A STUDY ON SOME INNOVATIVE MODIFICATIONS ON A SOLAR RACK DRYER

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ABSTRACT

Various types of solar dryers have been developed and experimented within the country but their applications are still limited due to several problems associated with them. An Innovative Solar Rack Dryer (ISRD) has been developed in this study as an attempt to mitigate some of the technical problems. The study deals with detailed design and fabrication of an ISRD having a drying capacity of 4 kg/batch of fresh Cauliflower. The dryer (2.27 m x 0.9 m x 0.48 m) consists of two solar collectors having total area of 1.65 m^2, four trays (each of 0.14 m^2) inside the drying chamber, a deflector just below the lower row of trays to distribute hot air uniformly throughout the drying chamber, a radiation distributor just below of upper collector to radiate heat flux uniformly throughout the trays of upper row, a sliding gate to control the airflow at the air inlet passage of collector and a chimney (340 mm x 110 mm x 150 mm) for air outlet at the top of drying chamber. The whole unit is supported by a stand of height 1.06 m. The intensive testing revealed that dryer had an efficiency of up to 21.4 per cent. Uniform drying of materials throughout each tray has been obtained.

Key words: Conservation technology, renewable energy, agricultural products, natural convection, efficiency

DRYING AS CONSERVATION TECHNOLOGY

Substantial amount of agricultural products get wasted in the country due to the lack of proper storage facilities and isolation from viable markets. The road infrastructure of the country is so poor that often-fresh agricultural products cannot be transported from the place of their origin to the market. The post-harvest loss for fruit and vegetable products is as high as (25-30) per cent due to lack of their appropriate conservation technology (AIT, 1997). The implications, however, are not only the losses that can be assessed directly but also the declining motivation among the farmers to intensify their efforts in cultivating high income generating cash crops that are perishable. This trend has reflected in the development of appropriate conservation technologies. Drying would be one of the most important technologies in the post-harvest handling of agricultural products. Adequate drying of crops can save between 5 and 20 per cent of the post-harvest losses (Bansal *et al.*, 1984). People have been using sun-dried foods for thousands of years. Artificial dehydration of foods, however, dates back only about two centuries. Under the sense of broad classifications, the drying technologies used are of two types: Traditional and Modern.

TRADITIONAL DRYING TECHNOLOGY

The traditional drying technology involves the drying of foods in an open sun or by fire/smoke in which the drying process takes place under the uncontrolled ambient conditions. Though traditional drying method of agricultural products is very common since ages, is simple and economical but suffers from many drawbacks such as:

- There is no control over the crop drying; the crop may be over dried resulting in discoloration, loss of germination power, nutritional changes and sometimes complete damage.
- Uniform drying of products may not always be possible.
- Due to slow drying, the product may deteriorate due to the growth of fungi and bacteria.
- In absence of protection in open sun drying, the product may be damaged due to rain, dust, storms, etc.
- There may be considerable loss in quantity and quality due to birds, insects, rodents and smoke.

MODERN DRYING TECHNOLOGY

To have a valuable quality product and minimize the wastage, modern drying technologies should be employed in which drying of the product is much faster and safer because the commodity is dried under controlled ambient conditions in an enclosed chamber. Besides, a better and uniform quality product is obtained. The modern drying technology either uses conventional (fossil fuels or electricity) or non-conventional (solar or biomass) sources of energy. Drying of foods using fossil fuels and electricity is far from reach for rural people due to their economic condition. Furthermore, such energy sources also pose a great deal of ecological and environmental threat to the country. In such situation, there is an urgent need of some kinds of food conservation technique that is simple, inexpensive, uses non-conventional energy resources and is environment friendly. Solar drying technology could be one such option.

SOLAR DRYING TECHNOLOGY

Use of solar energy for drying has been practiced in several parts of the world. They have vast potential provided that financially feasible appropriate technologies are made available to the users. Solar drying technology is more advantageous over traditional drying. It is because, in this technology, drying is controlled and dried products are hygienic, safe and hence fetch higher value. In addition, it does not need fuel and electricity. It is environment friendly and cheaper as well.

Solar dryers can be categorized according to mode of heating (direct, indirect and mixed mode type) and mode of air circulation (natural and forced convection type). Indirect type solar dryers are somewhat superior over the direct type of dryers since the temperature, humidity and drying rate can be controlled to some extent and sun does not act directly on the material to be dried. Solar Cabinet Dryer, Solar Rack Dryer and Solar Tunnel Dryer are the examples of direct, indirect and mixed mode type of solar dryers, respectively. Natural convection dryers are easy to fabricate and cheap. They are however suitable only for small drying loads. Forced convection dryer requires an electrical supply to operate the blower but have higher drying capacity.

TECHNICAL PROBLEMS IN SOLAR RACK DRYER

Solar drying in fact is already a globally proven technology. Some research institutions, NGOs, INGOs and local manufacturers in the country have practiced different types of solar dryers. Among them Rack Type Solar Dryer is most popular. An indirect type of Solar Rack

Dryer works generally on the principle of natural air circulation and can be used to dry several kinds of common materials including the ones sensitive to direct solar radiation. This dryer mainly consists of a solar collector, a drying chamber supported by a stand and a chimney. The ambient air gets heated in the collector, enters into the drying chamber, comes in contact with the drying materials spread on several trays, takes up their moisture as it rises up and finally exits through the chimney. Rack Type Solar Dryer available so far consists of several major problems:

- The designers of dryers hardly consider the parameters needed to be regulated during dehydration process. The dryer is considered normally good, once the temperature inside the dryer is found higher than ambient temperature.
- Specific designs for different products and quantities, considering the internal and external factors that affect drying process, are not available.
- Airflow inside the drying chamber of available Solar Dryers used so disturb greatly while opening doors for monitoring.
- The drying of materials is not uniform throughout the trays.
- All the chimneys designed till now are not functioning properly.

SOME INNOVATIVE MODIFICATIONS AND THEIR RESULTS

Following attempts have been made to solve some of the problems in this study.

- In order to match the proportion of collector area and drying chamber, design has been modified based on mathematical calculation.
- An inclined perforated deflector is used to spread the hot air uniformly throughout the drying chamber.
- A horizontal radiation distributor is used to emit the thermal radiation uniformly throughout the trays of uppermost row that is received from upper collector.
- The collector is provided with double air passage. This will cause the transfer of heat from both sides of absorber plate to the flowing air.
- Doors are replaced with drawers to prevent heat loss during loading and unloading of commodities.
- Wire mesh is placed in between the glazing and absorber plate of the collector. This will create turbulence in the airflow and will also increase the heat transfer surface area to the air.

Incorporating these modifications, an experimental prototype named with Innovative Solar Rack Dryer (ISRD) was fabricated. The design considers the meteorological data of Pulchowk, Lalitpur for the drying capacity of 4 kg fresh cauliflower per batch. The Innovative Solar Rack Dryer is shown in Figure 1.

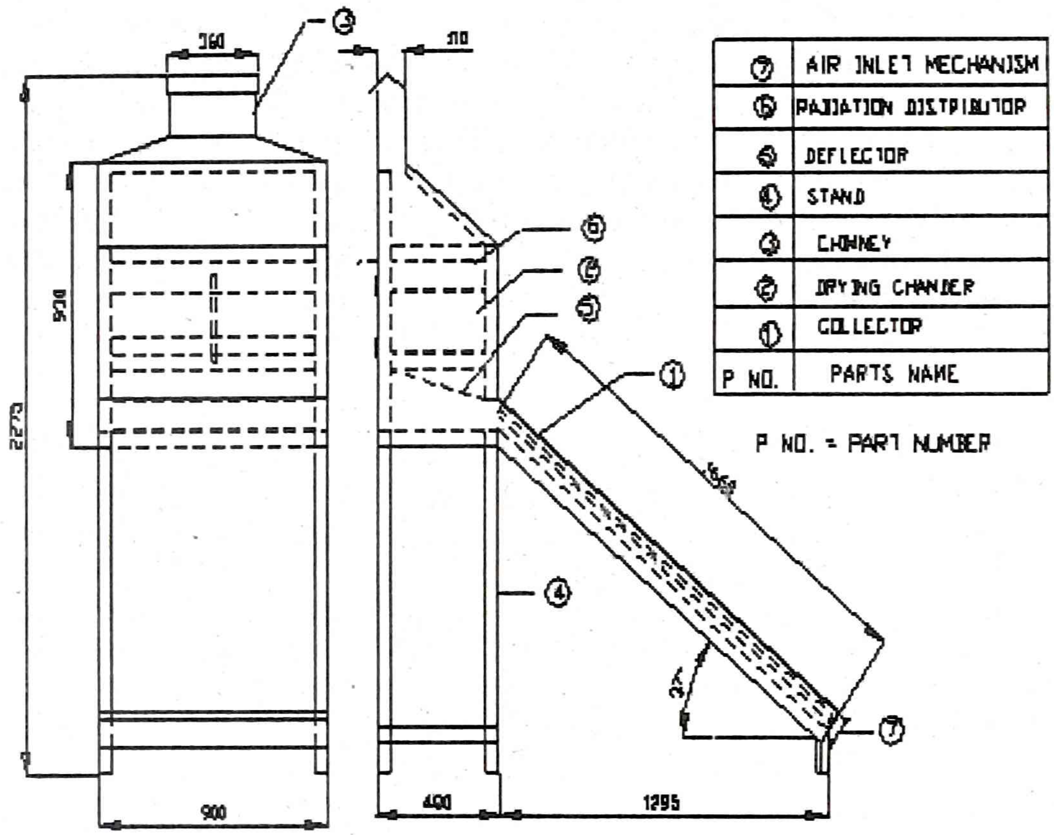

Fig. 1: Innovative Solar Rack Dryer

The working principle of ISRD is based on natural circulation of airflow. It mainly consists of four separate parts assembled together; a solar collector (1690 mm x 900 mm x 125 mm), a drying chamber (900 mm x 480 mm x 650 mm), a chimney (340 mm x 110 mm x 150 mm) and a stand of 1060 mm height. Solar collector consists of an absorber plate, outer and inner collector boxes, a wire mesh, a glazing and an air inlet mechanism. The corrugated aluminum sheet is used as an absorber. A galvanized iron (GI) wire mesh is placed just above the absorber plate. Outer and inner collector boxes are made of GI sheets with a 50 mm thick ordinary glass wool inserted in between them for insulation. A 3 mm thick ordinary window glass sheet is used as glazing. A sliding gate is riveted to the air inlet end of the collector as an air inlet mechanism.

The drying chamber is a rectangular box with an air inlet (800 mm x 90 mm) at its front face. The chamber consists of outer and inner boxes with a 50 mm thick ordinary glass wool inserted in between them. The outer box is made of GI sheet where as the inner one is made of aluminium sheet. The drying chamber is partitioned into two columns. The deflector and radiation distributor made of GI sheet are placed at their relevant positions as shown in Figure 1. Four trays (each of 0.14 m^2) made of stainless steel wire mesh and supported by frame are inserted inside the drying chamber. For ease of loading and unloading the commodities, each trays are provided with drawers.

The roof of drying chamber is replaced with upper collector (800 mm x 400 mm). The upper collector consists of an absorber plate made of aluminium sheet and a glazing of 3 mm thick ordinary window glass sheet. A chimney made of GI sheet is placed at the top of the drying chamber, which is provided with a roof to protect the commodities inside the drying chamber from rain and other foreign particles. Except glazing and trays, all the inner surfaces of collector and drying chamber that come in contact with air-stream are coated with blackboard paint. The collector is attached with the drying chamber at the rectangular air inlet of its front face such that it tends an angle of 37^0 to the horizontal. All the assemblies of the components are made airtight by inserting ordinary rubber gaskets around the joints. A number of thermocouples are inserted and fixed into the drying chamber and collector for measuring their respective temperature. The entire system is supported by a stand on the base of the drying chamber.

The intensive testing of the ISRD was carried out to ascertain its performance from August 28 to September 03, 2002 for drying Cauliflower. It has given satisfactory results. Figures 2, 3, 4 and 5 show the variation of intensity of solar radiation, temperature profile, and performance of ISRD for one lot of experiment on September 02-03, 2002. Figure 2 shows that the first day was cloudier but the second day was very good for performing the experiment. The average value of intensity of solar radiation was about 649 W/m^2 on these days. Figures 3 and 4 show the temperature profile of air and collector parameters on those days. During the second day, the temperature profile had increased almost continuously. Figure 5 shows that the moisture content was reduced rapidly during the second day and finally became almost constant. Moisture reduction rate of the tray placed on open sun drying was much lower. For this experiment, the total effective drying time required for the product being dried was recorded as 9 hours during two days. The efficiency of ISRD calculated from that experiment was 21.40 per cent. Other experiments were also performed under the same loading conditions to get the result confirmed. All the experiments showed that the experimental efficiency of ISRD was almost equal to that of theoretically calculated i.e., 21.6 per cent. The near about matching of experimental value with that of theoretical is due to the negligible change in the variable parameters such as drying time and the solar insulation, the other parameters being constant.

The experiments showed that increase in solar radiation had caused to decrease the relative humidity of ambient air and increase in the air velocity. These parameters had direct effect on temperature profile, leading to increase it. At the same time, the rate of increase of temperature profile was declining with increase in air velocity although intensity of solar radiation was almost same. This increase in temperature had caused to decrease the moisture content rapidly. During the initial periods of drying, the material on the lower trays was dried much faster than that of upper trays. This is caused by hot air coming from the collector, which first comes in contact with the materials in the upper trays. Later on, the material on the upper trays was dried faster and lastly the drying rate was quite same. The rate of drying of the product placed in open sun drying was significantly low. The measured values of temperature showed that the temperature of air leaving the drying trays was always lower than that of air leaving the chimney. The product placed on the trays of upper row was found uniformly dried. Both the effects might be due to upper collector and radiation distributor. The product placed on the trays of lower row was also found uniformly dried. This might be due to deflector.

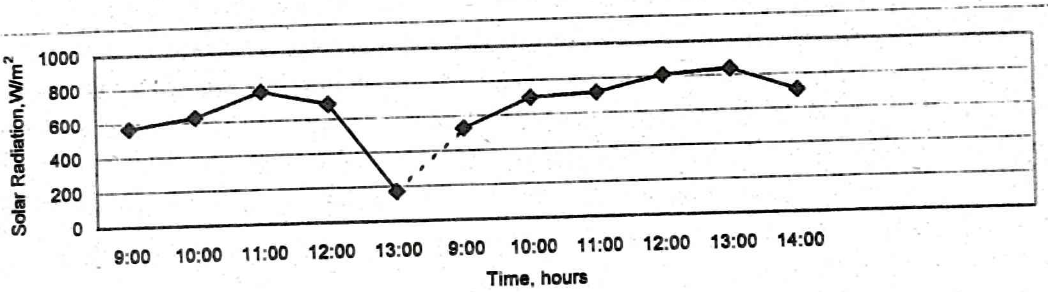

Fig. 2: Variation of Available Solar Radiation on Sept. 02-03, 2002

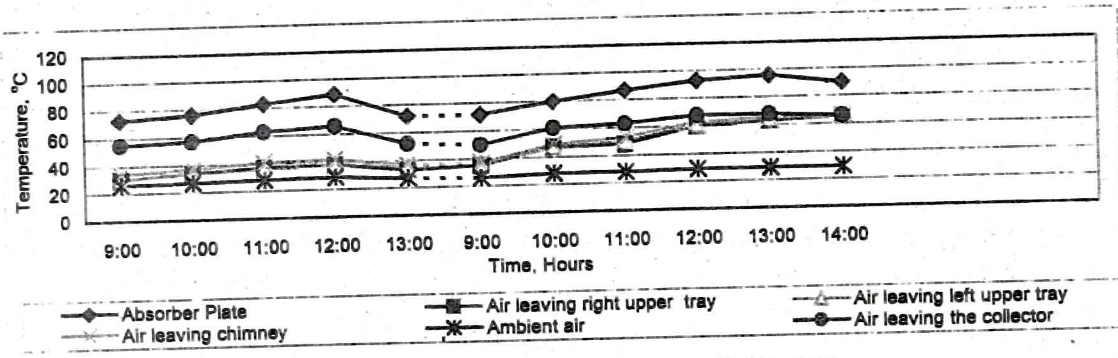

Fig. 3: Temperature Profile of ISRD on Sept. 02-03, 2002

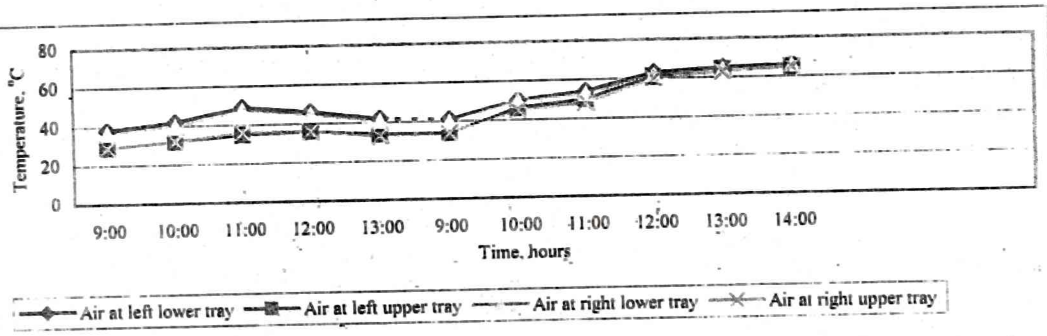

Fig. 4: Temperature Profile of ISRD on Sept. 02-03, 2002

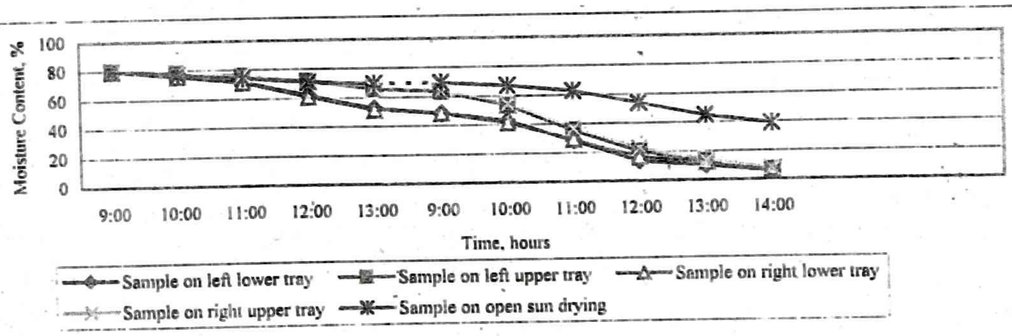

Fig. 5: Performance of ISRD on Sept. 02-03, 2002

NEED OF FURTHER EFFORTS

The design and testing of ISRD was conducted under the various limitations of time and cost. This study was confined to evaluate overall contribution of innovative designs in the drying process. Individual contributions of wire mesh, deflector, radiation distributor and double air passage through collector have yet to be evaluated. The air outlet (called chimney in this study) should be provided with a better design of chimney to create natural drafting of air circulation. These efforts will be beneficial to upgrade the design results and efficiency of ISRD.

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