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Comparative Study between Solar Dryer and Open Sun dried Tomato under North Plateau Climatic Zone

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ABSTRACT

The solar dryer consists of transparent glass window, tray, solar photovoltaic fans and solar panel. The solar radiation passes through the transparent glass window, located on the top of the cabinet. The cabinet is made of anti-corrosive material and of modular nature to meet the varying sizes and loading capacities of food products, ranging from 7 to 8 kg .The ambient air enters from the bottom of the cabinet and gets heated up with solar radiation incident from the top window. The heat energy is trapped in the cabinet and heats up the air. The hot air passed through the trays, carries the moisture from the product to the space below the glass. Then it is exhausted by Solar Photovoltaic Fans. The forced circulation of air in the cabinet is achieved through this solar fan. Assessment of the dryer showed a raised temperature of about 47^0c attainable in the drying chamber. The dryer temperature and drying rate was found to be higher than the natural open sun drying method. The dryer was able to reduce moisture content of tomato from initial moisture content of 93 per cent wet basis to 4 per cent in three days with effective drying time of 24hr and drying rate of 0.03833 kg/hr, whereas the traditional sun drying was able to reduce moisture content of tomato from initial moisture content of 93 per cent wet basis to 4 per cent in five days with drying time of 34hr and drying rate of 0.0272 kg/hr . The results showed a considerable advantage of solar dryer over the traditional open sun drying method in term of drying rate and less risk for spoilage.

Key Words: Moisture, Solar dryer, Spoilage, Sun, Temperature, Tomato.

INTRODUCTION

Tomato is a climacteric fruit (Vishal kumar *et al,* 2015), having a short shelf-life under ambient storage conditions (Shahnawaz *et al,* 2012). Tomato is grown extensively throughout India for fresh consumption and commercial processing (Maini and Kaur, 2000; Prakash, 2000, Gupta *et al*, 2011). The marketing of fresh tomato during the season is a great problem because of its short post-harvest life, which leads to high post-harvest losses (Jayathunge *et al*, 2012). Tomatoes are highly perishable and large quantities of tomato fruits go as a waste due to poor storage facilities. It has been estimated that out of 74.41 lac tones of annual tomato production in the country, 25-30 per cent of tomato fruits get spoiled in India due to glut in the market and improper handling and storage conditions (Gupta *et al*,2011). Short post-harvest life and inadequate processing facilities result in heavy revenue loss. Therefore, it is advantageous to develop a preservation method for tomatoes. Tomatoes are processed in a range of products, such as concentrated juice and pulp, which needs high cost technology for good quality products. Therefore, development of low-cost processing methodologies to produce shelf-stable convenience products is the prime requirement of the present competitive market (Nadia Bashir *et al*, 2014).

Drying is the best and convenient technique among all the food preservation and processing methods, for product moisture content is greatly lowered which in turn helps to prevent the microbial degradation (Fellows, 2009). Among the drying techniques, open sun drying is a seasoned,

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simple (requires less technology), cost effective and familiar food preservation method used to reduce the moisture contents of all agricultural commodities (Durance and Wang, 2002). Nonetheless, the quality of products can be seriously tainted and occasionally rendered inedible in open sun drying because of the potential risk from environmental problems (rain, storm, windborne dirt, dust) and biological hazards (infestation by insects, rodents and other animals). Thus the resulting products may become inferior in their quality and bring adverse economic effects both in domestic and international markets (Lahsasni *et al*, 2004).

To enhance the quality and value of the dried foodstuffs, the conventional open sun drying method should be substituted with modern industrial drying methods such as solar and hot air drying. Solar drying can be considered as an elaboration of sun drying and is an efficient system of utilizing solar energy. The introduction of solar drying system seems to be one of the most promising alternatives to reduce post harvest losses. The solar dried products have better colour and texture as compared to open sun dried products. The justification for solar dryers is that they dry products rapidly, uniformly and hygienically, the traits inevitable for industrial food drying processes. Solar dryers with typically attained temperature of up to 60-70^0 are suitable for drying a variety of agricultural products (Adejumo and Bamgboye, 2004). The present study was undertaken to compare solar dryer with open sun drying for tomatoes.

MATERIALS AND METHODS

Description of solar dryer

The solar radiation passes through the transparent glass window, located on the top of the cabinet, which is oriented to south with a tilt equal to altitude to collect maximum solar radiation. The cabinet is made of anti-corrosive material and of modular nature to meet the varying sizes and loading capacities of food products, ranging from 7 to 8 kg. The ambient air enters from the bottom of the cabinet and gets heated up with solar radiation incident from the top window. The heat energy is trapped in the cabinet and heats up the air. As result the wavelength of solar radiation shifts to infrared region, causing green house effect. The hot air passed through the trays, carries the moisture from the product to the space below the glass and then it is exhausted by Solar Photovoltaic Fans. The forced circulation of air in the cabinet is achieved through this solar fan.

Specifications of solar dryer

Model	:	SDM – 8
Solar window	:	0.9 Sq.m approx
Drying area	:	0.7 Sq.m approx
Loading capacity (Max)	:	6-8 Kg
Solar panel	:	20 W
No. of fans	:	1
Physical dimensions	:	3.6'L X 2.7'W X 2'H
Construction material	:	M.s. square Pipe structured, G.I. Cabinet with stainless steel wire mesh trays, aluminium

Special features of this technology

The special features of these solar dryers are: the temperatures achieved in the cabinet are in the range of 40-65^{0}C on clear sunny days. The temperature difference between the ambient and inside cabinet is 10 to 15^{0}C on good sunny days. The moisture control in the product is achieved by the regulation of drying time, basing on the intensity of solar radiation. Closed or mesh trays are provided for easy loading and unloading of product. Solar PV fan for air circulation. A clean and hygienically prepared product, meeting the cleanliness specifications of ASTA of USA and other countries, is processed in these dryers. These dryers are modular and to scalability of the design to any size of demand.

Operation

The dryer is placed in the open space free from shade throughout the day. One kilogram of tomatoes in weight is collected with initial moisture content of 94 per cent is spread on the empty dryer to study the maximum obtainable temperature per day for three days in January, 2019. Secondly a known mass of tomato slices of 5 mm in thickness of 1 kg with initial moisture content of 93 per cent were spread on the dryer tray and equal amount of 1kg with same moisture content on the control open air *i.e.,* in open space free from shed throughout the day. Temperature of the sample was taken for moisture content determination in every one hour for three days @ 8hr/day. The weight of the samples were measured in every two hours from 9 AM to 5 PM every day till attains 4 per cent moisture content. The solar dryer was tested under a period of low temperature from 23 to 35^{0}C and humidity period of 60-88 per cent. The prevailing physical conditions, temperature, and relative humidity of the dryer and ambient conditions were monitored using thermometers and relative humidity sensors located at strategic points within the solar collectors/heat storage unit and drying chamber. A similar quantity and size of tomatoes was spread outside using the traditional open-air sun drying method as a control. The moisture content of the sample was determined from weights of samples before and after drying by an oven at 80 per cent wet basis. The loss on product weight is assumed to be equivalent to product moisture loss during drying.

The dryer's performance parameters were evaluated from the testing results using Equation (1) and Equation (2) below.

Amount of moisture to be removed: $Ww = Wg \frac{(Mi - Mf)}{100 - Mf}$.....(1)

Tomato drying rate: Wdr = $\frac{Ww}{Td}$ .... (2)

where, *Ww* = Amount of moisture removed, kg; *Wg* = Initial mass of wet tomato to be dried, kg; *Mi* = Initial ``moisture content, %; *Mf* = Final moisture content, %; *Wdr* = Average drying rate, kg h-1; *Td* = Total drying time, h.

RESULTS AND DISCUSSION

The result (Table 1) showed that a maximum temperature of about 49^o C is obtainable in empty chamber of solar dryer compared to maximum open air temperature of 38^{o}C and the temperature varied with the time of the day. The temperature obtained in this work was higher than the temperature range of 30-45^0 C for drying foods and fruits.

Table 1. Empty chamber temperature and open air temperature.

Time of the day	Day 1		Day 2		Day 3		Average	
	Solar Dryer	Open sun	Solar Dryer	Open sun	Solar Dryer	Open sun	Solar Dryer	Open sun
09.00	25	25	26	26	26	25	25.6	25.3
10.00	33	27	31	28	31	27	31.6	27.3
11.00	35	28	35	29	36	30	35.3	29
12.00	37	30	38	32	39	33	38	31.6
13-00	39	32	41	35	42	35	40.6	34
14.00	49	38	48	37	48	38	48.3	37.6
15.00	42	35	45	38	44	38	43.6	37
16.00	41	34	42	35	41	34	41.3	34.3
17.00	37	29	38	30	38	30	37.6	29.6

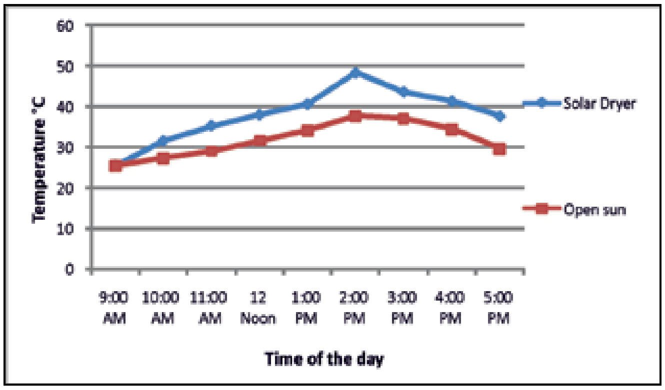

Fig 1. Temperature curve for solar dryer empty chamber and open air

Figure 1 showed the obtained temperature profile for empty chamber similar to those obtained by Adejumo and Bamgboye (2004) with high average temperature of about 49^{o} C.

The data (Table 2) showed that the final moisture content of tomato at the end of the three days is lower in the solar dryer than that in the open air. This was because of the raised chamber temperature and relative humidity of the open air. The dryer was found to dry the products to safe storage moisture content of 4 per cent for long period in three days drying which is not obtainable in the open air sun drying in three days. The dryer was able to reduce moisture content of tomato from initial moisture content of 93 per cent wet basis to 4 per cent in three days with effective drying time of 24 h and drying rate of 0.03833 kg/hrwhereas the traditional sun drying was able to reduce moisture content of tomato from initial moisture content of 93 per cent wet basis to 4 percent in five days with drying time of 34 hr and drying rate of 0.0272 kg/ hr.

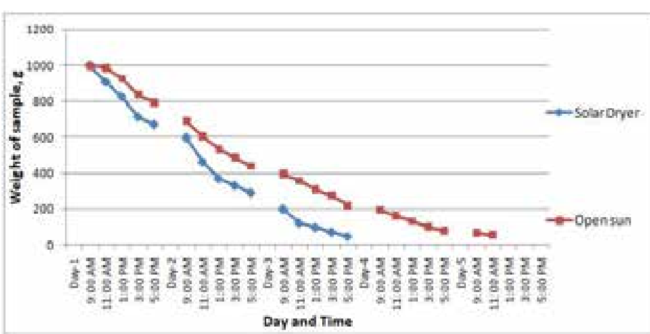

Fig 2 Weight reduction curve for tomato

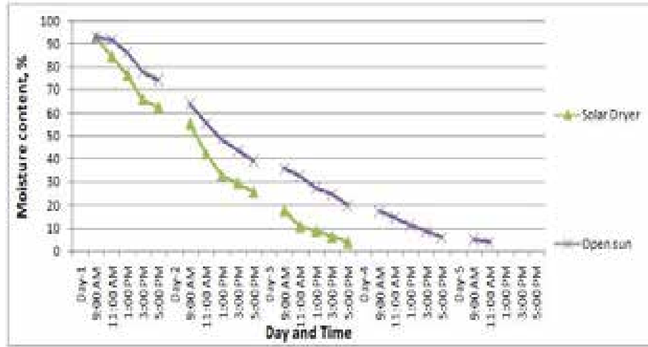

Fig 3 Drying curve for solar dryer and open air

Figure 2 and 3 showed the pattern of weight reduction and drying curve in both solar dryer and open air during drying of tomato slices. Extra 10 hr or nearly additional 2d were required to attain desirable moisture content of tomato slices for safe storage and use. Weight reduction was also at faster rate in solar dryer in comparison to open air as visualised in figure 2. The open air tray was slower in drying than that of the solar dryer (Adejumo and Bamgboye, 2004).

Despite the fact that the dryer evaluation was carried out in January under low temperature of 25-38^{0} C and a high mean relative humidity of 80–90 per cent , which covers a period of crop harvest and processing, the dryer attained a higher temperature range of 25-49^{0} C.

The solar dryer resulted in the shortest drying time to meet desired moisture content of tomato slices (4% wet basis), which corresponds to the highest drying rate comparing to open drying method. Although the initial investment of dryer was higher the overall drying efficiency was more than two times higher in case of solar dryer compared to open drying.

The greatest moisture reduction was observed to have occurred between 11.00 to 15.00 PM daily when the solar intensity and collector drying air temperature was the greatest. The samples dried in the solar dryer were clean and of high quality with no contamination through dust or insect and did not change colour while those under open air sun drying showed changes in colour indicating signs

Table 2. Solar dryer performance continues drying at 08 hr/day.

Time	Weight of sample/g		Moisture content (WB)/%	
	Solar Dryer	Open sun	Solar Dryer	Open sun
Day-1				
9	1000	1000	93	93
11	908	987	84.5	91.8
13	826	927	76.7	86.3
15	712	838	66	77.8
17	671	795	62.5	74.3
Day-2				
9	597	690	55.4	64
11	462	604	42.2	55.5
13	368	533	33	48.6
15	330	485	29.5	43.7
17	290	438	25.6	39.3
Day-3				
9	198	395	17.8	36
11	120	358	10.8	32.5
13	96	308	8.9	27.5
15	70	276	6.4	24.6
17	45	220	4	19.8
Day-4				
9		193		17.3
11		160		14.5
13		130		11.4
15		98		8.5
17		76		6.1
Day-5				
9		65		5.2
11		52		4

of deterioration in quality. It was concluded that the solar dryer increased the drying rate significantly. Hence, solar drier was found to be technically and economically suitable for drying of tomatoes under the specific conditions.

CONCLUSION

The result of the performance evaluation showed that the solar dryer dried faster than the natural open sun drying method with drying chamber temperature of up to 49^{0}c. The solar energy can be harnessed and used to dry tomatoes especially during crop harvest. Tomatoes dried under the solar dryer gives high quality products and 50 per cent time savings than open air sun drying. The results showed a considerable advantage of solar dryer over the traditional open sun drying method in term of drying rate and less risk for spoilage.

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