Development a Solar Dryer for low income group Farmers for sub cooled region

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Abstract. Solar dryer is a device that use solar energy to dry substances, especially food and agriculture product. Drying is one of the indispensable techniques for large-scale food preservation. There are already various types of solar dryer available but need a better performing solar dryer which can perform better in low sunshine hours and also in off sunshine hours. In present work combination of trapezoidal and tunnel type structured solar dryer developed for experimental trials. It showed better efficiency and effectiveness in compared to the existing solar dryers with respect to previous design available so far. After the experiments, it is found that maximum temperature rise was recorded 76°C however ambient temperature was 24 °C. At same time % reduction in weight was highly appreciable after three to four hour drying. Results of drying rates up to 50% after three hour drying. So present solar dryer is economical and potential solution to preserve the vegetables and crops to improve income of formers.

1. Introduction
Renewable energy are obviously a better option than fossil fuels since they are abundant, limitless, and non-polluting. Solar energy is used for cooking, heating, and drying by people living in the tropics and semi-tropics [1]. The goal of drying items is to minimize the amount of moisture in them. The elimination of moisture inhibits the decay produced by microbe growth and reproduction, reducing the number of moisture-mediated deteriorative events [2]. Developing and under-developed are employing open sun drying. It is the common and traditional way to drying food and agriculture product to preserve [3]. And if take example of tropical region where solar radiation intensity is good, solar system is the best alternative to the other techniques. But open sun drying have several limitations like degradation of food, wind and raining problem, Direct U-V rays also affect our food quality. In open sun drying we are unable to control external parameter like temperature, moisture, relative humidity etc. Open sun drying is also less hygienic and high wastage of product. Large area required. Labour intensive is too high because they have to work in direct sun light. So solar dryer is the only solution to these problems. Different investigations have been undertaken over decades to produce solar dryers to eliminate these difficulties and offer better management of sun drying elements. Classification of solar dryers is based on solar heat usage like direct, indirect, or mixed modes [4]. Another classification is based on air circulation; namely natural air circulation, forced air circulation. Addition fan assembly is used in the forced air circulation to circulate air through the dryer [5]. Additionally, it can be categorize on the basis of following parameters like incidence of solar radiation, circulation of hot air, design or construction...
and hybrid. With component, it can store sun’s heat during sunshine hours and utilized during late evening hours [6].

Previous studies shows continuous improvement it terms of design and drying efficiency. In this series PVT collectors is playing significant role to improve the performance of solar-dryers [7]. So this context, hybrid solar dryers is playing important role. It is combination of design, technology/techniques and heat sources [9].

1.1. Drying Technologies

Drying of goods is one of the energy demanding processes. Reducing moisture content is a suitable process to save the food from contamination and germination. Recent advancement in field of saving have been explored like solar, infrared, microwave, and other. These technologies have own pros and cons. However solar assisted technology is renewable and sustainable source of drying. It is relatively advantageous to maintain the quality of dried foods. There many drying technologies like Hybrid drying [10], Solar drying [11], Infrared drying [12], Infrared drying [13,14], Microwave drying technologies [15,16] and hybrid drying technologies [17,18].

After the survey, the present objective was to build a system for a place like a Kashmir where the connectivity is not good in full year so the food supply is not very good and people in this area use dry product in the time of winter so that can make an effective way to dry the food supply. Basically, problem is to dry product in most effective way and help farmers to content their high moisture material to preserve to long time and reduce their losses in terms of money. This is a solar based system in which used solar energy as a primary source to dry product like food and vegetables.

2. Materials and Methods

2.1. Experimental Set up

The drying system was fabricated and investigated experimentally within the unit of Research on renewable energy in the environment of Kashmir at National Institute of Technology Srinagar. As shown in Figure 1. It consists of the following elements.

![Figure 1- Schematic diagram of solar dryer](image)

2.1.1. Solar Collector: It is a removable extended portion which is attached with dryer. It's the only element where inlet air gets heated before entering to drying chamber. This collector is placed at a particular tilt angle which varies according to latitude of the place. It is composed of a transparent
Polycarbonate sheet and a wooden chamber painted with black colour to get maximum solar radiation. This collector is made of 130×75 cm long plywood 25 cm thickness which is covered by 6mm polycarbonate sheet. Its entrance is perforated with holes and fan to make sure enough air entry.

2.1.2. **Drying chamber:** Drying chamber consist two storing treys made of wooden box with volume of 90×90×75 cm\(^3\). This the element where drying process is carrying out. The structure is made up of plywood, the main reason to use wood is to achieve a good insulation at very cheap cost. Chamber is covered by a triangular rooftop with 45cm height. This cabinet is the key element of dryer. Chamber is installed into a stand. This top is covered by 6 mm polycarbonate transparent sheet. Inside of the chamber is fully covered with black coloured aluminium foil paper to make it air tight and also to trap maximum energy from upcoming radiation. Two circular holes of 120mm (diameter) created at lower portion of the chamber to install outlet DC fan.

2.1.3. **DC fan:** Four (two inlet & two outlet) 12V 3.36Watt DC fan installed for a uniform air circulation to make sure a forced convection. Air flow rate is 017 m\(^3\)/s for each fan of set up.

2.1.4. **Trays:** Trays are made of (85×85x 3) cm\(^3\) stainless steel net with wooden frame. Trays are placed into drying chamber with and product to be dried is placed on to it.

2.1.5. **Solar panel:** A 100Watt Mono crystalline solar panel with 12V battery and a solar charge controller is used to regulate electric supply to fan.

2.2. **Working Principle:** The main basic principle of any dryer is based on greenhouse effect where sun heat is trapped inside the drying chamber and thus increase the temperature level. The basic function of a dryer is to rise the vapour pressure of moisture found inside the product and increase its moisture carrying capacity of the dried air by decreasing its relative humidity. In drying chamber, dryer will transmit heat from solar radiation to product and transfer mass (in form of moisture) from the surface of the product to the surrounding air inside the chamber and here this air get exit from dryer through exhaust by fan or naturally. Design considerations like titling angle and collector position are important for achieving more sun radiation. Existing solar dryer have tunnel type drying chamber or Trapezoidal shaped drying chamber. In this work, developed a combination of both tunnel and Trapezoidal having a solar collector also. Existing solar dryer are made for plane or desert area but developed dryer also function in hilly area in cloudy season.

3. **Results and Discussion**

These experiments were conducted in Srinagar, the city of Kashmir which is located at 34°0837′ north and 74°7973′ East at 1585 m above sea level. The days of experimentation were chosen on the basis of the relative clarity of the sky according to meteorological forecasts. The weightings are performed at an interval of 25 minute. Three different scenario has taken for experimental trials.

Scenario 1- Fully sunshine
Scenario 2 - Cloudy
Scenario 3 – Partially cloudy

Testing of this experimental setup in mid of April at National Institute of Technology Srinagar and the testing has been carried out drying rate basis on drying time, moisture content, Flow rate and inside surface temperature.

3.1. **Scenario 1 (Fully sunshine):** Figure 2 representing the relation between time and weight. On first day (Scenario 1) when sun is full sunshine take three vegetables beetroot, potato and ginger initial weight of all the vegetables is 500g. Start the experiment at 11:15 AM and get product at 5pm. From the Figure 1 the reduction of weight in terms of moisture content is nearly 50%. Drying rate is defined by (weight reduction)/(time taken). Drying rate of beetroot, potato and ginger after 45 minute is 18%,
16%, 15% respectively. Drying after 1 hour 45 minute is 19.5%, 7.14% and 8.23% respectively. Drying rate after 2-hour 45 minute is 12.12%, 6.41% and 7.69% respectively. Drying rate 3-hour 45 minute is 17.24%, 9.58% and 9.72% respectively. Drying rate 4-hour 45 minute is 8.33%, 3.03% and 7.69% respectively. Drying rate after 5-hour 15 minute is 1.81%, 0.3% and 3.33% respectively. The first day experiment shows on this day drying rate of beetroot is maximum.

![Figure 2: Relations between Time and Weight (Scenario 1)](image)

3.2. Scenario 2 (Cloudy): Figure 3 illustrating 2nd Scenario of testing when Weather is cloudy it shows relation between time and weight in terms of moisture content. On second day take 3 vegetables carrot, Spanish and capsicum with same weight 400g. Experiment Start at 11:15 AM and get product on 5:00 PM. From the Figure 2 the reduction in weight of carrot is 18.75%, reduction in weight of Spinach 43.75%, reduction in weight of capsicum is 26%. Drying rate of carrot, spinach and capsicum after 45 minute is 5%, 20%, 8% respectively. Drying after 1 hour 45 minute is 7.89%, 12.5% and 6.52% respectively. Drying rate after 2-hour 45 minute is 4.28%, 9.28% and 9.30% respectively. Drying rate after 3-hour 45 minute is 1.49%, 3.14% and 2.56% respectively. Drying rate after 4-hour 45 minute is 1.21%, 3.25% and 2.63% respectively. Drying rate after 5-hour 15 minute is 0.30%, 0.91% and 0% respectively. On this day maximum drying rate get in spinach.

![Figure 3: Relations between Time and Weight (Scenario 2)](image)
3.3. Scenario 3 (Partially Cloudy): The third Scenario testing conditions are partially cloudy it shows relation between time and weight in terms of moisture content as shown in figure 4. On third day take three vegetables beetroot, spinach, and capsicum with same weight 250g. Experiment start at 11:15 AM and get product on 5:00 PM. From Figure 3 the reduction in weight of beetroot is 36%, reduction in weight of spinach 52%, reduction in weight of capsicum is 28%. Drying rate of beetroot, spinach and capsicum after 45 minute is 20%, 25%, 12% respectively. Drying after 1 hour 45 minute is 10%, 13.33% and 6.82% respectively. Drying rate after 2-hour 45 minute is 5.55%, 13.84% and 4.88% respectively. Drying rate from after 3-hour 45 minute is 2.94%, 10.71% and 2.56% respectively. Drying rate after 4-hour 45 minute is 1.81%, 4% and 5.26% respectively. Drying rate after 5-hour 15 minute is 1.23%, 0% and 0% respectively. On this day maximum drying rate get in spinach.

![Figure 4- Relations between Time and Weight (Scenario 3)](image)

3.4. Relation between weight and flow rate: Figure 5 showing different condition of fan and give the relation in reduction of moisture content in terms of weight. From 11:15 to 11:50 No fan is on in this condition flow rate is 0 in and reduction in moisture content in terms of weight is 18%. After 50 min. one inlet fan is on in this condition flow rate of air is 0.17 m³/s and drying rate is 19.51%. After 35min. one exhaust fan is on in this condition flow rate is 0.17 m³/s and drying rate is 12.12%. After 50 min. both exhaust fan is on in this condition flow rate is 0.34 m³/s and drying rate is 17.24%. After 45 min. All Fan on in this condition flow rate is 0.51 m³/s and drying rate is 8.33%.

![Figure 5- Relation between weight and flow rate](image)
4. Conclusion

From the above experimental trials, solar dryer is showed following results. When percentage change with time was recorded. On scenario1 when weather was fully sunny, with consideration of three vegetables (beetroot, Potato, Ginger) the maximum reduction in weight was 56.80% in Beetroot. On scenario 2 when weather was cloudy, with consideration of three vegetables (carrot, spinach, and capsicum) the maximum decrement in weight was 43.75% in Spinach. On scenario 3 when weather was partially cloudy, with consideration of three vegetables (beetroot, spinach, and capsicum) the maximum loss in weight was 52% in spinach. On the other hand % reduction in weight of beetroot with Airflow was recorded with Different conditions. The maximum decrement was 19.51% with one inlet fan ON with air flow of 0.17 m³/s.

After exhaustive trials in different scenarios, present model of solar dryer found viable solution procure the vegetable and crops for low income group formers.

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