Design, Construction and Performance Test of Potato Solar Dryer

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Abstract- The solar drying system utilizes solar energy to heat up air and to dry any food substance loaded, which is beneficial in reducing wastage of agricultural product and helps in preservation of agricultural product. Based on the limitations of the natural sun drying e.g. exposure to direct sunlight, liability to pests and rodents lack of proper monitoring, and the escalated cost of the mechanical dryer, a solar is therefore developed to cater for this limitation. This paper presents the design and construction of solar dryer for potato. The dryer is composed of solar collector (air heater) and a solar drying chamber constraining rack of single trays. The air allowed in through air inlet is heated up in the solar collector and channeled through the drying chamber where it is utilized in drying. The design was based on the geographical location and meteorological data were obtained for proper design specification. The dimensions of the dryer are 71cm x 35.5cm × 100cm (length ×width × height). Locally available material were used for the construction, chiefly comprising of wood, glass, aluminum metal sheet, copper rod for collector and tray. The optimum temperature of the dryer is 49.33^{O}C with a corresponding ambient temperature of 36.5^{o}C.

Indexed Terms-construction,design, solar dryer, results

I. INTRODUCTION

Preservation of fruits, vegetables, and food are essential for keeping them for a long time without further deterioration in the quality of the product. Several process technologies have been employed on an industrial scale to preserve food products; the major ones are canning, freezing, and dehydration. Among these, drying is especially suited for developing countries with poorly established low-temperature and thermal processing facilities. It offers a highly effective and practical means of preservation to reduce postharvest losses and offset the shortages in supply. Drying is a simple process of moisture removal from a product in order to reach the desired moisture content and is an energy intensive operation. Drying by solar energy is a rather economical procedure for agricultural products, especially for medium to small amounts of products. It is still used from domestic up to small commercial size drying of crops, agricultural products and foodstuff, such as fruits, vegetables, aromatic herbs, wood, etc. contributing thus significantly to the economy of small agricultural communities and farms.

II. MATERIALS AND METHOD

Solar energy drying systems are classified primarily according to their heating modes and the manner in which the solar heat is utilized. They can be classified into two major groups, namely: passive solar-energy drying systems (conventionally termed natural-circulation solar drying systems) and, active solar-energy drying systems (most types of which are often termed hybrid solar dryer. Among them this type is mixed mode type. Solar dryers are mainly made up of three parts. These are solar collector, drying chamber and drying racks and chimney.

(a) Solar Collector

Solar collectors are used to convert direct and diffuse radiation from the sun into thermal energy. Flat plate collectors are mechanically simpler and require little maintenance than concentrating type of collectors. Generally, flat plate collector designs consist of three major parts. These are transparent cover, absorber plate and insulation. The daily average insolation of Hpa-An is taken to be 27.46 MJ/m^2/day. The size of the collector was 46.5 x 35.6 cm. It had three major components: transparent cover, absorber plate and insulation.

The transparent cover is made from a single layer glass of 3 mm thickness. 5mm Copper rod cover by Zinc-Aluminum sheet of 1 mm thickness, painted black, was used as an absorber. The collector casing was made from wood and plywood. The air inlet is holes with 4 x 2.3cm diameter. The flat plate solar collector should be tilted and oriented in a way that it receives maximum radiation. the test location is Hpa-An (Latitude 16°53' 26"N and longitude 97°38''W), a collector tilt angle of 40^o was considered to avoid the accumulation of rain water on the collector during rainy periods.

(b) Drying Chamber and drying racks

The drying chamber will be an enclosed structure where drying takes place. It will consist of trays for putting in the produce to be dried. At the drying chamber there should be means for loading and removing the material to be dried. This is usually provided by a door at the back side of the dryer. The drying chamber should be insulated and well sealed in order to contain the heated air without any leaks. The drying chamber was made from plywood with wood support. It consisted of single tray, each with size of 28.3 x 22.3 cm, for the produce to be dried. The trays were made from perforated Aluminum. At the slide of the drying chamber, a door will provide a means for loading and removing the material to be dried.

(c) Chimney

The height of the chimney is 35cm. The material selected for the chimney is 5.5 centimeter diameter plastic PVC. 90^oelbow was used to cover the chimney to prevent rain from entering the dryer. The chimney was painted black to facilitate the flow of air through the dryer. This would allow increasing the temperature of the air flowing through it, i.e. the moist air coming from the drying chamber air outlet.

Figure 1. Side View of the Constructed Dryer

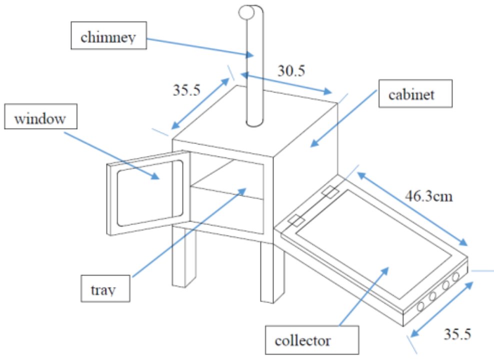

Figure 2. Solar Dryer Drawing

III. DESIGN SPECIFICATION AND CONSTRUCTION

The performance of the dryer was evaluated in Hpa-An(Myanmar)(Latitude 16°53' 26"N and longitude 97°38''W) . According to measurements done by Solar Ange Calculator of Solar Electricity Handbook page, the average solar irradiation for Hpa-An(Myanmar) was about 317.71 W/m^2. The ambient temperature, $T_{a,}$ for the test location was 28^oC with relative humidity of 79 %.

(a) Sizing the Collector

The daily average insolation of Hpa-An is taken to be 27.46 MJ/m^2/day. Struckmann (2008) gives a typical flat-plate collector efficiency (at ambient temperature of 28^oC and I = 317.71 W/m^2) to be between 25% and 45%. The collector efficiency is influenced by factors such as temperature, air flow rate, insolation, type of transparent material, absorber plate and insulation used (Struckmann, 2008). To achieve an optimal design, average value of collector efficiency of 35% was considered as a design parameter. As a result, Daily expected energy production by the collector =27.46MJ/m^2/dayx0.35= 9.611 MJ/m^2/day .For 2 days (the drying period), the energy production would be = 2x9.611 = 19.22 MJ/m^2 since the total heat energy required for drying is 2.294 MJ.

(b) Collector Orientation and Tilt Angle
The flat plate solar collector should be tilted and oriented in a way that it receives maximum radiation. The collector performs well when it is oriented perpendicular to the sun. Optimal tilt angle varies according to the season. As a general rule, optimum angle of tilt is equal to the degree of latitude of the site. For this design since the test location is Hpa-An (Latitude 16°53’ 26”N and longitude 97°38’’W), a collector tilt angle of 40^o was considered. This was to help avoid the accumulation of rain water on the collector during rainy periods.

(c) Construction of the Solar Dryer
The size of the collector was 46.5 x 35.6 cm. It had three major components: transparent cover, absorber plate and insulation. The transparent cover is made from a single layer glass of 3 mm thickness. 5mm Copper rod cover by Zinc-Aluminum sheet of 1 mm thickness, painted black, was used as an absorber,in order to minimize heat loss from the absorber plate. The collector casing was made from wood and plywood. The air inlet is holes with 4 x 2.3cm diameter.

(d) Drying Chamber
The drying chamber was made from plywood with wood support. It consisted of single tray, each with size of 28.3 x 22.3 cm, for the produce to be dried. The trays were made from perforated Aluminum. It was chosen to avoid rusting due to high initial moisture content of the produce. At the slide of the drying chamber, a door will provide a means for loading and removing the material to be dried.

(e) Chimney
The height of the chimney is 35cm. The material selected for the chimney is 5.5 centimeter diameter plastic PVC. 90^o elbow was used to cover the chimney to prevent rain from entering the dryer. The chimney was painted black to facilitate the flow of air through the dryer. This would allow increasing the temperature of the air flowing through it, i.e. the moist air coming from the drying chamber air outlet.

(f) Drawing of the Dryer
The dryer was designed using software called Auto-CAD. The drawing of the design and the corresponding side views with dimensions are shown in Figure 1 and 2

IV. TESTING THE DRYER

Potato was obtained from the local market in Hpa-An. They were then washed, peeled and sliced of 2mm of Potato was used. The fresh produce was arranged in a single layer to avoid moisture being trapped in the tray. The parameters measured during the evaluation of the solar dryer included weight of the material to be dried, temperature, humidity, wind speed and solar insolation. The temperature and humidity inside the dryer and collector as well as the ambient temperature were measured using Thermometer. The initial weight of the potato to be dried was measured before putting it in the dryer. Once the drying process started, the produce being dried was taken out from the dryer every three hours for the weight or moisture loss to be checked.

1. No Load Test
The first performance test was the no load test, where the temperature in the dryer was measured without materials to be dried. The temperature variation at the collector output, in drying chamber and ambient temperature values were recorded every one hour interval. Doing the no load test helped to know the maximum possible temperature rise in the drying chamber as compared to the corresponding ambient value. Parameters such as temperature and solar radiation recorded during this test were used to determine the collector efficiency.

2. Solar Drying Test
Loaded test of the solar dryer was carried out using 160 g of slices of potato. The slices were laid on a single layer over tray. This helped to avoid overlapping and ensure uniform drying. Only solar energy was used as heat source for drying during this test. Ambient temperature and humidity, dryer temperature and collector output temperature were recorded every one hour interval while the weight of the produce kept in the dryer was measured end of the day.

3. Relative Humidity (RH)
Relative humidity may be defined as the ratio of the water vapor density (mass per unit volume) to the saturation water vapor density, usually expressed in percent:

$$RH = \frac{Actual Vapour Density}{Saturation Vapour Density} \times 100$$

4. Moisture Content
Moisture content was taken at the beginning and at the end of each drying day using the oven drying method and calculated using the following equation:

$$Moisture Content = \frac{M_i - M_f}{M_i} \times 100$$

Where:
M_i = Mass of potato slides before drying
M_f = Mass of potato slides after drying
The initial data before test is as follows.
Total mass of freshly potato = 160 g
Drying period required = 7 Hours/day
Average ambient temperature (T_a) = 39 °C
Relative humidity (RH) = 43 %

The testing of an indirect solar potato dryer was done in the month of April for two days starting from 9:00 am to 4:00 pm. Evaluation of the dryer was centered on the temperature variations and moisture content reduction. 160 g of fresh potato was used for evaluation. The result obtained for hourly reading is tabulated in tables.

Day -1 Temperature Results

Time	Ambient	Collector	Cabinet	Mass(g)
9	35.1	38.5	35.3	160
10	39.2	52.5	47.7	
11	39.2	58.7	47.7	
12	46.2	60.5	52	
13	42.9	70	53.4	
14	43.6	68.6	48.6	
15	36.4	61.5	44.2	
16	35.7	44.1	41.7	96.7

Moisture removed = 160- 96.7 = 63.3 g
Moisture Loss = 39.6%

Day -2 Temperature Results

Time	Ambient	Collector	Cabinet	Mass(g)
9	31.5	40.5	32.8	96.7
10	32	53.4	38.6	
11	40.6	64.6	46.3	
12	40.8	68.3	44.7	
13	42.1	70	44.1	
14	43.2	64.6	45.2	
15	33.1	55	39	
16	32.4	54.6	38.6	53.5

Moisture removed = 96.7-53.5 = 43.2 g
Moisture Loss = 45%

V. DISCUSSION OF RESULTS

Variations in temperature were observed as shown in Day 1 and Day 2 and Figures 3 to Figure 5 shows temperatures were recorded during the morning and evening hours with the morning hours recording the lowest temperatures.The following Figure 3 shows no-load condition.

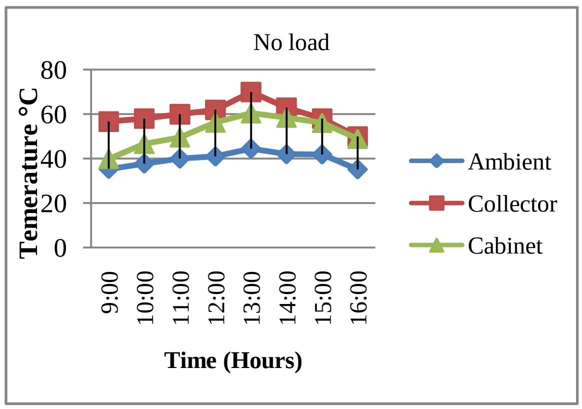

Figure 3. Variation of Temperature with Time on No Load Condition

During the day time when the sun was the only source of heat supply, a maximum temperature of 70°C was attained by the collector output after four hours while the average collector temperature from 09:00 to 16:00 Hour was 59.73°C. From Figure 3, the trend of the graph shows that the temperature starts to increase from morning and reaches its peak value in the afternoon, where the sun insulation is highest, and starts to descend again in the evening when the sun sets.

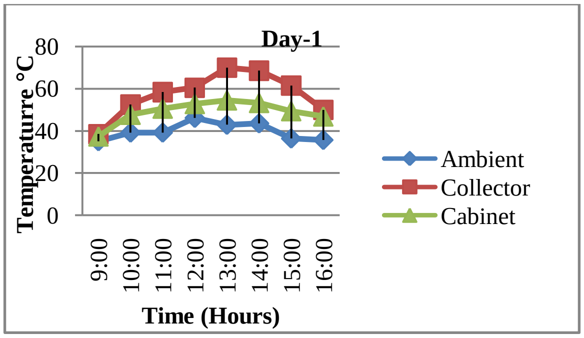

Figure 4. Variation of Temperature with Time on Day 1

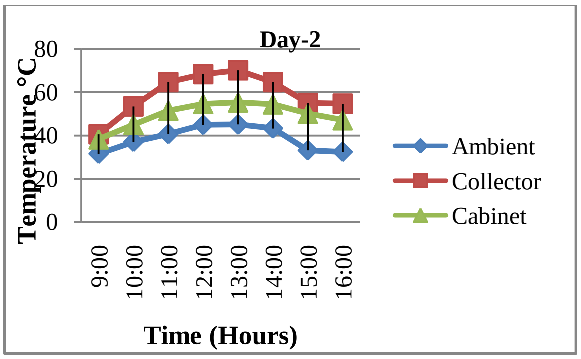

Figure 5. Variation of Temperature with Time on Day 2

VI.CONCLUSIONS AND RECOMMENDATIONS

From the test results, the moisture loss in day 2 is more than day 1.This is all of the temperatures in day 2 is higher than day 1.Moreover, in the cabinet, the temperature is still higher in the evening. For this result, people can dry the food or vegetables in this dryer no worried for this. Therefore, the dryer is helpful for people are sure.The performance of the dryer can further be enhanced by making modifications and following the recommendations given below:

The glass cover of the collector should be insulated on the edge. In addition, the gap between the collector and drying chamber should be covered with permanent insulation that can withstand rain. The performance of existing solar potato dryers can still be improved upon especially in the aspect of reducing the drying time, and probably storage of heat energy within the system by increasing the size of the solar collector.

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REFERENCES

[1] Visavale, G.L., Principles, Classification and Selection of Solar Dryers. In Solar drying: Fundamentals, Applications and Innovations, Ed. Hii, C.L., Ong, S.P., Jangam, S.V. and Mujumdar, A.S., 2012

[2] R. Vidya Sagar Raju, R. Meenakshi Reddy and E. Siva Reddy, Design and Fabrication of Efficient Solar Dryer, 2013

[3] MA. Aravindh and A. sreekumar, Solar Drying- A Sustainable Way of Food Processing , 2015

[4] Sundy Sobowale, Design Construction and Evaluation of a small scale solar dryer, 2015

[5] Tiruwork Berhanu Tibebu, Design, Construction And Evaluation of Performance of Solar Dryer for Drying Fruit, 2015

[6] Y. Baradey, M. N. A. Hawlader, A. F. Ismail, M. Hrairi and M. I. Rapi, Solar, Drying of Fruits and Vegetables, 2016