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DEHYDRATION OF VEGETABLES BY USING INDIRECT SOLAR DRYER

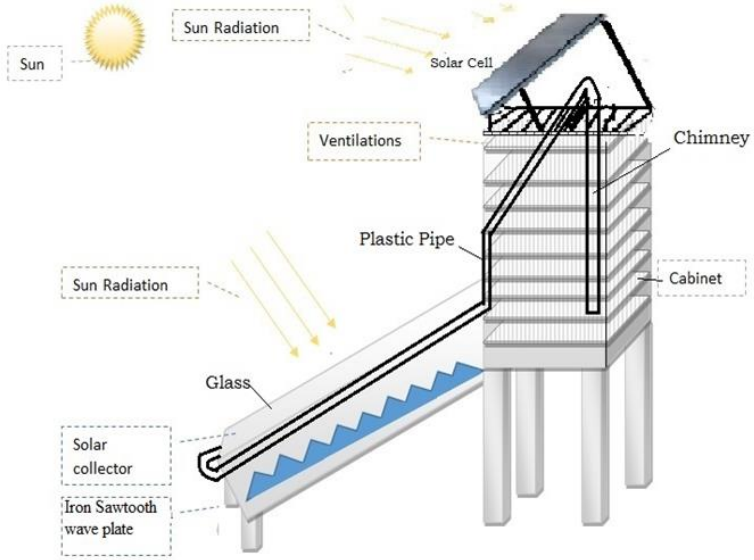
Younas KHAN[1*], Jafar Khan KASI[1], Ajab Khan KASI[1]

[1] *Department of Physics, University of Balochistan, Quetta, Pakistan*

HIGHLIGHTS

- Indirect solar dryer is designed to dry vegetables such as tomatoes, eggplant, onion and mint leaves.
- Indirect solar dryer is designed with low cast and easy to process.
- Indirect solar dryer provide close atmosphere for the agricultural products.
- It has temperature controlled system in the range of 50-60^{o}C, avoiding the high temperature which may damage the quality of the products.

GRAPHICAL ABSTRACT



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ABSTRACT

The temperature controlled indirect solar dryer is designed in Quetta by using simple available stuffs in the market to dry the agricultural products for its longer shelf life. The dryer consists of drying cabinet, solar cell, electrical fan and collector. Inside the cabinet there are four trays at equally distance from each other, each tray receive uniformly heated air from the collector to dry the agricultural product. During the drying process temperature and relative humidity inside the cabinet is measured with help of digital hygrometer. Tomatoes, mint leaves, eggplant and onion were dried in newly low cost designed dryer. The drying time, color and quality of these products are compared with open sun drying. The result shows that the product dried in the newly dryer is good in quality and dry faster than open sun drying method. The drying occurs in falling rate period. Uniformity of the dryer in each tray was also checked by placing vegetable slices of same size and weight in each tray, the drying time for each tray was same. By increasing the size of vegetable slices increase the drying time, result also shows that increasing in drying air temperature also increase the drying time.

1. INTRODUCTION

Drying is a process to remove the water from the agricultural products in order to increase its shelf life [1]. Drying is one of the oldest methods to save the food from spoilage and store it for longer period of time without use of refrigerator [2]. The drying of agricultural products is done for two purposes; the first is to stop the growth of micro-organism and second is to store it for longer period of time [3]. Drying reduces space for storage, lighter the

* Corresponding Author: younaskhankasi@gmail.com

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weight, make it easy for the transport of the agricultural product and make sure its presence throughout the year [4]. Open sun drying is traditional method to dry the agricultural products. This method is practice in many developing countries because the energy required in this process is free, renewable, non-polluted and abundant in most of the environments [5]. As this method is cheap and easy to process but it contains some drawback such as microbial attack, dust, rain and insects which damage the products [6]. In this method agricultural product is placed in open ground on which sunlight directly exposure on the product to dry it, this damage the colour and quality of the product [6]. The products dried in traditional method are not acceptable in standard market which is economic loss of the country [7]. To overcome these problems, the agricultural products should be dried in solar dyer, the solar dryer provide close atmosphere for dryer process to save the product from microbial attack, rain, dust, and insects in order to improve the quality of the products. Different researcher designed different types of dryer.

Azad explained the two modes (mixed + indirect) dryer to dry the grapes in five days, moisture from the grapes is reduced from 81.1% to 36.7% [8]. Amer et al., designed hybrid dryer to dry banana from moisture content 82 to 18% [9]. Musembi designed indirect natural convection solar dryer to dry apple from moisture content 86% to 8.12% [10]. Different types of dryers have been used for drying vegetable products, Tunnel solar dryer which consist of a transparent plastic sheet, two DC fan and flat plate collector which is connected in series to dry pineapple from moisture content 87.32% (wet basis) to 14.13% (wet basis) in 3 days [11]. Chen et al. designed close type solar dryer to dry lemon slices [12]. The small size dryer which consists of biomass burner to provide heat at night time was designed by Bena and Fuller to dry fruits and vegetables [13]. The aim of this research is to study and design low cost and easy process dryer, which can provide close atmosphere to save the product from microbial attack, dust, rain and insects. For controlled temperature (from 50˚C to 60˚C) an automatic system, is installed in the dryer which maintains the temperature throughout drying cabinet to dry short life agricultural products for longer period of time.

2. METHODS

2.1. Indirect Solar Dryer

Indirect solar dryer is designed in Quetta from local stuffs available in the market during the year of 2018. The designed dryer is so simple that it can be constructed by farmer for dying agricultural products. The dryer consists of solar cell, cabinet, and collector. The schematic diagram of solar dryer is shown in Figure 1.

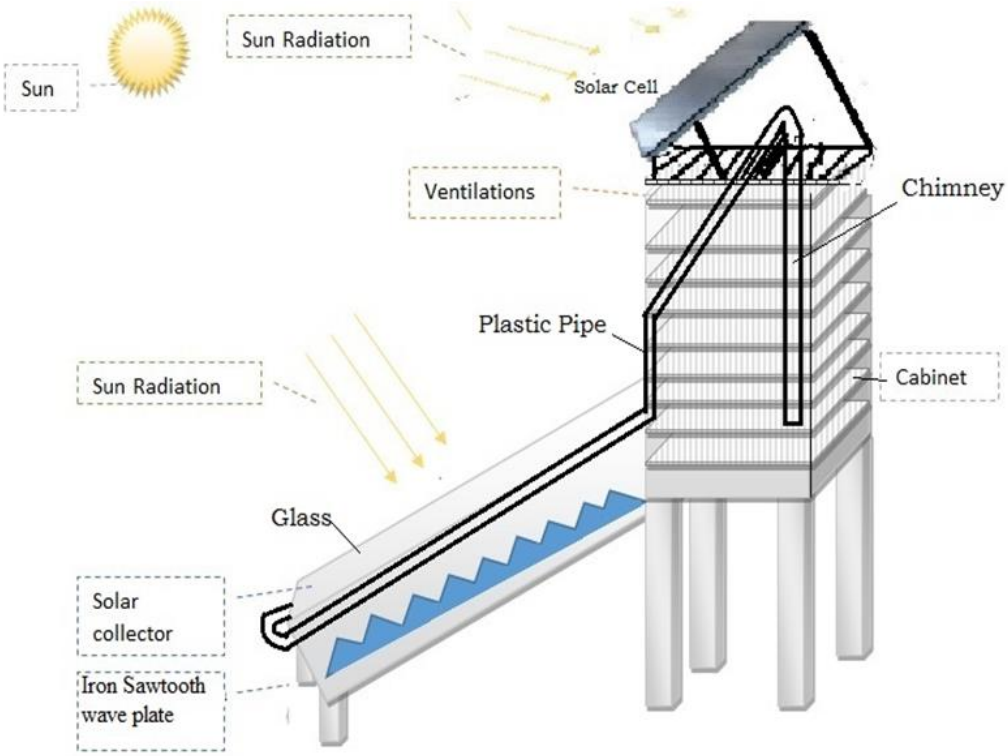


Fig. 1. *Indirect solar dryer*

2.2. Solar Cell

The dimension of solar cell is 53x76 (cm). The maximum power of solar cell is 50W; maximum power voltage (V_{mp}) is 18.2V and its maximum power current (I_{mp}) is 2.7A. The purpose of solar cell is to run the electrical fan connected with designed dryer.

2.3. Collector

Collector consists of electrical fan, absorber plate and transparent glass. The dimension of collector is 2ft in width and 4ft in length and the dimension of the glass is (0.49x121.92 (cm)). At the base of collector there is mat mash (net) which is the path for entering the fresh air from surrounding. The absorber plate of length 3ft is in the form of sawtooth waves which is placed in collector. The absorber plate is black painted to absorb more sun light. The purpose of sawtooth wave form of absorber plate is to increase the surface area of the collector. When fresh air from atmosphere enters through a mat which is at base of collector, the molecules have more contact time with sawtooth wave form of absorber plate and increase the heat energy of the air molecules. The heated air is forced in the cabinet by means of electrical fan. There are five electrical fans from which two are placed at the base of the collector and three are placed at the end of the collector. These electrical fans are run with the help of solar cell. The fans at the base are used to take air from the atmosphere and push it into the dryer, which decreases the temperature of the dryer up to 3℃. Where three fans at the end of collector forces the heated air in the drying cabinet. At the base of the collector there are two small doors which are closed at night time avoiding the air entry from surrounding into the dryer.

2.4. Drying Cabinet

The dimension of drying cabinet is 3ft in height and 2ft in width was constructed from plywood which is light in weight. This plywood is supported by frame of massive wood. The cabinet is at height 2ft from the surface of earth by means of four legs. The cabinet of the dryer is made from plywood, beside of it three sides wall and top side of the cabinet is also made from Iron sheet in order to increase the temperature of the cabinet. The iron sheets are joined together in such a way that there is no leakage of air from it. The back side of iron sheet (collector side) has 4 holes of 4cm diameter at left side and 4 holes of 4cm diameter at right side. The holes of both sides are parallel to each other. Pipes of dimension (2.5x51cmx4.1 (cm)) are fixed in these holes; each pipe has equal number of holes except the bottom pipe which has 4 extra holes. The number of pipe in the cabinet is eight, four from left side and four from right side. These pipes are fixed in the holes of iron sheet such that they are parallel to each other. The cabinet have four trays which are made from mat mash and supported by frame of wood, these trays have dimension (19.7x20.2 (cm)) are placed on the pipes. The heated air from the collector enters in the pipes, from the holes of the pipes it comes in the cabinet. These heated air take out moisture from the agricultural product which were placed on the tray and comes out from the holes which is at the top side of iron sheet and from here it cannot escape in the atmosphere because at the top of iron sheet there is plywood roof, so the moisture air is recirculated from the side of iron sheet then come out from the chimney. This recirculation of air from the sides of the conductor heats the iron sheet and increases the temperature of the cabinet. The air which comes out from the chimney is again entering at the base of the collector with the help of plastic pipe which helps to increase the temperature up to 2℃.

3. EXPERIMENTAL

In the designed dryer tomatoes, mint leaves and apricots were dried, the drying time and quality of the dried product is compared with product which is dried in open sun method.

3.1. Drying of Tomatoes

Fresh tomatoes were purchased from local market. Before slicing the tomatoes, it was washed with clean water and dried with soft piece of cloth. After cleaning and drying the tomatoes was cut into slices with sharp knife. About 30g of sliced tomatoes having thickness 5mm were placed in the dryer. Before starting the experiment the dryer was run up to one hour to gain its momentum. The experiment was carried out from 10.00 AM in the month of August. The 30g of same size tomatoes were placed on net above the surface from earth under open sun light. The weight loss of tomatoes slices was measured after every one hour with digital physical balance (±1g) heaving maximum capacity 7kg. The moisture content of tomatoes slices was removed up to 93.33% (wb).

3.2. Mint Leaves

Second vegetable for drying was mint. The fresh mint leaves were purchased from the local market, were washed dried. After washing the mint leaves, about 15g of mint leaves were placed in dryer as a drying sample. The mint leaves is separated from its branches. The same quantity of mint leaves were placed in net which is above from the ground under open sun light. The weight loss of mint leaves was measured with the help physical balance after every 30min. The initial moisture content of mint leaves was 80% (wb).

3.3. Eggplant

Fresh eggplants were purchase from local market of Quetta. The eggplant is washed and dried from soft clean cloth then placed at room temperature for 15min. After that eggplant is cut into slices of 5.5mm, 55g of eggplant was placed into the dryer. The weight loss of the eggplant slices were measured with digital physical balance after every one hour.

3.4. Onion

Fresh onions were purchased from the local market. The onion is cut into its slices of 3mm, and 33g of onion were placed into the dryer. The weight loss of onion was measured after every one hour.

3.5. Uniformity of the Dryer

To check the uniformity of the dryer the tomatoes slices of size 5mm having weight 30g were placed in four trays of the dryer. The weight loss of the tomatoes was measured after every one hour with the help of digital physical balance.

3.6. Effect of Temperature on Drying Process

It was observed that drying air temperature greatly affect the drying time. The 30g of tomatoes slices of size 5mm was placed in the solar dryer, the temperature inside the dryer is in the range of 45-50℃. This temperature was less as usual temperature range of the dryer because of cloudy day. The weight of the tomatoes was measured after every one hour by using digital balance. The drying process was continued until there is no change in weight of tomatoes slices observed. The same size and weight of tomatoes slices were placed in solar dryer having temperature in the range of 50–60℃ in shining day. This temperature is the maximum range temperature of the dryer. The change in weight is measured after every hour.

3.7. Temperature and Relative humidity

The range of temperature inside the dryer is 50 to 60℃ and relative humidity is 10% which is measured with the help of digital hygrometer. Where the ambient temperature range is 35 to 38℃ and relative humidity is 10%. At night ambient temperature is in the range of 20 to 32℃ and range of relative humidity is 35 to 70%.

3.8. Moisture Content

The moisture content of the drying products was determined by using formula.

$$MC = \frac{W_i - W_{ab}}{W_i} (\%\ \text{wb}) \quad (1)$$

Where MC is moisture content, W_i is initial weight and W_{ab} is bone-dry weight. The equilibrium moisture content was found out when there is no further changes in weight of the product. Wet basis (wb) means (g of water/g of moist sample).

3.9. Moisture Ratio

The moisture ratio can be calculated by using formula:

$$MR = \frac{M_t - M_e}{M_i - M_e} \quad (2)$$

Where MR is moisture ratio, M_e is equilibrium moisture content of product (g water/ g of moist solid). The value of M_e is very small relatively small compared to M_t or M_i so M_e is consider to be zero Diamante and Munro [14].

4. RESULT AND DISCUSSION

The drying behaviour of agricultural product depends on drying air temperature and relative humidity. The increase in drying air temperature increases the drying rate and decrease the drying time. The increase in humidity slows the drying rate and increase the drying time. This statement was confirmed by several authors [15-18]. The dryer provide close atmosphere for dying the agricultural products and protects the product from microbial attacks, rain, dust and insects. The dryer also protect the product from humidity, the area which have high humidity then drying the agricultural products in open sun drying increase the drying time because the humid air is unable to take out moisture from the products. In such area the dryer is used to speed up the drying process.

The drying behaviour of tomatoes slices in dryer and open sun method is shown in Figure. 2. The graph shows that moisture content reach to its equilibrium position faster than traditional method. The graph shows that there is not constant rate drying period while drying occurs in falling rate period. In falling rate period drying rate decrease continuously with decrease in moisture ratio. To check the quality of the dried product, the dried product is shown to the different experts. The result obtain from the experts shows that the quality of the

tomatoes slices dried in dryer is good than open sun drying which contain dust particle.

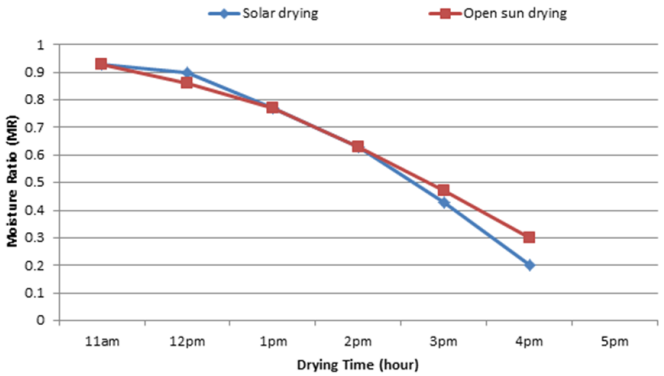
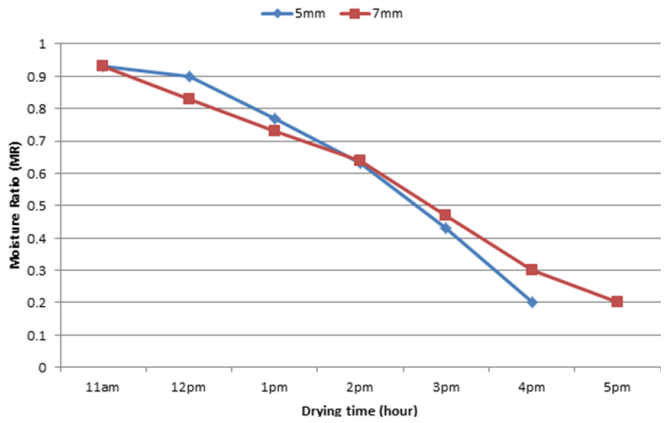


Fig. 2. *Drying behaviour of tomatoes in Solar Dryer vs Open sun*

By increasing the size of the tomatoes slices effect the drying time, increase in the size of thickness increase the drying time as shown in Figure 3. This result was confirmed by several authors in their paper [19-21].



Fig,3. *Size effect of tomatoes on drying time*

The uniformity of the dryer is shown in Figure 4. The graph shows that drying time is approximately same in each tray and moisture content reach to its equilibrium position in the same time.

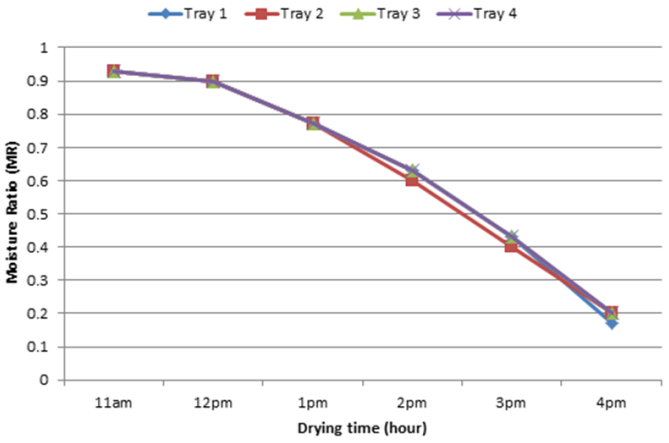


Fig. 4. *Uniformity of the dryer*

The Figure 5 shows that drying process of mint leaves. The drying of mint leaves occur in falling rate period. The graph shows that the drying process is fast in newly designed dryer as compare to open sun drying.

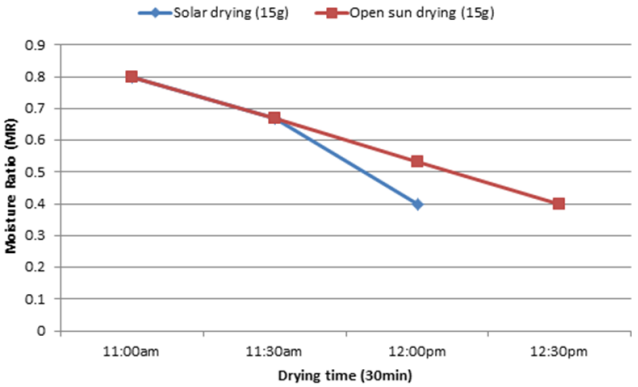


Fig. 5. *Drying behaviour of mint leaves in Solar Dryer vs Open Sun*

The drying process depends on drying air temperature, by increasing the drying air temperature increase the drying rate. The Figure 6 shows the result of tomatoes of same size and weight but different temperature range. The temperature ranges in drying process of tomatoes slices of same size are 45-50˚C and 50-60˚C. It shows that increase in temperature increase the rate of drying process.

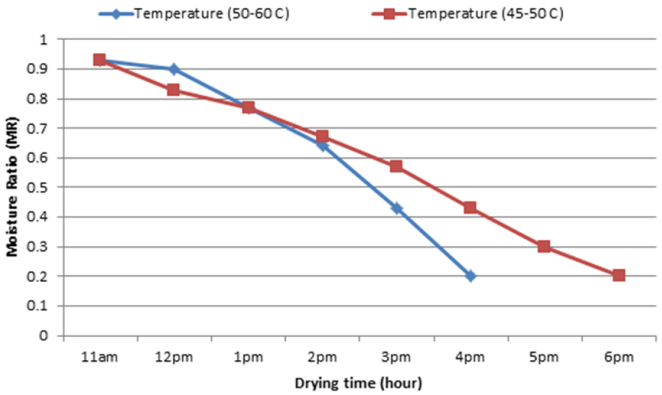


Fig. 6. *Temperature effect on drying time*

Figure 7 and 8, shows the drying behaviour of eggplants and onions. The drying behaviour of eggplant and onion in designed solar dyer were compare with open sun process. The drying process is fast in dryer than open sun. The drying occur in falling rate period not in constant rate.

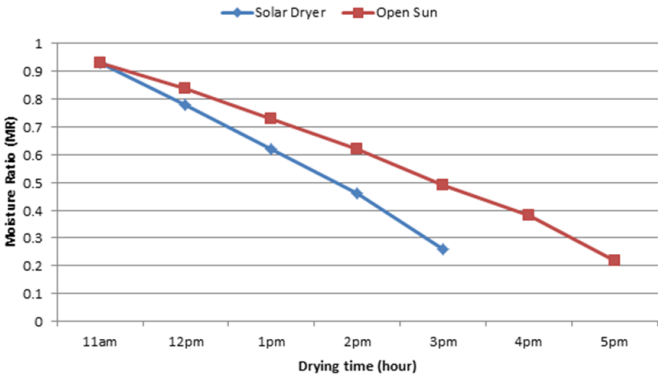


Fig. 7. *Drying behaviour of Eggplant in Solar Dryer vs Open Sun*

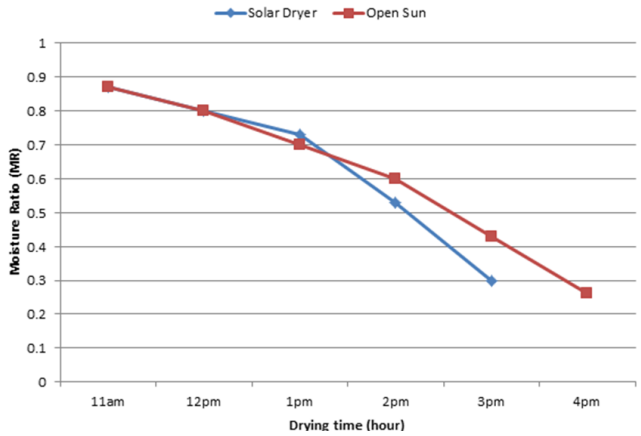


Fig. 8. *Drying behaviour of onion in solar dryer vs open sun*

5. CONCLUSION

The newly designed dryer was used to dry the tomatoes, mint leaves, eggplant and onion. The designed dryer provides close atmosphere to dry the product in order to protect it from microbial attacks, dust, rain and insects. The drying of these products occurs in falling rate period. Drying time of the dried products in the designed dryer is less than open sun drying and quality of the product in dryer is also good than open sun method. It was observed that increase in drying air temperature increase the drying rate and decrease the drying time. The total cost of the dryer is low so it reduced the cost of drying product.

ACKNOWLEDGEMENTS

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