

Performance of PV Winnower cum Dryer for Processing of Agricultural Products

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1. Abstract

Performance studies on PV winnower cum dryer, a device developed for post harvest applications, were carried out both as a winnower and as a dryer. As a winnower 200-300 kg grains could be separated in a clear day from threshed material. The device was found of immense utility when there was lull in the natural wind, used generally for this purpose. The winnower was also used in the development of a dryer to enhance the utility of the system and year round applications. The major advantage was the regulation of the temperature inside the drying bin due to enhancement in the speed of the fan with more irradiance and thus providing appropriate conditions for drying of fruit and vegetables. A pre heating tunnel was incorporated in the system for reducing the thermal gradient inside the drying bin. The system was successfully used for dehydrating grated carrot, spinach, coriander leaves, *ber* and local fruit *kachara* slices with retention of colour and aroma. With the incorporation of a battery and illumination system, the PV winnower cum dryer has a tremendous potential in rural areas.

2. Introduction

Considering the importance and requirements to utilize solar energy for sustainable development of arid region work has been carried out on the development of photovoltaic systems for arid agriculture at the CAZRI, Jodhpur. A solar PV sprayer and a PV duster were developed earlier for plant protection purposes [1-2]. Subsequently extensive work was carried out on the development of PV pump based drip irrigation system for growing orchards [3]. Then considering the difficulties in cleaning the threshed material a PV winnower was developed [4]. The utility of the winnower 's fan was explored in a solar dryer for providing forced circulation [5]. Experiments were carried out successful for dehydrating chillies, *ber* and coriander leaves. Work was also carried out on economical production of PV electricity both through basic and applied studies [6-8]. Results on the enhancement in the PV output by the addition of reflector of extended length were found of practical importance to run the system [8]. The performance of the PV winnower for cleaning of different threshed materials and for dehydration of agricultural produce was studied with PV module –reflector assembly. Although it worked satisfactorily, a thermal gradient of 5-6 °C was observed in the drying bin across the height. To reduce it a tunnel was designed for pre heating of air and to reduce the thermal gradient inside the bin. The performance of the dryer with tunnel was studied for dehydrating different produce. Different stages of the development of the PV winnower cum dryer and performance are reported.

3. Background

Winnowing and drying are two important post harvest applications, which require attention. The villagers find difficulty in cleaning the threshed material if there is lull in natural winds, generally used for this purpose. A Photovoltaic Winnower was developed at CAZRI Jodhpur for winnowing of threshed material and separating the grains. However, it was found to have

limited use only after the harvest and therefore the utility of PV winnower was extended in the development of the forced circulation type solar dryer. A lot of work has already been carried out on solar dryer at CAZRI [10-16], although it remained limited to natural circulation type as far as dissemination is concerned due to constraint of ensured electricity. Since drying has been considered to be appropriate technology for preservation of fruit and vegetables [17-20] enabling farmer to accrue higher benefits through the sale of dried products, this PV dryer developed by using the fan of the winnower was found to provide very good results as far as colour and aroma of the product was concerned. But there have been some thermal gradient across the height. A pre air heater was designed and fabricated. The performance of the dryer with this pre air heater was studied for dehydrating different fruit and vegetable. Additional facility to use the system for lighting has also been incorporated, which makes it more practical and economically viable.

4.The Project

4.1 Design and development of PV winnower cum dryer

The solar PV winnower- cum- dryer is unique system, which was designed and developed to provide a convenient device for winnowing and cleaning threshed agricultural produce and also for dehydrating fruit and vegetables with forced circulation of air, the two post harvest processing activities associated with agriculture production. The composite photovoltaic-thermal unit comprises a PV module- mirror booster assembly, a compatible winnower, a pre air heating tunnel, an especially designed solar drying cabinet for utilising solar energy effectively and having interfacing arrangements to use the fan of the winnower for enhanced air circulation while dehydrating the produce.

The winnower is essentially a trapezoidal chamber comprising a PV run blower, hopper and guide for feeding the material and guide flaps for enhancing the air speed. Basically, it consists of an iron angle frame with aluminium sheet casing from the three sides. The top is covered with an especially designed tray having slope and a movable slit. This tray acts as hopper and simultaneously facilitates the flow of air in the forward direction towards the falling product from the slit.

The dryer comprises a cabinet, especially designed to take the advantage of the sun's position in different months for getting the required energy gain and simultaneously to load the drying material conveniently on twelve trays stacked one above another in two parallel compartments. The cabinet is made of iron angle with a top cover of two glass windows (each 66 cm x 100 cm) fixed on wooden frame and inclined at an angle of 23 degree from horizontal. Two vertical glass windows (each 98 cm x 68 cm) are provided in the front side and another glass window (55.5 cm x 65.5 cm) is fixed on east side of the cabinet. The base of the cabinet is 45 cm above the ground and provisions are made to insert the PV run fan of the winnower on the west opening. Two doors (each of 101cm x 72 cm), are provided at the rear side for loading and unloading of the material. Four ventilation holes (each of 5 cm diameter) are provided at the base with detachable caps. This facilitates the operation of the dryer both in natural and forced circulation modes. The openings on the east side above the window and on the rear side above the doors are provided with GI wire mesh to prevent the entry of insects and to facilitate the air circulation. There is proper interfacing to connect the winnower's fan to the bin. In the beginning two PV modules (35 Wp each) were used to have sufficient out put to operate the winnower for more than six hours a day. The PV system as winnower and dryer are shown in the figure 1a and b respectively.



Fig. 1 a. PV winnower



Fig. 1.b PV winnower added to dryer (Drying of coriander leaves)

Subsequently the PV module was provided with a reflector of extended length after carrying an extensive study on PV-reflector systems where it was found that the energy gains between 9 to 11 a.m. was 22.6 and 35.4% more respectively for PV module - reflector system having 1.5 and 2 times more length of the reflector compared to that of obtained from PV module without reflector and the overall gain was about 20% with additional cost of some 2-3 % of the PV panel [15]. The PV winnower cum dryer operated with PV mirror booster assembly are shown in Fig. 2



Fig.2 a. PV winnower with single PV module and reflector of extended length



Fig.2 b. PV dryer with PV panel and reflector of extended length used for drying ber

Performance of this unique device the PV winnower cum dryer has been carried out both as a winnower and as a dryer. As winnower, 950 kg cluster bean could be winnowed by operating it for 6 hours each for 4 days, 360 kg pearl millet with in 8 hours, 460 kg mustard in 9 hours indicating that as a winnower on an average 35-50 kg cleaned grains/seeds could be obtained in one hour with this device.. Experiments were conducted for dehydrating chillies (Fig. 3) and other different fruits also. *Kachara* (local fruit like that of cucumber) slices could be dehydrated from 94 % moisture content to 5 % with in 70 hours, 46 kg *ber* were dehydrated in overcast weather conditions from 75 % moisture content to 15 % in 288 hours reducing the drying time to more than one third compared to open sun. The overall drying efficiency varied from 15 % to 22 % for different products.



Fig. 3. Drying of Chillies in PV dryer with winnower's fan

These studies revealed that there were enhancement of 15-20 °C in air temperature but gradient of 6-8 °C was observed across the height inside the bin resulting in non- uniform drying. The PV dryer was therefore provided with an extended air heater after carrying out the thermal analysis of tunnel. This pre heater comprises an especially designed blackened aluminium sheet tunnel of about 2m in length and having 34.5 cm width and a height of 31 cm with a provision of inserting the mouth of the tunnel to the outer of winnower's fan. The tunnel encased with PVC sheet was provided with suitable fins for better heat transfer. The tunnel is kept on iron angle stand and fixed to the entry of the winnower, which is placed on the west side of the drying bin of the PV dryer [Fig.4]



Fig. 4. PV dryer with winnower and pre air heating tunnel

The performance of the system with extended air heater was studied. The temperature rise of air due to this pre air heater was 3-4 °C. Experiments for drying spinach, fenugreek, mint (*poodina*) and coriander leaves (10 kg) were carried out successfully for dehydrating the produce from 85-87% moisture content to 5% in 24-28 hour compared to 50-70 hours in open sun. The enhancement in the fan speed with more irradiance regulated the temperature

inside the bin while the pre air heating in the extended tunnel reduced the thermal gradient inside the drying cabinet and thus provided excellent quality of the dried material with retention of aroma and green colour (Fig. 5) .



Fig.5. Green coriander leaves dried in PV winnower cum dryer

The incorporation of the tunnel reduced the temperature gradient from 6-8 °C without air heater to 2-2.5 °C with the extended air heater in between the top and middle trays. However, still there is a thermal gradient in between the lowest and the middle one, which is being taken care off in further improving the design. Nevertheless the PV dryer has provided excellent results in drying different fruit and vegetables.

The system is provided with additional features to use it for illumination also with incorporation of a battery and charge regulator and thus making it an extremely useful device for processing different agricultural produce and utilising the generated PV electricity for one or other purpose round the year.

5. Conclusions

PV winnower cum dryer is a practical device for rural areas. The system can be used through out the year for one or other purposes. The system can be used for winnowing and separating 200-300 kg of grains from threshed material. As a dryer using the winnower's fan, the quality of the dehydrated product is of high with retention of temperature and aroma and therefore the farmers can accrue higher benefits by using this system. With addition of a battery storage and illumination facility, it becomes a multipurpose PV system of practical utility in rural areas.

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