

CHEMICAL ELEMENTS	UNIT	VALUE
Carbo (C)	%	0.14 - 0.20
Iron (Fe)	%	98.81 - 99.26 (as remainder)
Manganes (Mn)	%	0.60 - 0.90
Phosphorous (P)	%	≤ 0.040
Sulfur (S)	%	≤ 0.050
MECHANICAL PROPERTIES	**UNIT**	**VALUE**
Tensile Strength, Ultimate	MPa	440
Tensile Strength, Yield	MPa	370
Elongation at break (%)	%	15
Hardness Rockwell B	HB	71
PHYSICAL PROPERTIES	**UNIT**	**VALUE**
Density	kg/m^3	7870
Melting Point	ºC	1375-1400
Modulus of Elasticity	GPa	205
Electrical Resistivity	Ω.m	0.159x10-6

6.6.2 Material Model

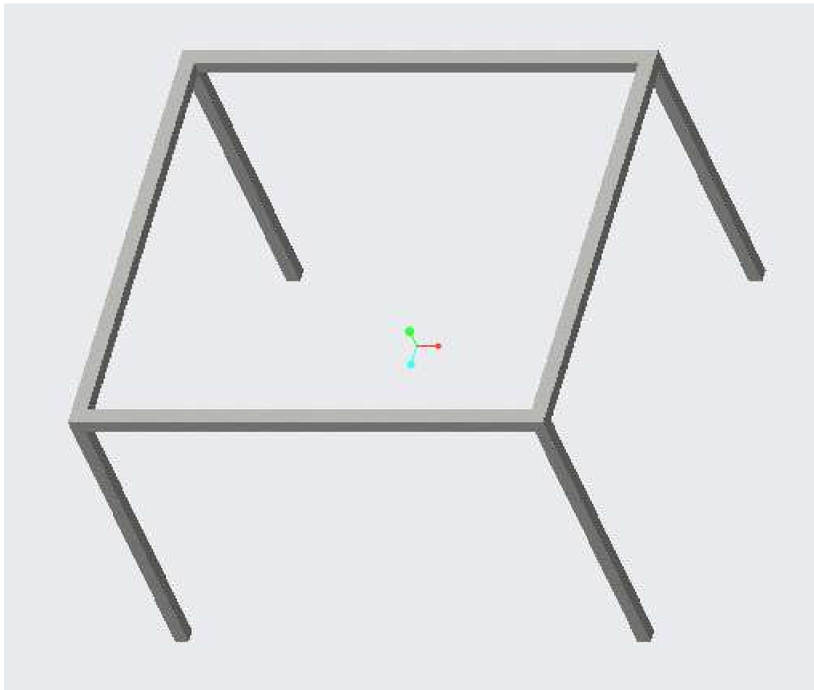


Figure 6-5: Material Model

6.6.3 Boundary Condition

A static structure analysis has been carried out. The total weight of the upper chamber and gate is 19.7 N. So we take 20N and divide this 20N on each side of the portion of the frame. All four legs of the frame will be fixed.

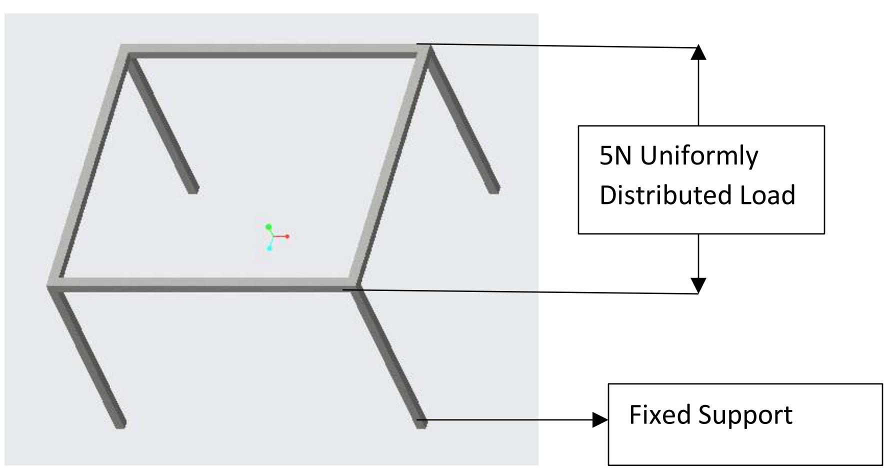
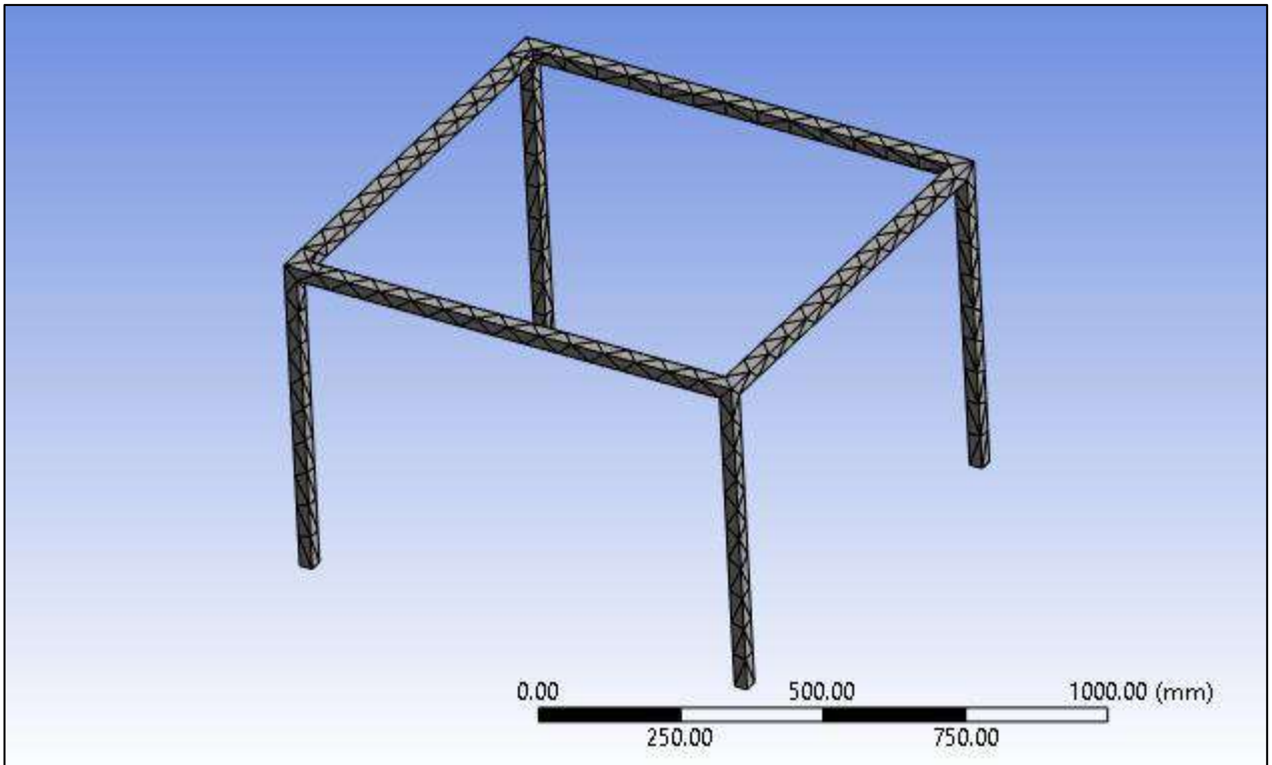


Figure 6-6: Boundary Condition

6.6.4 Meshing



Details of "Mesh"	
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	Default
Sizing	
Use Adaptive Sizi...	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Di...	1390.3 mm
Average Surface ...	28151 mm^2
Minimum Edge L...	25.4 mm
Quality	
Check Mesh Qua...	Yes, Errors
Error Limits	Aggressive Mechanical
Target Elemen...	Default (5.e-002)
Smoothing	Medium
Mesh Metric	None

Figure 6-7: Meshing

6.6.5 Result (Von Mises Stresses)

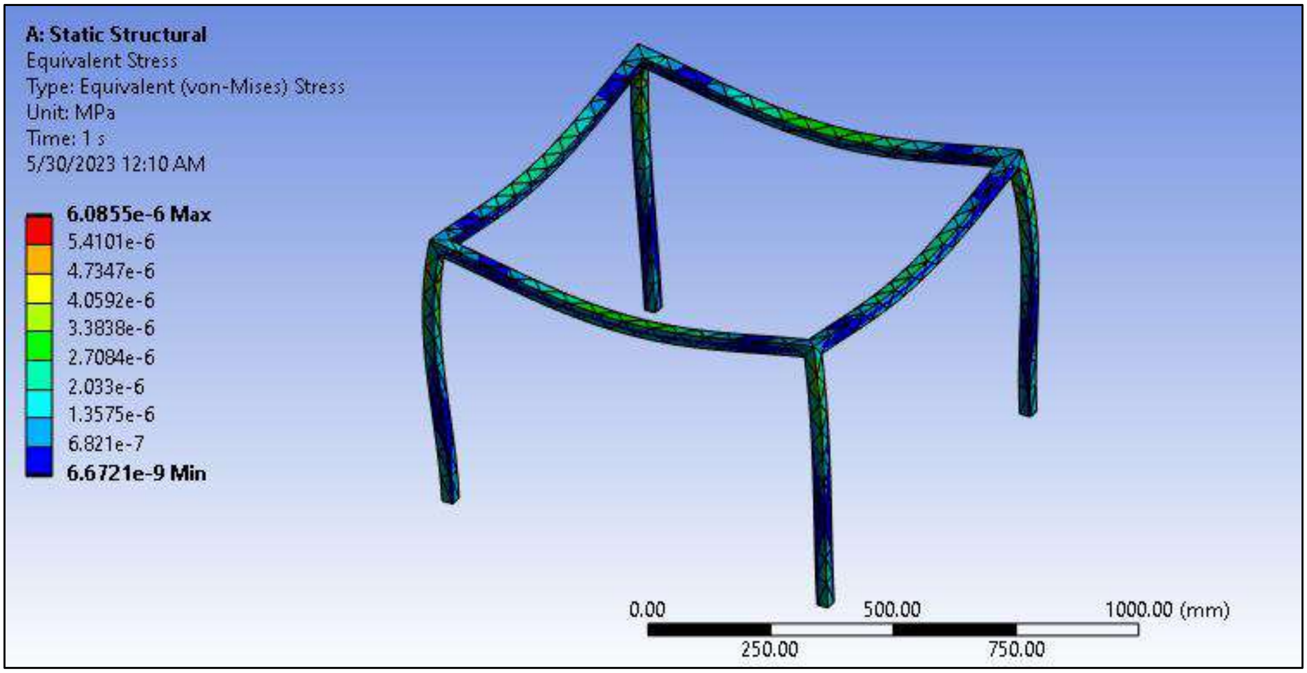


Figure 6-8: Von Mises Stresses of Lower Frame

6.6.6 Discussion

As clear from the static structure analysis our lower frame is safe under 20N load of drying chamber and gate. If a certain material will yield or fracture, it can be determined using the von Mises stress value. Metals and other ductile materials are its main applications. According to the von Mises yield criterion, material will yield if the von Mises stress is equal to or greater than the yield limit of the same material under simple tension.

6.7 Summary

In this chapter, we discuss and perform a static structure analysis of our dehydrator lower frame. Using advanced solver options including linear dynamics, nonlinearities, thermal analysis, materials, composites, hydrodynamic, explicit, and more, Ansys Mechanical is a finite element analysis (FEA) program used to do structural analysis. The next chapter is about fabrication of solar vegetables and fruits dryer with procedure.

CHAPTER # 07

7 Fabrication

7.1 Introduction

In this chapter, we will discuss the fabrication of different components and their manufacturing processes. The fabrication process is done according to the design and specifications made in CAD. There are two Tm/RH sensors and one Tm/RH controller installed.

7.2 Fabrication of Lower Frame

Figure 7-1: Fabrication of Lower Frame

7.2.1 Manufacturing Process

1) The material for fabrication of the lower frame is “mild steel”.
2) After analysis in FEA Section 6.6.5, mild steel bar is cut according to CAD design as mentioned in Section 5.2.3.

7.3 Fabrication of Inlet Chamber

Figure 7-2: Fabrication of Inlet Chamber

7.3.1 Manufacturing Process

1) The lower frame of the inlet chamber is fabricated using wood.
2) The polycarbonate sheet is placed above it using screws.
3) A sheet of mild steel is placed inside to absorb solar radiation.
4) This inlet chamber is fabricated in such a way that we can engage and disengage it from the drying chamber.
5) There is one Tm/RH measuring sensor installed to provide readings of inlet temperature and relative humidity.

7.4 Fabrication of Drying Chamber

Figure 7-3: Fabrication of Drying Chamber

7.4.1 Fabrication process

1) This drying chamber is also fabricated using wood.
2) The drying chamber has three trays, but they can be increased.
3) There is a Tm/RH controller that will control temperature and humidity levels.
4) There is also a Tm/RH measuring sensor, which will indicate the inner temperature and relative humidity.
5) There is also a fan installed, which will control the humidity level.
6) The gate of the drying chamber has normal mirrors installed, and their displays are toward the outside.

7.5 Final Assembly

Figure 7-4:Fabrication Assembly

7.6 Compliance w.r.t SDGs

The Sustainable Development Goals (SDGs), sometimes referred to as the Global Goals, were enacted by the United Nations in 2015 as a global call to action to eradicate poverty, safeguard the environment, and guarantee that by the year 2030, peace and prosperity will be experienced by everyone [17].

The seventeen Sustainable Development Goals (SDGs) understand that development must balance social, economic, and environmental sustainability and that actions in one area will have an impact on results in others. Our solar fruit and vegetable dryer was one of 17 and focused on the following SDGs:

Table 7-1:Sustainable Development Goals

SDGs	REASON/EXPLAINATION
1:**No Poverty**	There will no loss in quality and quantity of foods for farmers, so the farmers will preserve and sell food in good quality, and their economic condition become good.
2:Zero Hunger	The poor people will buy food in lower price and they will not sleep with empty stomach.
3:Good Health & Well-Being	The health of the people will be improved if they buy good quality of food.
4:Quality Education	In this dehydrator, the quality of the food will be improved.
7:Affordable & Clean Energy	This dehydrator is manufacture from the available material in Pakistan local market, so everyone can afford it. Also this dehydrator is clean energy.
10:Reduce Inequality	By this dehydrator, poor and rich will buy same quality of food and inequality will be reduce.
11:Sustainable Cites & Communities	This dehydrator is used in sustainable cities and communities.
12:Responsibel Consumption & Production	This dehydrator consume sun energy and electricity as secondary source and will produce good quality and quantity of food.
13:Climate Action	This dehydrator can be use in every environmental condition.
15:Life on Land	This dehydrator have the potential to improve life on land.

7.7 Summary

In this chapter, we discussed the fabrication of components and their processes of fabrication. We also discuss sensors installation locations in the dryer. We then discuss Sustainable Development Goals (SDGs) and indicate which goals our dryer targeted out of 17. In the next chapter, we will discuss progress and testing analysis of our dehydrator by drying some food.

CHAPTER # 08

8 Conclusion

And

Future Work

8.1 Introduction

This is very important chapter of the thesis. In this chapter we will perform particle working and analysis of food drying process in our fabricated dehydrator. In this chapter, we will deal with graphs, tables and hurdle if any uncertainty happens during preservation process.

8.2 Result & Conclusion

8.2.1 Drying of Apple Slice

Table 8-1: Time vs Weight of Apple Slice

Time(Hours)	**Weight (g)**
0	17
2	15
4	13.6
6	10.2
8	6.7
10	2.2

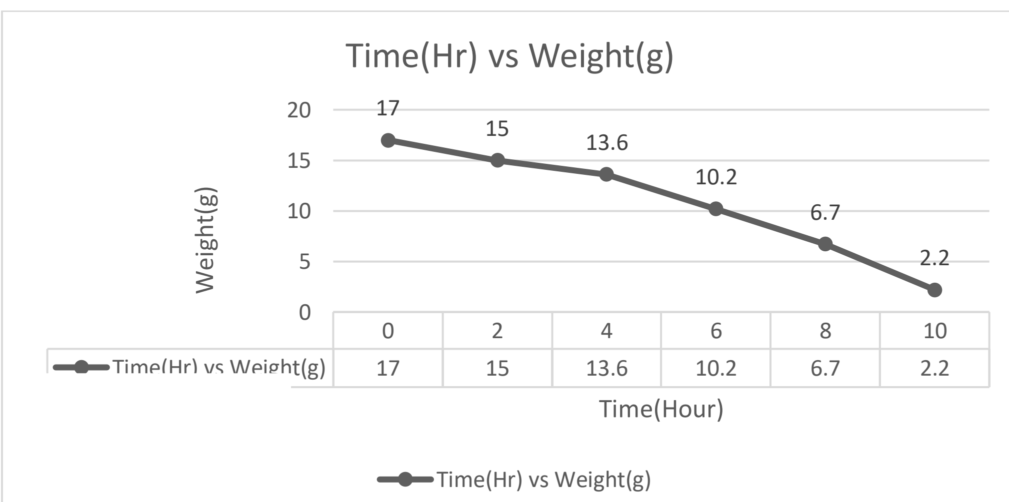


Figure 8-1: Time vs Weight

8.2.2 Drying of Tomatoes

Table 8-2: Time vs weight of Tomato slice

Time(Hours)	Weight (g)
0	5
2	4.6
4	4.1
6	3.6
8	2.9
10	1.7
12	0.3

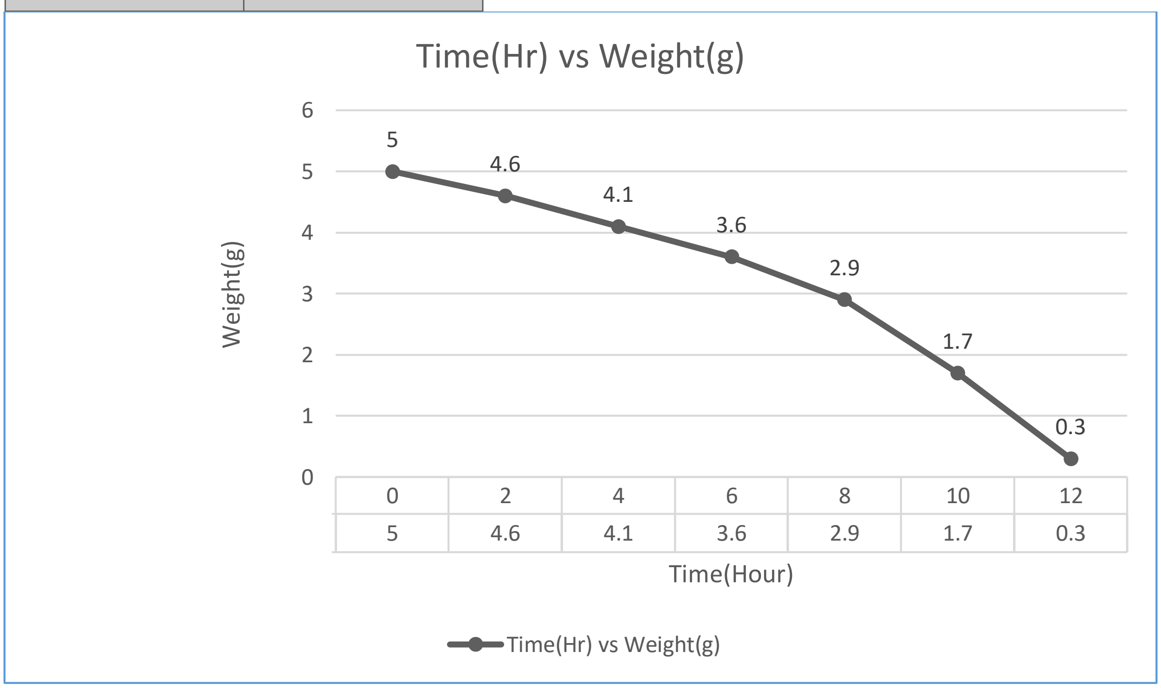


Figure 8-2:Time vs Weight

8.2.3 Drying of Mango Slices

Table 8-3: Time vs Weight of Mango Slice

Time(Hours)	**Weight (g)**
0	16
1	13.9
2	11.9
3	10.1
5	7.1
8	5.2
10	3.2

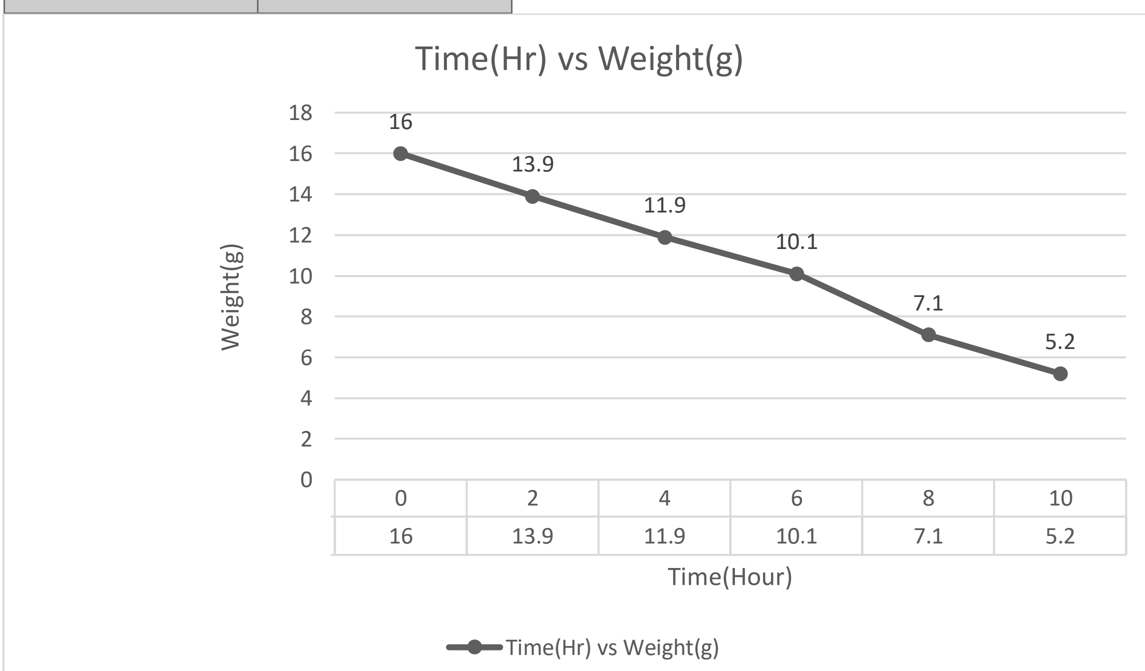


Figure 8-3:Time vs Weight

8.2.4 Temperature vs Time

Table 8-4: Time vs temperatures

Time(Hour)	Ambient Temperature [°C]	Inlet Chamber Temperature [°C]	Drying Chamber Temperature [°C]
0	27	63	45
2	26	61	46
4	27	62	48
6	29	64	50
8	30	62	52
10	31	32	38
12	29	24	37

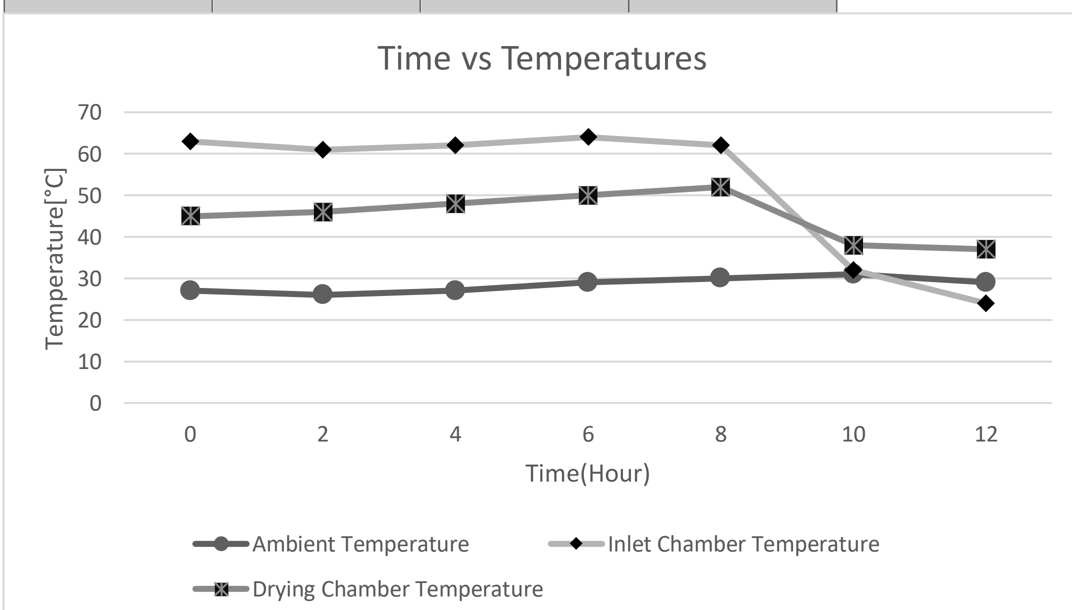


Figure 8-4: Time vs Temperatures

8.2.5 Relative Humidity vs Time

Table 8-5: Time vs Relative Humidity

Time(Hour)	Ambient Relative Humidity[%]	Inlet Chamber Relative Humidity [%]	Drying Chamber Relative Humidity [%]
0	48	10	22
2	45	12	19
4	45	11	16
6	44	13	12
8	43	10	10
10	43	37	28
12	44	55	31

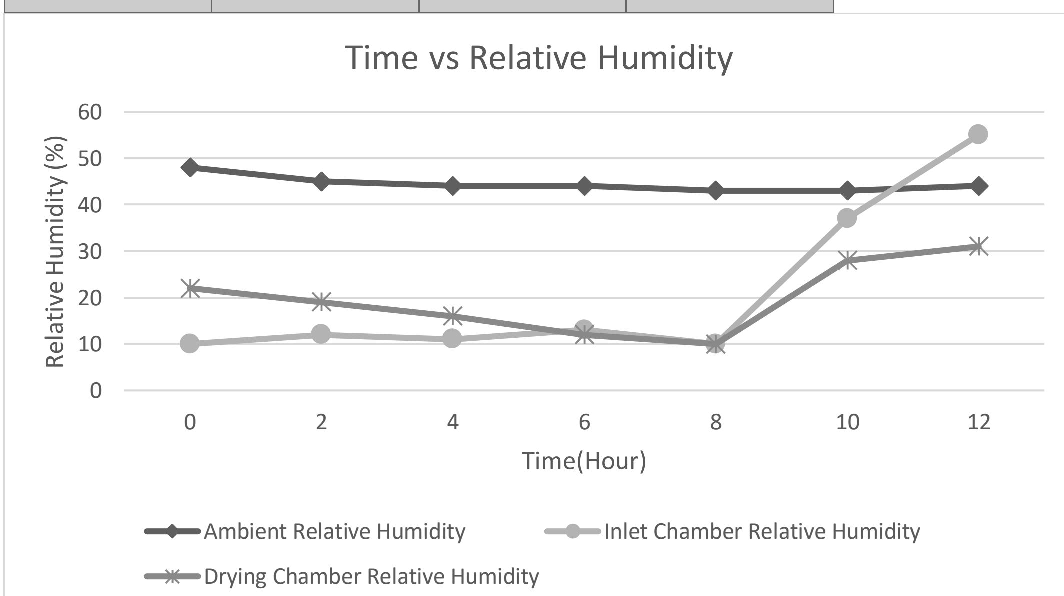


Figure 8-5:Time vs Relative Humidity

8.3 Conclusion

It is clear from the above-mentioned tables and graphs that our fabricated dehydrator works efficiently. It can dry vegetables and fruits to the required level of quality. We also succeeded in achieving the required level of temperature in the drying chamber with a secondary source, i-e., electricity. During rainy weather, where the temperature outside was low, our dehydrator with a secondary source provided an 8-12 °C increase in temperature in the drying chamber with the help of secondary source. Moreover, our dehydrator takes less time to dry food. Additionally, our temperature and humidity controller works efficiently by maintaining the required amount of temperature and humidity in the drying chamber. Below are the images of dried food.

Dried Apple Slices

Dried Mango Slices

Dried Tomato Slices

Figure 8-6: Dried Food Slices

8.4 Future Work

This dehydrator is a gateway for publishing research paper and innovation. In this dehydrator food can be preserve efficiently and make it economic by selling it in Pakistan and also export them. By export we can improve Pakistan economic condition. Hybrid solar vegetables and fruits dryers are gaining popularity in Pakistan due to their cost and environmental benefits. There is a need for further research and development in this area in order to improve efficiency and reduce cost. Additionally, creating standards for the use and installation of these dryers can help to ensure that they are used safely and effectively. Furthermore, developing models that can be used to assess the potential energy savings of using these dryers can help to make them more attractive to potential users. Finally, improving the availability of solar dryers in Pakistan, through increased production and distribution, could help to make them more accessible to rural communities.

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