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Drying of agricultural products using forced convection indirect solar dryer

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Abstract:- Drying of three agricultural products namely potato slices, onion slices and whole grapes was done using an indigenously designed and fabricated forced convection indirect solar dryer and under open sunlight. The diurnal variation of temperature, relative humidity in the solar dryer was also compared with the ambient temperature and relative humidity during March and April 2017 for all the three products. The study showed increase of temperature and lower humidity inside the drying chamber at different time interval. Hourly moisture loss for all the three agricultural products in the drying chamber and open sun drying was also compared and the percentage of moisture loss in the drying chamber was found to be higher compared to open sun drying for all the products. The mass of water removed for all the three products in the drying chamber was also found to be higher than the open sun drying. Results of the study showed that forced convection indirect solar dryer is better than the open sun drying method for drying the agricultural products more efficiently.

Keywords: Solar drying, Open sun drying, Agricultural products, Forced convection solar dryer

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I. INTRODUCTION

Open sun drying is one of the most common and oldest methods of preservation of agricultural products, where the products such as grains, spices, vegetables and fruits are exposed directly to the sun. Drying under direct sun light has many disadvantages such as uneven drying, uncontrolled moisture content, spoilage of products due to rain, wind, dust, insect infestation, animal attack and fungi etc. Because of these limitations the quality of the resulting products can be degraded, sometimes beyond edibility [1]. It has been reported that the losses of fruits and vegetables during drying in developing countries are estimated to be 30-40% of production [2]. To overcome the post harvest losses of agricultural products particularly in the rural areas of the developing countries efficient cost effective method of drying is the need of the hour.

Solar thermal technology is rapidly gaining acceptance as an energy saving measure in agriculture application. It is preferred to other alternative sources of energy such as wind and shale, because it is abundant, inexhaustible, and non-polluting. Solar air heaters are simple devices to heat air by utilizing solar energy and it is employed in many applications, like drying of agricultural commodities, which require low to moderate temperature below 80°C. Solar dryers are specialized devices that control the drying process and protect agricultural produce from damage by insect pests, dust and rain. 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. In addition, it takes up less space, less time and relatively inexpensive compared to artificial mechanical drying method. Thus, solar drying is a better alternative solution to all the drawbacks of natural drying and artificial mechanical drying. Numerous types (direct, indirect, mixed type) of solar dryers have been designed and used in different parts of the world for drying agricultural products, but indirect forced convection solar dryer has been reported to be superior in terms of speed and quality of drying [1,2,3].The present study was designed to dry few commonly used agricultural products like potato slices, onion and grapes using forced convection indirect solar dryer and open sun drying.

II. MATERIALS AND METHODS

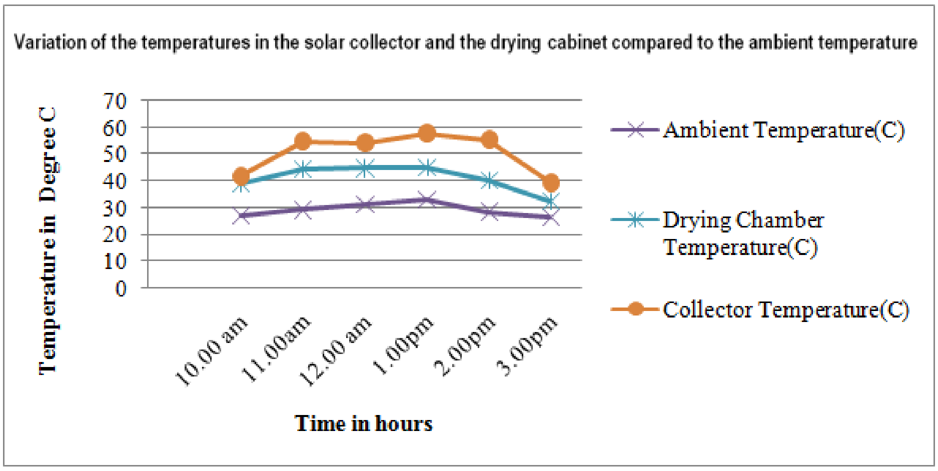
Potato, onion and grapes were selected for drying in the present study. Potato and onions are the most commonly used vegetables across the world. Dried potato slices are abundantly used in chips making and dried onion slices are also used as spices. Similarly drying of grapes is the most common method of preservations. These three commodities selected for drying were procured from market, washed properly and used in the study. Potato and onions were sliced into 5mm thickness and whole grapes were used as such. All these items were measured in weighing balance and 400 grams of each of the samples were divided equally into two parts. One part of each of the samples was spread out in a tray and kept under the effect of direct sunlight. The other part of the samples was spread out in another tray and kept inside the drying chamber of an indirect forced convection solar dryer. The design, fabrication of the solar dryer has been reported elsewhere [3]. The dryer consists of a solar collector, a drying chamber and a centrifugal blower. The unique feature of the dryer was the use of baffles for allowing a non linear movement of air so that air takes more time to travel through the collector to the drying chamber and thereby it heated up easily. The heated air from the solar collector is allowed to pass through the products placed inside the drying chamber. Ambient temperature was measured using normal thermometer and temperature in the collector and drying chamber are taken at equal intervals of time from 10am to 4 pm for the samples placed in the drying chamber and open sun separately using digital LCD thermometer (-50^{0}C to +250 ^{0}C). Humidity and hourly water loss of the samples at equal time intervals was also measured using hygrometer. Mass of the samples was measured by taking weight in weighing balance at 10 am and 3 pm and total mass of water removed was calculated by subtracting the weight at 3pm from the weight of the samples at 9am. The experiment was conducted during March and April, 2017.

III. RESULTS AND DISCUSSION

Results of the diurnal variation of temperatures in the solar dryer, collector and ambient temperatures for potato slices, onion slices and grapes are shown in the Tables 1,2,3 and Figs.1,2,3. In all the cases the temperature inside the dryer and the solar collector were much higher than the ambient temperature during most hours of the daylight. The temperature inside the drying chamber increases from 11am and reaches the peak temperature at 1 pm and maintained for about three hours. This indicates the better performance of indirect solar dryer for drying the products effectively at lesser time than drying by open-air sun drying.

Table 1: A typical day results of the diurnal variation of temperatures in the solar dryer for Potato slices.

Time (hr)	Ambient Temp.(^{0}C)	Drying Chamber Temp.(^{0}C)	Collector Temp.(^{0}C)
10.00 am	27	39	41.8
11.00am	29	44.1	54.9
12.00 am	31	44.5	54.18
1.00pm	32.8	44.78	57.92
2.00pm	28.3	40.2	55.52
3.00pm	26.32	32.4	39.43



Time (hr)

Fig. 1: Variation of the temperatures in the solar collector and the drying chamber compared to the ambient temperature for potato slices

Table-2: A typical day results of the diurnal variation of temperatures in the solar dryer for onion slices.

Time(hr)	Ambient Temp. (^{0} C)	Drying Chamber Temp.(^{0}C)	Collector Temp.(^{0} C)
10.00 am	32	39	42
11.00am	33	41.1	51
12.00 am	35	43	56
1.00pm	38	50	60
2.00pm	35	48.3	55.8
3.00pm	34	36	48
4.00pm	33	31	42

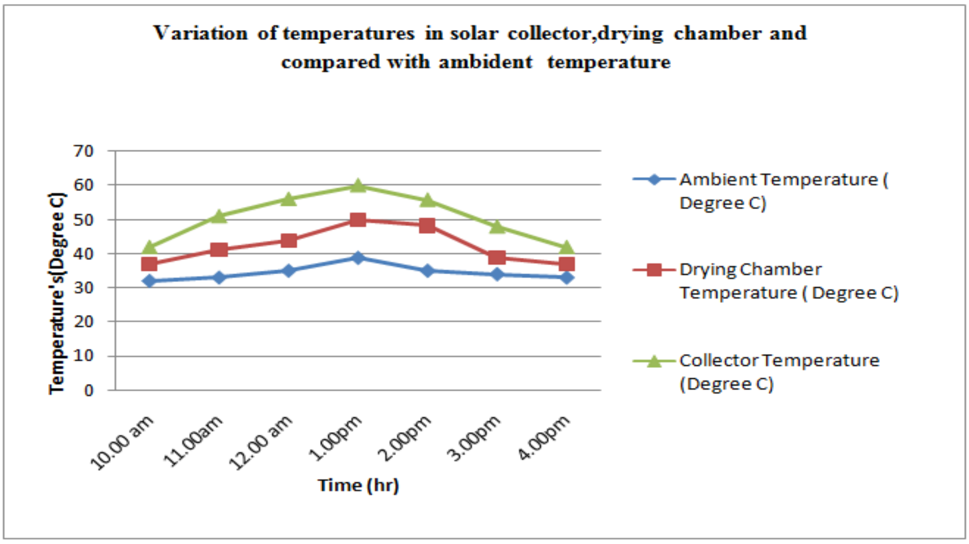


Fig.2 : Variation of the temperatures in the solar collector and the drying chamber compared to the ambient temperature for onion slices

Table -3 : A typical day results of the diurnal variation of temperatures in the solar dryer for grapes.

Time(hr)	Ambient Temp.(^{0}C)	Drying Chamber Temp.(^{0}C)	Collector Temp.(^{0}C)
10.00 am	27	39	40
11.00am	29.3	41.2	47
12.00 am	31	46.5	56.54
1.00pm	34	49.35	60
2.00pm	32.4	45.2	52
3.00pm	30	43.1	50
4.00pm	28.1	34	38.6

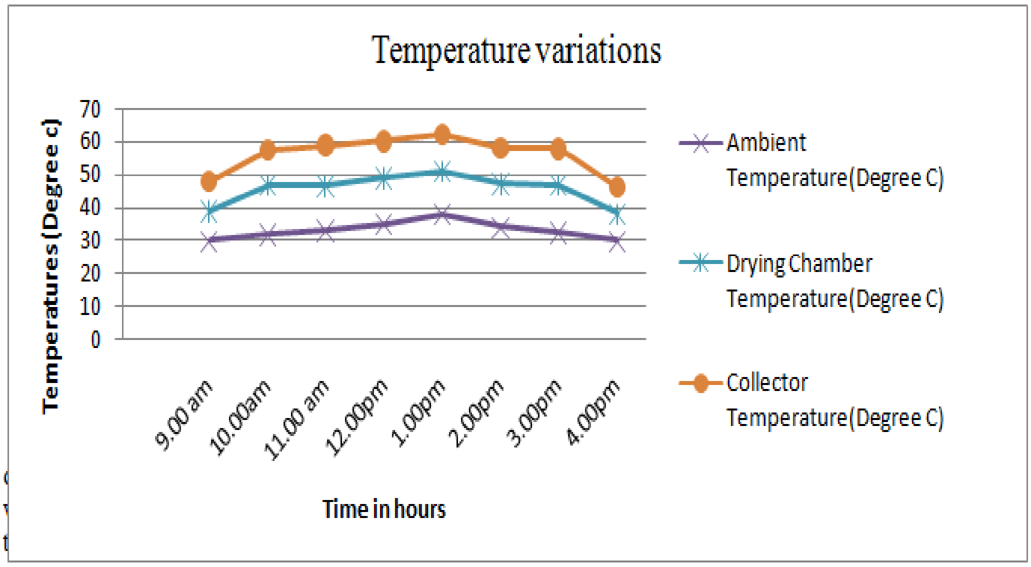


Fig.3: Variation of the temperatures in the solar collector and the drying chamber compared to the ambient temperature for grapes

The results of the diurnal variations of relative humidity in the drying chamber and ambient air humidity during drying period of potato slices and grapes are given in the Tables 4,5 and Figs.4,5. Humidity percentage was found to be lower in the drying chamber for both the samples as compared to the ambient air humidity and this further suggests that the drying chamber is better for drying the products than drying under open sunlight.

Table 4: A typical day results of the diurnal variation of relative humidity in the dryer for potato slices

Time	Ambient Temp. (^{0}C) DBT	Ambient Temp. (^{0}C) WBT	Ambient Air Humidity (%)	Drying Chamber Temp. (^{0}C) DBT	Drying Chamber Temp. (^{0}C) WBT	Drying Chamber Humidity (%)
10 am	27	22.1	65.2	39	28.1	50.1
11am	29	19.5	40.4	44.1	29.2	33
12 am	31	23.2	51.6	44.5	29	31.4
1pm	32.8	20.8	33.1	44.78	30.2	30.7
2pm	28.3	18.6	38.5	40.2	25	28.5
3pm	26.32	17.3	39.7	38.4	27	26.7

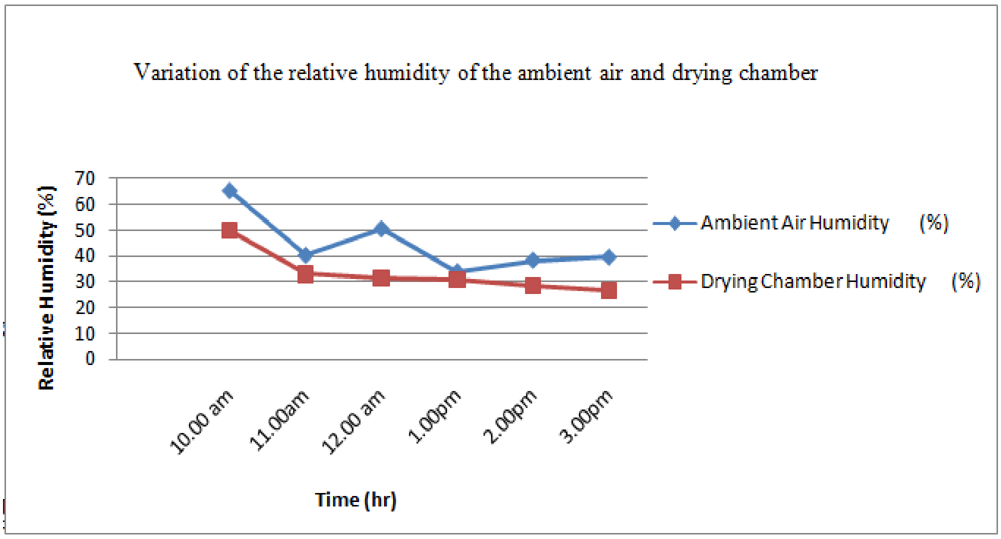


Fig.4: Shows the diurnal variation of the relative humidity of the ambient air and drying chamber for potato slices.

Table 5: A typical day results of the diurnal variation of relative humidity in the solar dryer for grapes.

Time (hr)	Ambient Temp. (^{0}C) DBT	Ambient Temp.(^{0}C) WBT	Ambient Air Humidity (%)	Drying Chamber Temp. (^{0}C) DBT	Drying Chamber Temp. (^{0}C) WBT	Drying Chamber Humidity (%)
10.00 am	27	25	84	39	28	44
11.00 am	29.3	22	60	41.2	29.33	40
12.00 am	31	27	74	46.5	30	33
1.00 pm	34	32	85	48.35	32	33.5
2.00 pm	32.4	30	84	45.2	33	44
3.00 pm	30	27	78	43.1	34	53
4.00 pm	28.1	26	83	34	27	58

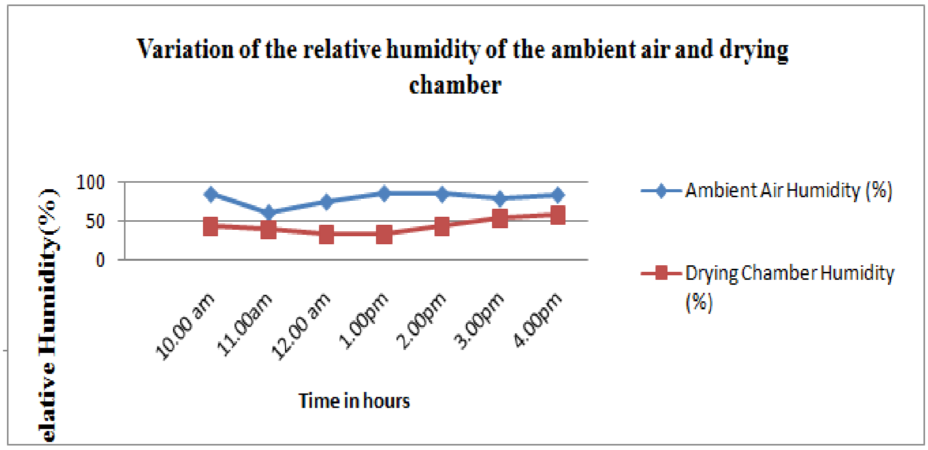


Fig.5: Shows the diurnal variation of the relative humidity of the ambient air and drying chamber for grapes.

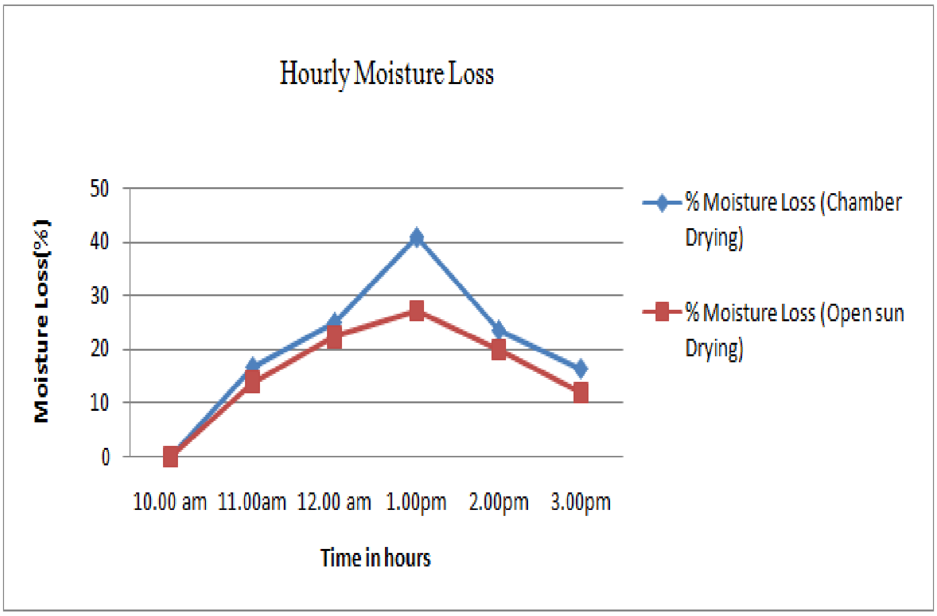
Results of the hourly moisture loss for all the three agricultural products in the drying chamber and open sun drying are shown in the Tables 6,7,8 and Figs.6,7,14. Mass of the items at the initial hour (10 am) and after 5 hrs (3 pm) of drying at the drying chamber and the open sun is also shown in the Tables 6,7,8.The percentage of moisture loss in the drying chamber for all the three items was found to be higher compared to the open sun drying. Similarly mass of water removed from all the three products in the drying chamber was higher than the open sun drying. These further indicate that indirect solar dryer is more efficient for drying of agricultural products than open sun drying.Physical appearances of potato and onion slices before drying and after drying in the drying chamber and open sunlight are shown in the Figs.8-13.

Table 6: Hourly Moisture Loss and Mass of the Potato in the drying chamber and open sun

Time (hr)	Mass of Potato (g) (Drying Chamber)	Moisture Loss (g) (Drying Chamber)	% Moisture Loss (Drying Chamber)	Mass of Potato (g) (Open sun Drying)	Moisture Loss (g) (Open sun Drying)	% Moisture Loss (Open sun Drying)
10.00 am	200	0	0	200	0	0
11.00am	166.7	33.33	16.67	172.3	27.7	13.85
12.00 am	125.15	41.55	24.92	134	38.3	22.22
1.00pm	74.09	51.06	40.8	97.74	36.26	27.05
2.00pm	56.71	17.38	23.45	78.255	19.48	19.93
3.00pm	47.44	9.27	16.34	70.56	7.69	11.79

Drying Chamber:
Mass of water removed= (200-47.44) g =152.56 g

Open Sun Drying:
Mass of water removed= (200-70.56)g=129.44g



Time (hr)

Fig. 6: Moisture loss curve for o potato slices in the solar dryer and open sun drying

Table 7. Hourly Moisture Loss and Mass of Onion slices in the drying chamber and open sun

Time(hr)	Mass of Onion (g) in (Drying Chamber)	Moisture Loss (g) in	% Moisture Loss (Drying Chamber)	Mass of Onion (g) Sun Drying	Moisture Loss (g) (Sun drying)	% Moisture Loss (Sun Drying)
10.00 am	200	0	0	200	0	0
11.00am	174.31	25.69	12.8	182.2	17.85	8.9
12.00 am	145	29.31	16.7	156.2	26	14.2
1.00pm	100.2	44.8	30.8	125	31.2	19.97
2.00pm	84.52	15.69	15.64	115.2	9.8	7.89
3.00pm	75.32	9.2	10.8	110	5.2	4.5

Drying Chamber:
Mass of water removed= (200-75.32) g= 124.68g

Open Sun Drying:
Mass of water removed= (200-110)g=90g

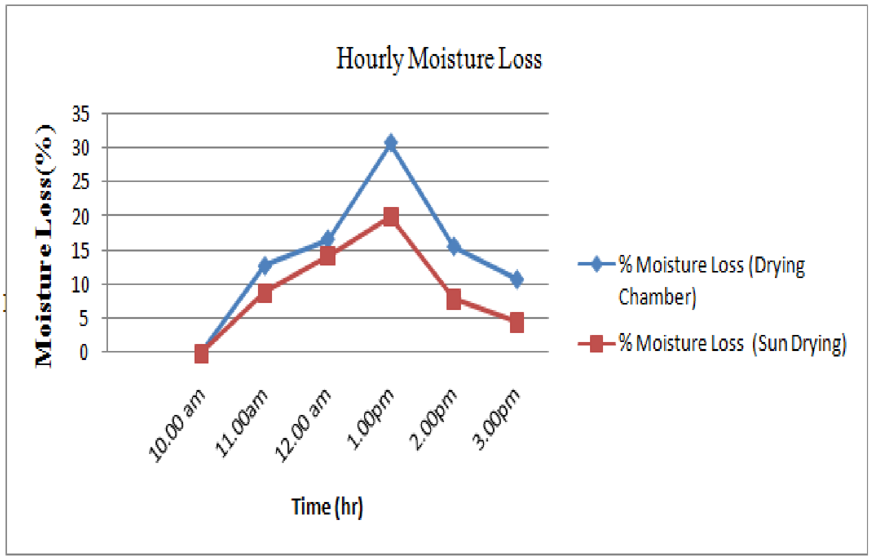


Fig.7: Hourly Moisture Loss in the drying chamber and open sun for onion slices

Fig.8: Potato slices before drying

Fig.9: Potato slices after drying in the drying chamber

Fig.10: Potato slices after drying in open sunlight

Fig.11: Fresh onion slices before drying

Fig.12: Onion slices after drying in drying chamber **Fig. 13:** Onion slices after drying in open sunlight

Table : 8 Hourly Moisture Loss and Mass of Grapes in the drying chamber and open sun

Time	Mass of Grapes (g) (Drying Chamber)	Moisture Loss (g) (Drying Chamber)	% Moisture Loss (Drying Chamber)	Mass of Grapes (g) (Sun Drying)	Moisture Loss (g) (Sun Drying)	% Moisture Loss (Sun Drying)
10.00am	200	0	0	200	0	0
11.00am	190	16	7	196	6	2.85
12.00am	180	13.6	9	190	7	4.3
1.00pm	160	22.9	12.3	179	18	9.1
2.00pm	144	18.2	11.2	167	11.2	6.2
3.00pm	132	12.3	9.3	158	9.3	5.5
4.00pm	120	9.8	7.42	150	8.2	5.1

Drying Chamber:
Mass of water removed= (200-120) g=80 g

Open Sun Drying:
Mass of water removed= (200-150) g =50g

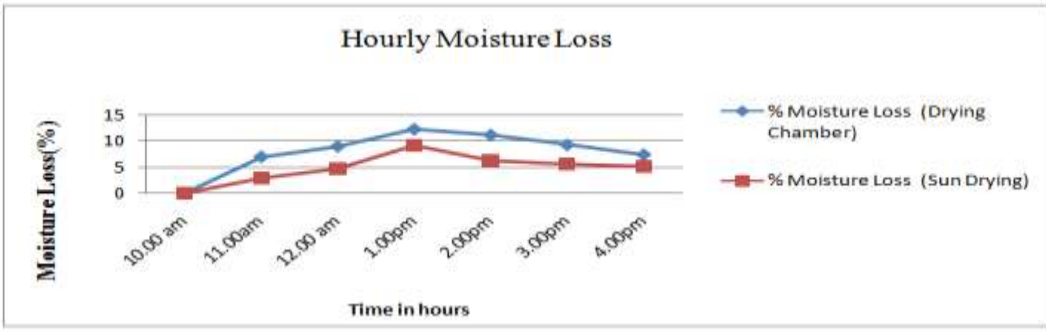


Figure 5.1.2 (xi)**Hourly Moisture Loss**

Fig.14: Hourly Moisture Loss in the drying chamber and open sun for grapes

Several workers have reported that solar drying is the most attractive method to preserve fruits and vegetables as it can eliminate wastage and improve the quality and quantity of the fruits and vegetables [4,5]. Different workers have compared the drying process of fruits and vegetables using natural convection solar dryer and forced convection dryer was found to be better in terms of drying rate [3,4,5].The present study also showed that the percentage of moisture loss and the mass of water removed in the forced convection indirect solar dryer were higher than the open sun drying methods for all the three agricultural products and this is due to increase of temperature inside the dryer by the use of collector to trap more solar energy. Present study also showed lower humidity inside the dryer than the ambient air humidity, which favours dying process without the deteriorating colour of the products.

IV. CONCLUSION

Drying of three agricultural products namely potato slices, onion slices and whole grapes was studied using a forced convection indirect solar dryer designed and fabricated indigenously using low cost materials and the drying process in terms of percentage of moisture loss and mass of water removed for all the three products was compared with open sun drying. The study showed that the indirect solar dryer is better than the open sun drying.

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