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Modification and Performance Evaluation of Modified Natural Circulating Solar Dryer

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Abstract : The use of solar energy in recent years had reached a remarkable edge. It had become even more popular as the cost of fossil fuel continues to rise. A study was undertaken to develop a natural circulating solar dryer and evaluate its performance with Open sun drying. The drying experiments were carried out at lab VSAET, SHIATS Allahabad. The performance of the dryer was evaluated by drying samples of potato. This solar drying system consisting of two parts, solar collector and solar drying cabinet. In this experiment two solar collector were joined in series. Solar collector with area of 0.97 m^2 (1.06 m x 0.91 m x 0.19 m) had placed black marble, area of marble 0.64 m^2 (0.76 m x 0.84 m), angle of frame was 37^0 and float glass of rectangular shape had thickness 0.008 m to absorb solar radiation and there are 4 hole in each collector it size was 0.075 m. A cabinet that was divided into two divisions separated by two removable shelves. Each shelf was 0.36 m width and 0.53 m length and made of wire mesh framed. Three sides of the drying chamber walls were covered by tin sheet (0.0011 m) and a door in the back. The highest temperature inside the cabinet significantly elevated compared to environmental air with temperature increases of up to 55°C and 66°C depending on air flow and loading. Loading tests conducted with an average of 100g of potato slices resulted in effective drying within one days from a moisture content of 86.8% (wb) down to approximately 1.02% (wb) for modified natural circulating solar dryer of operation respectively. These results indicated sufficient drying and preservation of potato slices within one day of sunlight. It was found that the dryer was suitable for drying of potato slice.

Key words - solar dryer, natural circulating, performance evaluation, solar collector, solar cabinet, pvc pipe, black marble.

Introduction

Drying is an excellent way to preserve food and solar dryers are appropriate food preservation technology for sustainable development. Drying was probably the first ever food preserving method used by man, even before cooking (Alamu *et al*., 2010). It involves the removal of moisture from agricultural produce so as to provide a product that can be safely stored for longer period of time.

Open sun drying is one of the oldest techniques employed for processing of agricultural food products. Open sun drying has been traditionally practiced in India for drying agricultural products such as paddy, wheat, fish, fruits and vegetables. It involves simply laying the agricultural products in the sun on mats, roofs or drying floors, but the products dried in the open sun often suffer from rain, wind-borne dirt and dust, infestation by insects, rodents and other animal, products may be seriously degraded to the extent that sometimes become inedible and the resulted loss of food quality in the dried products may have adverse economic effects on domestics and markets value. Totally dependent on good weather and very slow drying rate with danger of mould growth thereby causing deterioration and decomposition of the produce. The process also requires large area of land, takes time and highly labour intensive. Some of the problems associated with open-air sun drying can be solved through the use of a solar dryer which comprises of collector, a drying chamber and sometimes a chimney (Madhlopa *et al.*, 2002). Due to the current trends towards higher cost of fossil fuels and uncertainty regarding future cost and availability, use of solar energy in food processing will probably increase and become more economically feasible in the near future.

Solar dryers have some advantages over sun drying when correctly designed. The solar dryer can be seen as one of the solutions to the world's food and energy crises. With drying, most agricultural produce can be preserved and this can be achieved more efficiently through the use of solar dryers. In comparison to natural "sun drying", solar dryers generate higher temperatures, lower relative humidity, lower product moisture content and reduced spoilage during the drying process.They give faster drying rates by heating the air to 20 degree above ambient, which causes the air to move faster through the dryer, reduces its humidity and drying time is also significantly reduced.

Materials and methods

This chapter deals with the material and methods employed for fabrication and modification and evaluate the performance of natural circulating solar Dryer with open sun drying. The drying experiments were carried out at APFE lab VSAET, SHIATS Allahabad (N 25.41414º E 81.84876º). The campus is located at Naini, a satellite neighbourhood of Allahabad on the bank of river Yamuna. In Allahabad, the climate is warm and temperate. The average annual temperature in Allahabad is 42^0 c in month of the May. The average annual rainfall and wind speed 981 mm and 5 – 10 km/h.

This experiment presents developments and potentials of modified natural circulating solar dryer technologies for drying of potato slice. Previous efforts on solar drying of potato slice are critically examined. Recent developments of modified

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natural circulating solar dryer such as solar dryer, improved version of solar dryer is also critically examined in terms of drying performance and product quality, and economics in the rural areas.

Fabrication of modified natural circulating solar dryer
Solar collector

The collector used consists of a 0.018 mm wooden frame (1.6m long x 0.91m wide x 0.19m high), insulated by Thermocol sheet. Black Marble were placed on wooden box. The insulator to absorb solar radiation and to store thermal energy. In order to reduce the heat loss the collector was covered with 0.008 m float glass. Air enters through the open bottom end of the collector and is heated while it passes over the black marble. The warm air outlet of the collector is connected to the bottom side of the drying chamber through two elbow coupler having diameter 0.075 m. The solar collector which is inclined at angle of 37 degree from the horizontal is oriented along the N-S direction. Instead of a single plate two collectors were used in series.
It was fabricated by L shaped angle iron having thickness 0.005 m for placing the solar collector in 37 degree from the horizontal (depends on latitude and longitude of that particular area to absorb maximum solar radiation) & drying chamber in 90 degree from the horizontal (for effective natural circulation of air). The dimension of frame was 1.07 m x 0.92 m

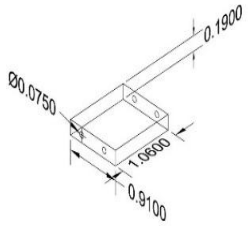

Plate: 2D diagram of solar collector and dimension Frame
Cabinet
It consists of tin sheet and thickness of tin was 0.0011 m. The dimension of the cabinet was 0.95m x 0.56m x 0.39m (l x w x d). Solar heated air is passed through two removable trays each of size 0.53m length x 0.36m wide in equidistance of total height of the drying chamber and made of wire mesh framed on which the drying product is spread. The trays are inserted and removed through the door provided in the back of the cabinet. To increase air circulation rates 4 pipes have been placed on the top of the dryer chamber.

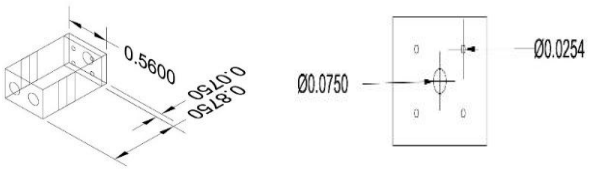

Plate: 2D diagram of cabinet

Polyvinyl Chloride (PVC) pipe
Polyvinyl Chloride (PVC) pipe is the most widely used plastic piping material. PVC piping systems are: Environmentally sound, Provide long service life, Easy to install and handle, Corrosion resistant. PVC pipe is made to conform to various American Society for Testing and Materials (ASTM) standards for both pressure and non-pressure applications. PVC piping is used for: Drain-waste-vent (DWV), Sewers, Water mains, Water service lines, Irrigation, Various industrial installations. In these experimental PVC pipe was used for circulating the air from one collector to second collector which was fitted in series and further connected to cabinet. 1.524 m long and 0.075 m diameter PVC pipe was used in these experiment.

Elbow
An elbow was a pipe fitting installed between two lengths of pipe or tubing to allow a change of direction, usually a 90° or 45° angle. This experimental plastic elbow was used and the diameter was 0.075m. Four piece of elbow was fitted in the collector and two elbow in the cabinet. The most important function of elbow was to joint pipe which was attached to the collector in series and collector to cabinet. To change direction of air from one collector to another collector from up to down and collector to cabinet air flow from down to up with help of elbow.

Experimental Procedure

The experiments were conducted on the VSAET, SHIATS Allahabad. The methods for performance evaluation are conducted between 9.00 a.m to 5.00 p.m solar times. Potato was purchased from the Allahabad market and used in the experiments. After purchasing, the sorting process was carried out manually to remove all the undesirable material. Then the potato was washed thoroughly in running water to remove the adhering soil and extraneous matter. Then peel the potato and slice with the help of manual slicer. The thickness of potato slice was 0.0025 m the slice was measured by Vernier caliper. Slice potato was boiling in a 100 ºc and add some salt & Alum. Purpose of adding Salt and Alum for the test and color. Product was then weighed and 100 g samples taken in each tray were made for each methods of drying. Initial moisture content of the potato was determined by oven drying method at 110°C ± 2°C till constant weight occurred.

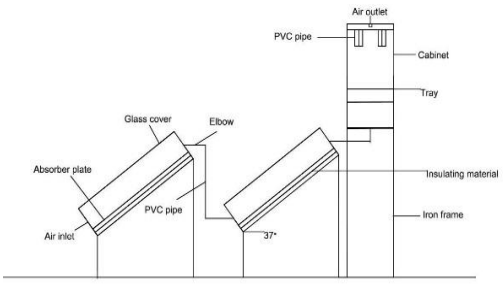

Plate: Cross-sectional view of the modified natural circulating solar dryer

Determination of moisture content

Moisture content Wet Basis – Wet basis moisture content is described by the percentage equivalent of the ratio of the weight of water (Ww) to the total weight of the sample (Wt)

$$MC(wb)=\frac{Ww}{Wt}\times 100=\frac{Ww}{Ww+Wd}X100$$

Note that wet basis moisture content can range from 0 to 100 percent.

Moisture content Dry Basis – Dry basis moisture content is described by the percentage equivalent of the ratio of the weight of water (Ww) to the weight of the dry matter (Wd)

$$MC(db)=\frac{Ww}{Wd}\times 100$$

Where,

MC (wb) = Moisture content per cent (wet basis)
Wt = Weight of sample, g
MC (db) = Moisture content, per cent (dry basis)
Ww = Weight of water, g
Wd = Weight of dry matter, g

Note that dry weight moisture content can range from 0 to very large percentages.

Drying rate - Drying rate, R in gm of water per minute per 100 gm of bone dry material. Drying rate of the potato slices was calculated by the following formula

$$R=\frac{Wr}{T\times Wd}\times 100$$

Where,

R = Drying rate (g min-1)
Wr = Amount of moisture removed (g),
T = Time of drying (h),
Wd= Total bone dry weight of sample (g),

RESULTS AND DISCUSSION

Modification of natural circulating solar dryer

Existing solar dryer BRSM CAET Mungeli was modified by connecting two collectors (1.06 m x 0.91 m x 0.19 m) in series. The dryer consists two collector, frame, and cabinet. Over all dimension was 1.06 m x 0.91 m x 0.19 m, 1.07 m x 0.92 m, 0.95m x 0.56m x 0.39m, Black Marble were placed on wooden box. In order to reduce the heat loss the collector was covered with 0.008 m float glass. Frame was fabricated by L shaped angle iron having thickness 0.005 m. Cabinet consists of tin sheet and thickness of tin was 0.0011 m. The dimension of the cabinet was 0.95m x 0.56m x 0.39m (l x w x d).

Open sun drying took nearly 540 min to dry potato slices from an initial moisture content of 657.57 per cent (db) to 3.83 per cent (db).The time taken under solar dryer was about 420 min. The final moisture content of product was 1.02 percent (db) for potato slices.

In all drying methods, there was rapid moisture removal at the initial stage of drying. Highest drying rate was achieved with solar dryer followed by open sun drying. The highest temperature recorded was for the solar cabinet dryer (66 °C) followed by open sun drying (45 °C).Solar dryer were found to be better over open sun drying in respect of moisture evaporation, as they required lesser time. The rate of drying was highest in solar dryer drying method followed by open sun drying

Performance Evaluation of modified natural circulating solar dryer

Dried potato is an excellent snack food and has a demand for both national and international markets. Comparison of the moisture contents of potato in the modified natural circulating solar dryer with those obtained by the traditional method for a typical experimental run during drying at Allahabad. The modified natural circulating solar dryer required 1 days to dry potato slice samples from 86.8% (wb) to 1.02% (wb) as compared to sun drying.

Variation in moisture content of potato slices with respect to drying time

It is evident from the figure 1 that in the initial stage of drying the amount of moisture evaporated from the product was high which gradually reduced as the time of exposure or the drying time increased in all the methods. The figure has been drawn from data in appendix II. This was due to the fact that availability of moisture for evaporation was higher at the beginning, which gradually reduced as the evaporation of water content, remained continued. In the later stages, only capillary moisture was available and took more time to evaporate from the product.

The figure 1 shows high correlation between drying rate and moisture content at the beginning was high when moisture content was high. Whereas, drying rate decreases as drying process proceeds until the moisture content of the potato slice reaches more or less a constant value.

Variation of drying rate of potato slices with respect to time

Figure 2 shows drying curve of potato slice obtained by plotting drying rate versus time. The figure has been drawn from data in appendix II.

A high correlation between drying rate and drying time was observed. Drying rate was high at the beginning of drying process and then decreased as the drying time proceeded until reaching more or less a constant value indicating that the potato slice had dried.

Plate: Side view of modified natural circulation solar dryer

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Plate: Front view of modified natural circulation solar dryer

CONCLUSIONS

In conclusion it can be stated that the drying of slices by the two methods employed. Though the quality of the dried product has not been evaluated but it appeared that the final product did not lose the quality significantly. It was possible to dry the potato slices to final moisture content of 3.83 percent and 1.02 percent (db) in open sun drying and solar dryer.The rate of drying was the highest in the solar cabinet dryer (4.28 to 1.54 gm/min) followed by open sun drying (3.10 to 1.16 gm/min) for potato slices. Thus solar dryer can be preferred over the open sun drying method.

In all the cases the use of modified natural circulating solar dryer leads to considerable reduction of drying time in comparison to sun drying and the quality of the product dried in the solar drier was of quality dried products as compared to sun dried products

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APPENDIX I

Specification of modified natural circulating solar dryer

Dimensions of Cabinet	
Box height	0.95 m
Box width	0.56 m
Box length	0.39 m
Base hole diameter	0.075 m
Upper hole diameter	0.025 m
Tin thickness	0.0011 m
Total length of plastic pipe	1.52 m
Width of wire mash plat	0.36 m
Length of wire mash plat	0.53 m
Dimensions of collector	
Wooden box height	0.19 m
Wooden Box width	0.91 m
Wooden Box length	1.06 m
Width of black Marble	0.76 m
Length of black Marble	0.84 m
Thickness of Glass	0.008m
Dimensions of frame	
Frame width	0.92 m
Frame length	1.07 m
Ground Clearance back side	0.71 m
Ground Clearance back front	0.3 m
Frame Inclination Angle	37 º

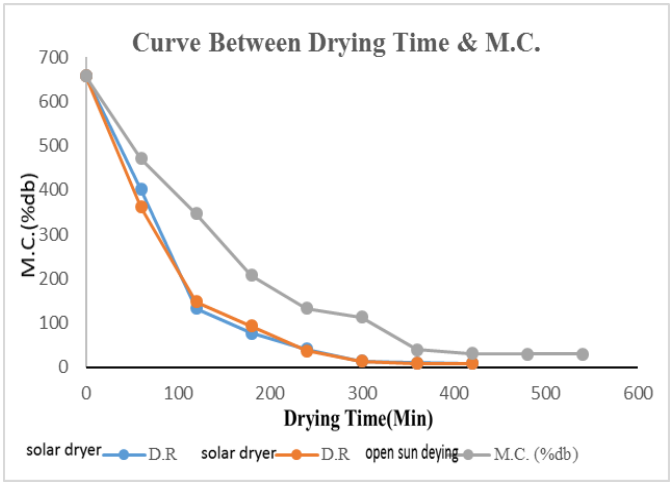

Fig.1 - Variation of moisture content with drying time for potato slice under different drying methods

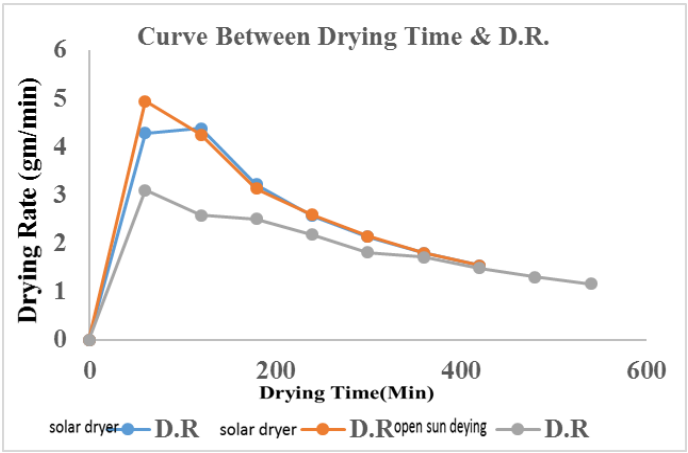

Fig.2- Variation in drying rate of potato slice with drying time in different drying methods

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APPENDIX II

Variation of moisture content and drying rate during drying of potato slice under different drying methods

Time (min)	Solar tray dryer				Open sun drying	
	Tray - 1		Tray - 2			
	M.C. (%db)	D.R	M.C. (%db)	D.R	M.C. (%db)	D.R
0	657.57	0	657.57	0	657.57	0
60	400.75	4.28	361.28	4.93	471.28	3.10
120	131.96	4.38	147.80	4.24	346.81	2.58
180	76.36	3.22	92.80	3.13	206.96	2.50
240	40.45	2.57	36.81	2.58	132.65	2.18
300	12.65	2.14	13.33	2.14	112.87	1.81
360	9.16	1.80	8.48	1.80	39.77	1.71
420	7.72	1.54	8.25	1.54	30	1.49
480					29.77	1.30
540					29.01	1.16