STUDY OF THE INSTALLATION of FORCED EVAPORATION MECHANISM AND SECONDARY HEAT SOURCE ON THE PERFORMANCE OF SOLAR VEGETABLES AND FRUITS DRYER EQUIPMENT

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1 Abstract

Pakistani farmers face a number of challenges to get a justified reward for their produce of vegetables and fruits. Hot weather and high charges incurred in farm-to-market transportation sometimes make the discarding of fruits and vegetables more economical. This affects the livelihood of the farmers adversely.

To overcome this issue, a number of solar dryers have been developed. These dryers can be used to dry fruits and vegetables in the season when the supply is high and the profit is low. The dried food can later be sold at suitable rates in the offseason when demand is high but supply is scarce. However, when the humidity is high or the weather is overcast, the drying process not only takes longer but also puts the quality of the dried product at stake.

Therefore, we have installed a fan and a secondary heat source—a 100-watt bulb—to improve the evaporation of moisture from the food. 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. These modifications have enabled our system to perform well in humid and overcast conditions. Our experiments show a reduction in the drying time for tomatoes, onions, bananas, apples, and mangoes by 16%, 15%, 12%, 8%, and 11%, respectively.

2 Introduction

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.

2.1 Aims

- To improve the livelihood of the farmers in Pakistan.
- To reduce food waste and greenhouse gases.
- To reduce the scarcity of fruits and vegetables.
- To prevent fruits and vegetables from being inferior in terms of quality and quantity.

2.2 Objectives

- To indigenously fabricate solar dehydrator.
- To reduce the drying time of fruits and vegetables.
- To operate in every environmental condition.
- To reduce post-harvest loss.
- To operate the drying process 24/7.

3 Materials and Methods

3.1 Components

Table 1: Materials and Specifications

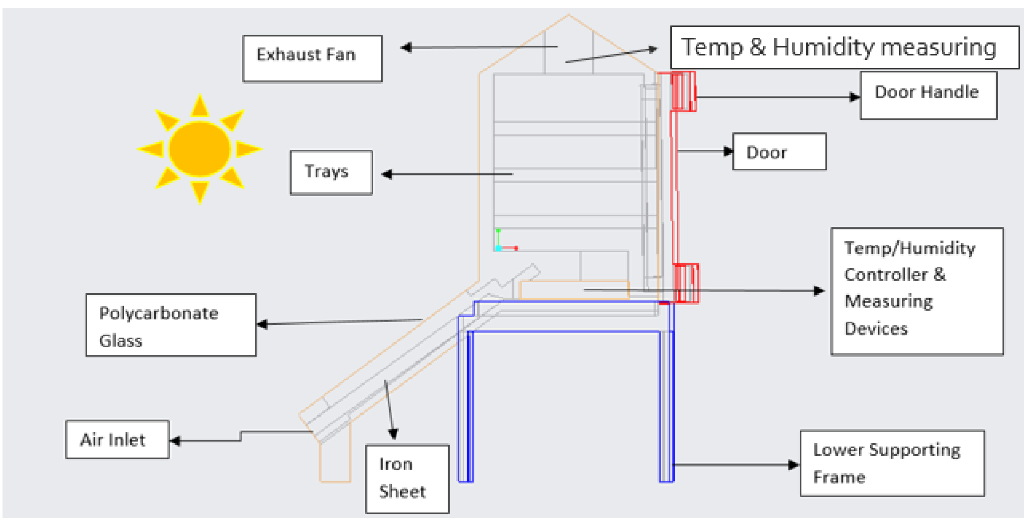
MATERIAL	**SPECIFICATIONS**
Chamber	Imported wood (4ft Height × 3ft width)
Gate	Imported Wood (4ft Height × 3ft width)
Lower supporting Frame	Mild Steel (1.5ft Height) (2.5ft Length × 3ft Width) Thickness = 1 inch or 25.4 mm
Temperature/Humidity Controller	Temperature range = (0 — 80) °C Measuring Humidity 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°C , 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
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

3.2 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. A new technology was developed in these dehydrators to provide the required temperature from secondary sources, i.e., fossil fuels, electricity, biomass, etc.

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 1: Concept Generation



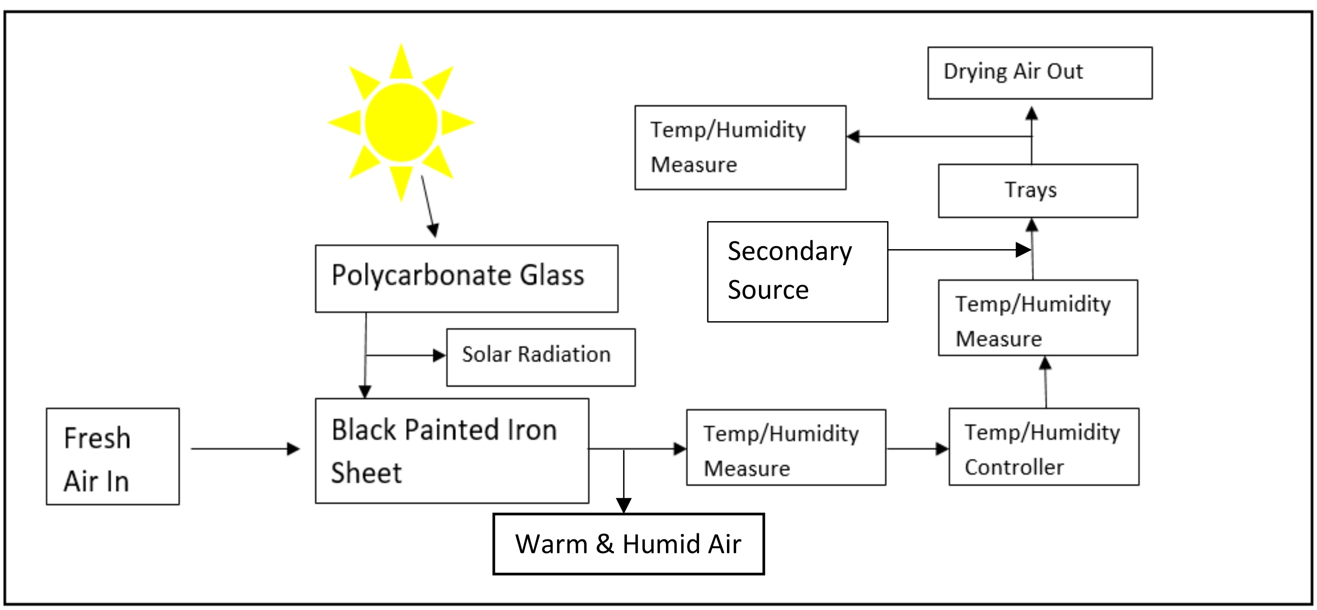
3.3 Scope of the Dryer

- 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.

3.4 Working Mechanism Flow Chart

Figure 2: Working Mechanism Flow Chart



3.5 Working Procedure/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.

3.6 CAD Modeling of Components

Figure 3: Component 01 Drying Chamber

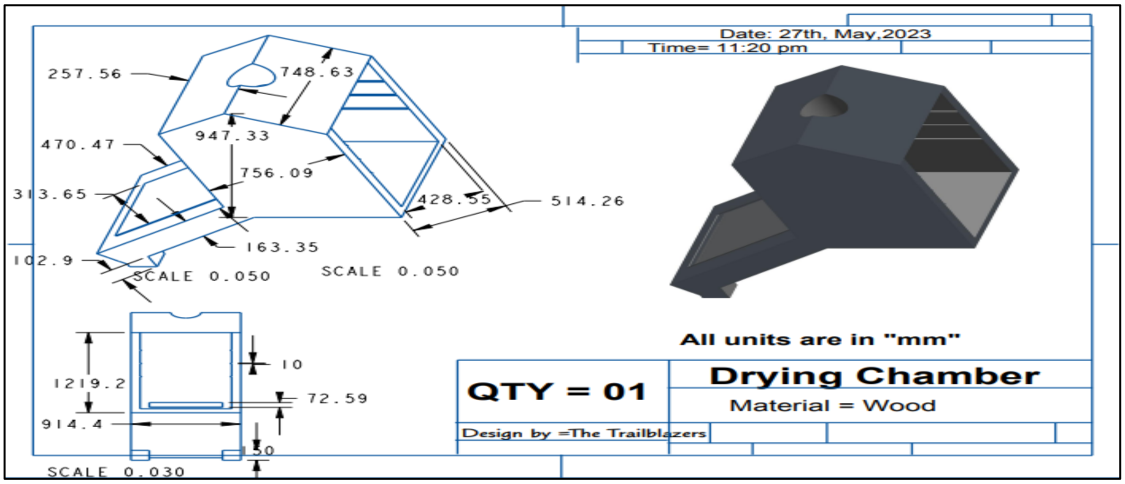


Figure 4: Component 02 Gate

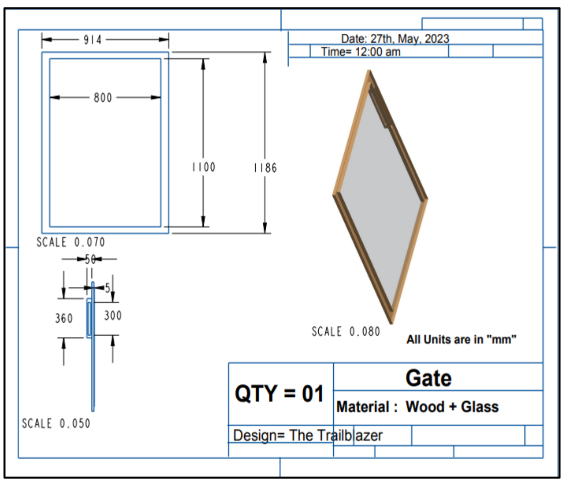
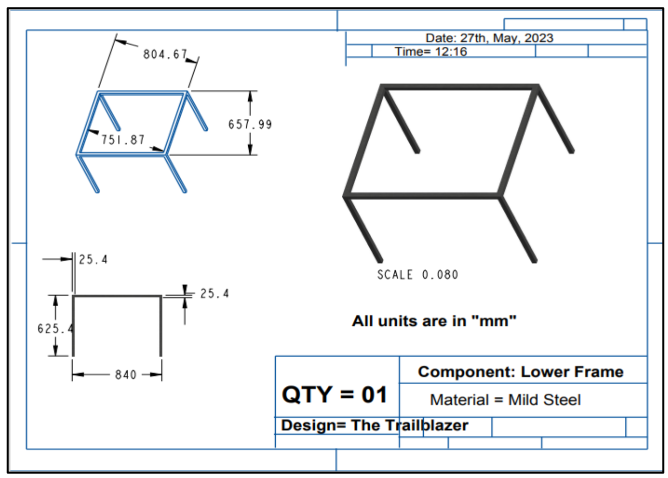
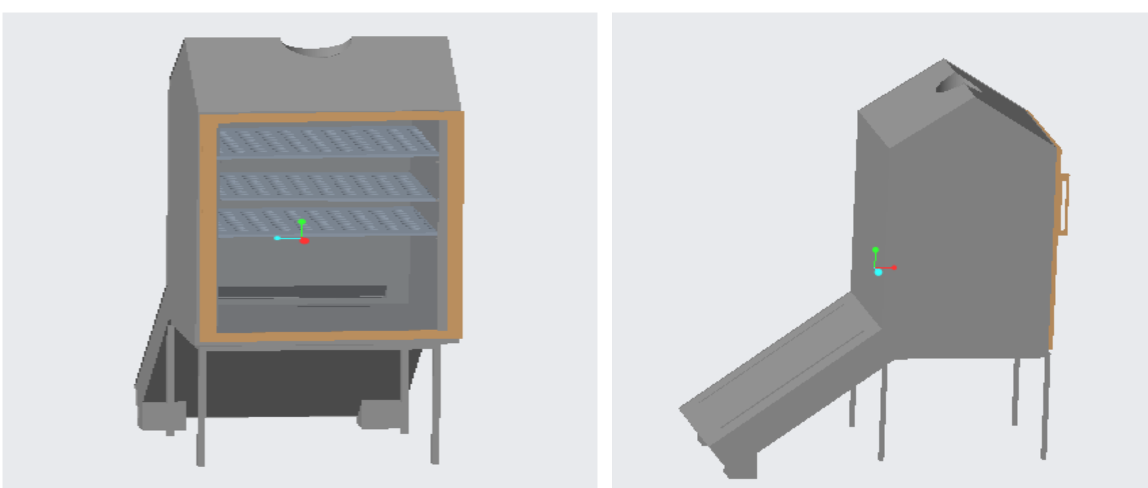


Figure 5: Lower Frame



3.7 Assembly

Figure 6: Assembly of Dryer components



3.8 Fabricated Dryer Components

Figure 7: Lower Frame

Figure 8: Inlet Chamber

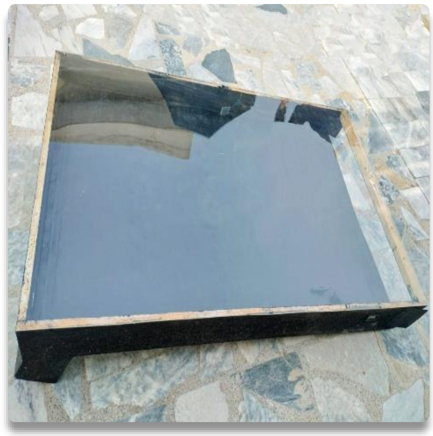


Figure 9: Drying Chamber

3.9 Assemble of Fabricated Components

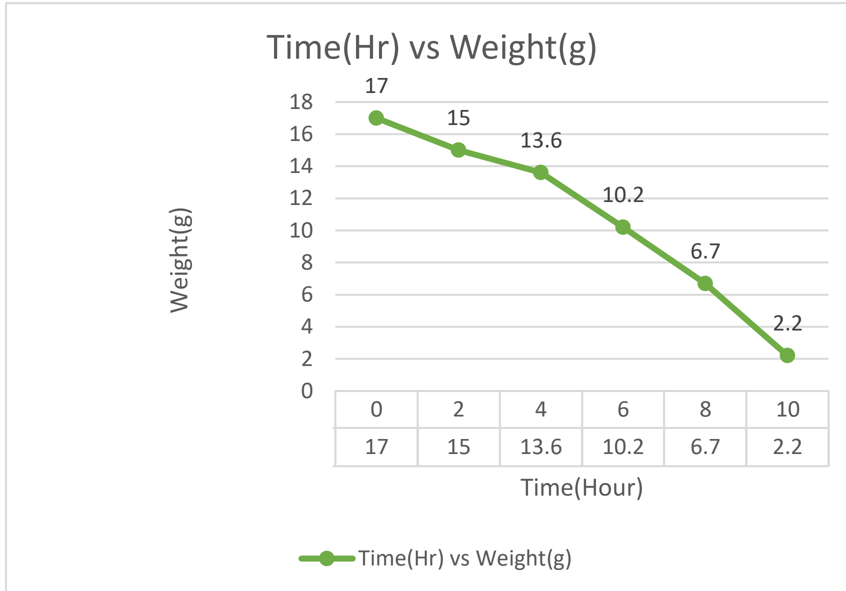
Figure 10: Assembly of Fabricated Components

4 Results and Conclusions

4.1 Drying of Apple Slices

Table 2: Time vs Weight of Apple slice

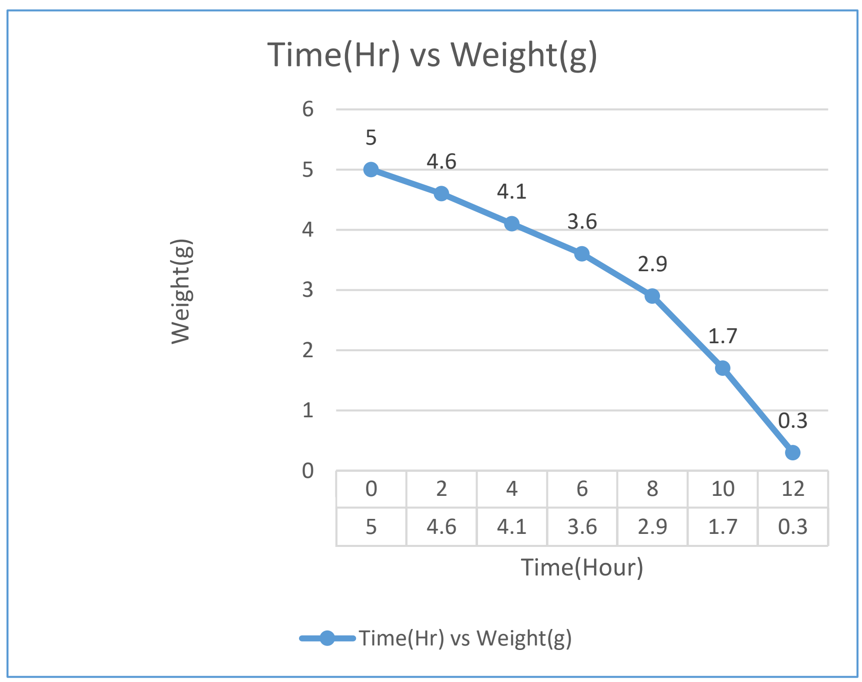
Time(Hours)	Weight (g)
0	17
2	15
4	13.6
6	10.2
8	6.7
10	2.2



4.2 Drying of Tomatoes

Table 3: Time vs Weight of Tomato slice

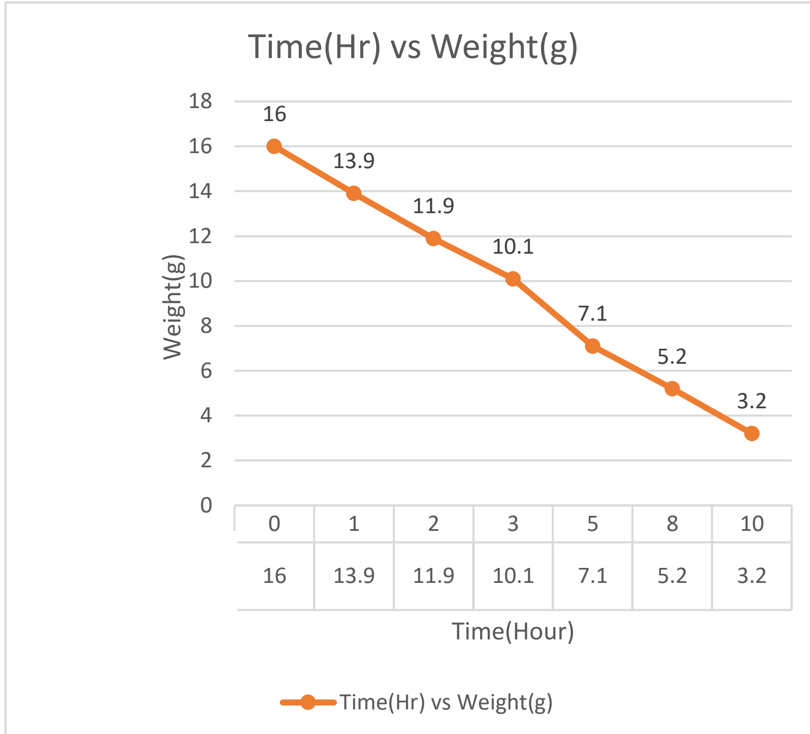
Time(Hours)	Weight (g)
0	5
2	4.6
4	4.1
6	3.6
8	2.9
10	1.7
12	0.3



4.3 Drying of Mango slice

Table 4: Time vs Weight of Mango Slice

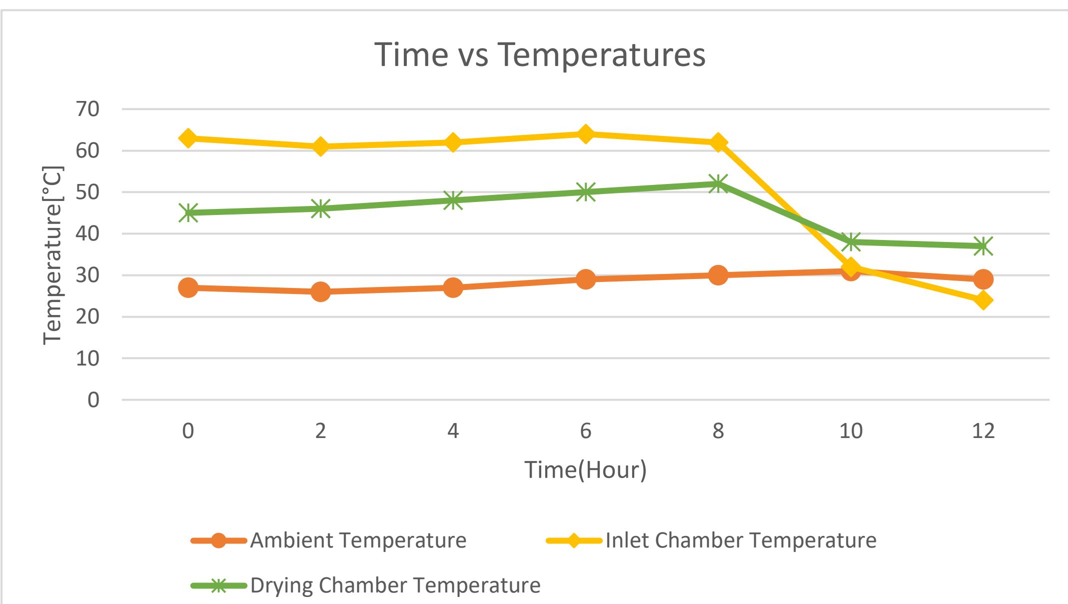
Time(Hours)	Weight (g)
0	16
1	13.9
2	11.9
3	10.1
5	7.1
8	5.2
10	3.2



4.4 Temperature vs Time

Table 5: Time vs temperatures

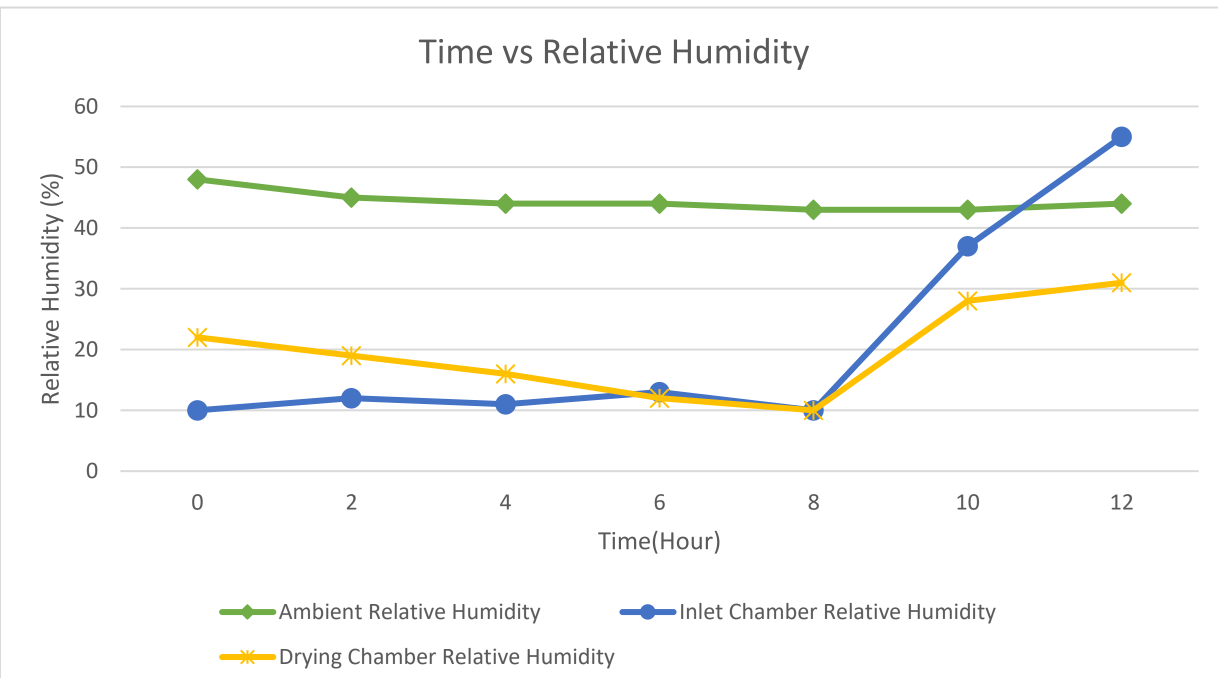
Time(Hour)	Ambient Temperature [°C]	Inlet Chamber Temperature [°C]	Drying Chamber Temperature [°C]
0	27	63	45
2	26	61	46
4	27	62	48
6	29	64	50
8	30	62	52
10	31	32	38
12	29	24	37



4.5 Relative Humidity vs Time

Table 6: 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



4.6 Conclusions

- 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 work efficiently by maintaining the required amount of temperature and humidity in the drying chamber. Below are the images of dried food.

Figure 11: Dried Food

Dried Apple | Dried Mango Slices | Dried Tomato

4.7 Future Work

In future our project has great potential of commercialization and contribution in the agro-food industry of Khyber Pakhtunkhwa in particular and Pakistan in general. In this dehydrator food can be preserve effectively and make it economic by selling it in Pakistan and also export them. By export we will improve Pakistan economic condition.