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PERFORMANCE EVALUATION OF A SOLAR DRYER FOR SAPOTA DRYING

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ABSTRACT

The performance of natural convection solar dryer was evaluated for sapota drying at 1 kg/m^2 area and compared with open sun drying. Sapota was sliced in 5mm pieces and dipped in 1% potassium meta-bisulphate for 10 minutes to retain its color. The results indicated that the moisture reduced from 78 % (w.b) to 7.9% (w.b) and the drying time for 1kg loading rates was observed to be as 23 h for solar drying and 35 h for open sun drying. The relationships between various drying parameters were studied. The total sugar of fresh fruit was increased from 18% to 32.10% solar dried fruit and 30.17% in open sun dried fruit, whereas the protein content of fresh sapota was reduced from 10.25% in fresh fruits to 8.68% and 6.55% in solar dried and the open sun dried fruit respectively.

Keywords: Natural convection solar dryer, Sapota drying.

1. INTRODUCTION

India produced 213 million tones of fruits and vegetables in year 2011 (NHB 2011). Most of the fruits and vegetables are perishable in nature due to availability of higher amount of water in the fruits and vegetables. The higher amount of water increases in water activity in turn deterioration in short soon of time. The way of increasing shelf life is by removing moisture of the commodity to the safe level. This can be achieved by using drying or dehydration techniques. There are several mechanical drying systems available for drying of fruits and vegetables. The mechanical drying system is an energy intensive operation. The solar drying system is an alternative to the mechanical drying system. The open sun drying has its own disadvantages i.e. the product is exposed to the dust, birds, rodents, insects etc. The other limitations of open sun drying is that in case of non seasonal rain or clouds, the drying may be effected. The exposure of food materials to the dirt, dust, rodents etc. is non hygienic too. Therefore the solar dryer can enhance and protect the fruits to be dried as well as it can save the conventional sources of energy. Keeping in mind the importance of fruits in general and sapota is particular, a study has been undertaken on natural convection solar dryer.

2. MATERIALS AND METHODS

The natural convection solar dryer (laboratory model) with capacity of 1 kg of sapota per batch had been used for the study.

2.1 Construction of the dryer

A flat plate solar collector was used in the dryer (Fig. 1 and 2). The solar collector has special black synthetic enamel coated aluminium sheet. The drying chamber is provided with chimney, PVC pipe as a connector, glass cover, insulation, etc. an air duct provided beneath the solar absorber sheet is prepared of aluminium sheet. The air is passed through this duct. The heated air at collector is conveyed to the drying chamber through a flexible connection. The whole unit was placed on G.I. angle frame. An insulation of glass wool (10mm thick) had been provided to the drying chamber to avoid heat loss. The chamber has been covered with a glass with 5 mm thickness.

The inner most layer of the drying chamber is made up of aluminium sheet which then covered glass wool whereas the outer most layers are of G.I. sheet. The drying chamber is provided with two aluminum trays kept one above another with 0.15 m vertical distance. The whole unit s placed in a chamber prepared of G.I. sheet. A door to the unit has been provided with proper insulation and sealing arrangement. The chimney had been with 0.1m diameter and 1m height which conveyed the air.

2.2 The Instrumentation used

The temperature and relative humidity were measured by a multi thermometer (ST-9283B). The solar intensity had been measured with help of solar meter (JASEE MR-66). To measure the outgoing air temperature and relative humidity a hygro- thermometer (3302) used. The wind speed measured device was hot wire anemometer (TECPEL-714) and an electronic platform was used for measuring weight.

2.3 Sample preparation

The sapota of Kalipatti variety had been selected for the experiment. The sapotas were washed before starting the experiment then the peeling was performed to remove the skin. Then the peeled sample had been cut into pieces of size ranging from 3mm- 5 mm thickness. The treatment with potassium metabisulphate had been given to the slices before keeping for the drying.

2.4 Quality analysis of dried sapota

Bio-chemical content which included protein contents of dried sapota were determined by standard methods (Micro kjeldhal method).

2.5 Protein content

Protein content was estimated by formula given by Guruswami et al., 2002. One gram of dried sample was for which three ml of 25% KMnO4 was added. To this solution 10ml to 15 ml of diacid (H2SO4: HClO3 = 5:2) was added. Then the digestion process was carried out in a KJEL plus digester apparatus by adding 20ml to 50 ml of 40% NaOH in a KJEL plus unit and the distilled sample was titrated against 0.1 NH_2SO4. The procedure was repeated thrice for each sample and the crude protein content of dried sapota was calculated using the following formula:

Nitrogen content, % = (TV × 0.014 × 0.1 × 100) / w

Where,

TV = titrated volume, ml

W = weight of sample, gm

Crude protein content, % = Nitrogen content × 6.25

2.6 Total sugar

Total sugar was estimated by the anthrone method. In this 10g of ground sample is mixed with 50 ml of distilled water and incubated for 30 minutes at 500C in a water bath to extract the sugars. 1 ml of the extract is diluted 100 folds with distilled water to obtain a uniform solution. 0.1 ml of the solution is taken in a test tube; volume made up to 1ml with 0.9 ml of distilled water and cooled in ice bath. 5ml anthrone is added from a wide mouthed pipette from the side of the tube at fast speed along with along with stirring of tube in ice bath. The sample should not show any turbidity or development of green color during addition of the reagent. The tube is then kept in boiling water bath for 10 minutes. After cooling, absorbance of the greenish color developed is measured at 625 nm using glucose as the standard. The procedure was repeated thrice for each sample and the reducing sugar content of wet and dried sapota was calculated using the following formula:

Glucose content (g/100g dry weight) = (glucose (µg/ml) x dilution factor x 100)/

(10^6 x dry weight of sample)

3. RESULTS & DISCUSSION

The experiment was carried out in the premises of Solar Energy Lab, Division of Agricultural Engineering at Indian Agricultural Research Institute, New Delhi during 2010-2011, which lies at latitude 28.63^{o}N and longitude 77.2^{o}E. The solar radiations measured during experiment ranged from 400 W/m^2 to 1200 W/m^2. The maximum insolation of 1200 W/m^2 was observed at 12.00 of the day. This can be attributed to higher incidence of solar radiations at noon hours.

The relationship between moisture content (% db) and drying time is presented in Fig. 3 for solar drying and open sun drying, from that it was apparent that moisture content decreased continuously with drying time. In this curve, there is no constant rate period but the falling rate period is seen to occur. Thereafter the removal of moisture from 355% db to 8.58% db in case of solar drying was in the falling rate period and the total drying time was approximately 23 h while 355% to 8.7% moisture removed in case of open sun drying was in the falling rate period and the total drying time was approximately 35 h. Guruswami et al., (2002) concluded that the solar dryer helps in reducing the drying time nearly 34 % over conventional open sun drying.

The drying rate curve for the solar drier and open sun drying is shown in Fig.4. From this it can be seen that at the start of the phase, the drying rate decreases very quickly. The drying rate became zero at 16 hours in solar drying while in case of open sun drying it took 26 hours. The evaporation zone is now inside the product. From each side of the evaporation zone, there are different methods of transport. Upstream, in the centre of the product, there is always migration of free water by capillarity and the temperature of the product is always equal to hygroscopic temperature. At the Downstream, the migration is due to the diffusion phenomena (vapour) or diffusion-sorption (water dependent) and there is increasing temperature in this zone. Water does not exist anymore but in dependent form and in vapour form. The drying rate decreases very slowly and tends towards zero. This value is reached when the moisture content balance of the surfaces in contact with air is obtained. This is related to the drying conditions which are given by the desorption isotherms. These results are in good agreement with those of Ayensu (1997. So, it can be said that the drying rate makes possible to see that the upstream phase of deceleration is very fast and short. It is in fact a transition zone. On the other hand, the downstream phase of the drying process is very long. This can be explained by the fact that low moisture contents, close to moisture content balance, must be reached. For a safe storage of harvests products of a relative humidity of 80–90%, Ayensu (1997) recommends moisture content balance Me ≤ 14%. The value in this study is 8 % to 9 %.

The relationship between moisture ratio and drying time for solar drying and open sun drying is presented in Fig.5. It showed that moisture ratio decreases continuously with drying time. In this curve, there was no constant rate period but falling rate period was seen. The moisture ratio became zero in solar drying at 20 hours while that in case of open sun drying it took 35 hours. This could be due to diffusion is the dominant physical mechanism governing moisture movement in the sample in solar drying than that of open sun drying. Similar results were obtained by different authors on drying of different fruits (Kadam and Samuel, 2006).

Protein content and total sugars of wet and dried sapota samples are shown in Table.1 which was estimated by the anthrone method. It was observed that proteins in wet, solar dried and open sun dried sapota were 10.23%, 8.68% and 6.55% respectively. While the total sugars were 18.5, 32.10 and 30.17% for wet, solar dried and sun dried sapota respectively. These results are in good agreement with those of Guruswami et al., (2002). The per cent increase in the total sugars in solar died and open dried sample as compared to initial sapota were in the range of 163% to 173% which may be due to the reduction in moisture content of the dried fruits.

The quadratic regression model has been fitted for moisture content, drying rate and moisture ratio with time points for solar dried and open sun dried sapota. The obtained ANOVA have been shown in Table.2 to Table.7. The Anova shown in Table 2 indicates that the F value (calculated= 41.2) is greater than that of the F value (Tabulated=3.49). It means that both, the moisture content and the time of drying affected significantly the process of moisture removal in the solar dryer. While the Anova of the Table 3 indicates that the F value (calculated= 22.1) is greater than that of the F value (Tabulated=3.49). This indicates that both, the drying rate and the time of drying affected significantly the process of moisture removal in the dryer. Whereas the Anova of

the Table 4 indicates that the F value (calculated= 41) is greater than that of the F value (Tabulated=3.49). It reveals that, the moisture ratio and the time of drying affected significantly the process of moisture removal in the dryer. The Anova of the Table 5 indicates that the F value (calculated= 53) is greater than that of the F value (Tabulated=3.30). It suggests that the moisture content and the time of drying both are affecting significantly the process of moisture removal in the sun drying. The figures in the Table 6 indicates that the calculated F value (calculated= 40) is greater than that of the F value (Tabulated=3.30). It showed that both, the drying rate and the time of drying affected significantly the process of moisture removal in the sun drying. While the Anova of the Table 7 indicates that the F value (calculated= 55) is greater than that of the F value (Tabulated=3.30). The significance of the value is that, the moisture ratio and the time of drying affected significantly the process of moisture removal in the sun drying.

4. CONCLUSION

On the basis of the study, it was found that the natural convection solar drying significantly reduced peeled sapota drying time by 32% as compared to open sun drying similarly it was also found that the total sugar varied from 18% in fresh fruits to 32.10% in case of solar dried fruit and 30.17% in open sun dried fruit. It was observed that the protein content of sapota was 8.68% in solar drying and 6.55% in open sun drying which were reduced from 10.25% in fresh fruits.

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Table 1: Protein content estimated for Wet, Solar dried and Open sun dried sapota

Treatment	Replications	Protein content (%)	Concentration of glucose (g/100 g)
Wet Sapota	R1	10.23	18.3
	R2	10.25	18.5
	R3	10.28	18.7
Solar dried Sapota	R1	8.70	32.09
	R2	8.68	32.10
	R3	8.65	32.11
Open sun dried Sapota	R1	6.60	30.15
	R2	6.55	30.17
	R3	6.50	30.19

Table 2: ANOVA for moisture content with time points of solar dried Sapota

SV	df	SS	MS	F	Regression equation
Regression	2	117	58856.0	41.2	
Error	21	299	1427.97		$260.4-32.92t + 0.99t^2$
Total	23	147			

Table 3: ANOVA for drying rate with time points of solar dried Sapota

SV	df	SS	MS	F	Regression equation
Regression	2	1.66	0.83	22.1	
Error	21	0.79	0.03		$0.94- 0.13t + 0.004t^2$
Total	23	2.46			

Table 4: ANOVA for moisture ratio with time points of solar dried Sapota

SV	df	SS	MS	F	Regression equation
Regression	2	0.98	0.49	41	
Error	21	0.25	0.01		$0.73 -0.09t + 0.0029t^2$
Total	23	1.23			

Table 5: ANOVA for moisture content with time points of open sun dried Sapota

SV	df	SS	MS	F	Regression equation
Regression	2	149	746	53	
Error	33	460	139		$234- 20.43 + 0.42t^2$
Total	35	195			

Table 6: ANOVA for drying rate with time points of open sun dried Sapota

SV	df	SS	MS	F	Regression equation
Regression	2	1.1	0.58	40	
Error	33	0.47	0.01		$0.63- 0.05t + 0.001t^2$
Total	35	1.64			

Table 7: ANOVA for moisture ratio with time points of open sun dried Sapota

SV	df	SS	MS	F	Regression equation
Regression	2	1.2	0.64	55	
Error	33	0.38	0.01		$0.66 – 0.06 + 0.0012t^2$
Total	35	1.6			

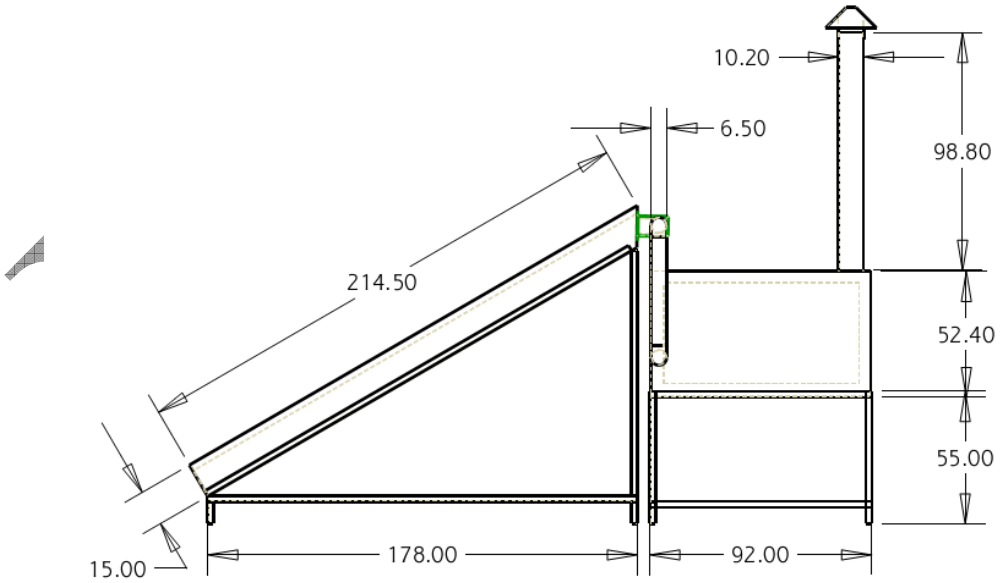

Fig 1: Natural convection solar dryer (Side view)

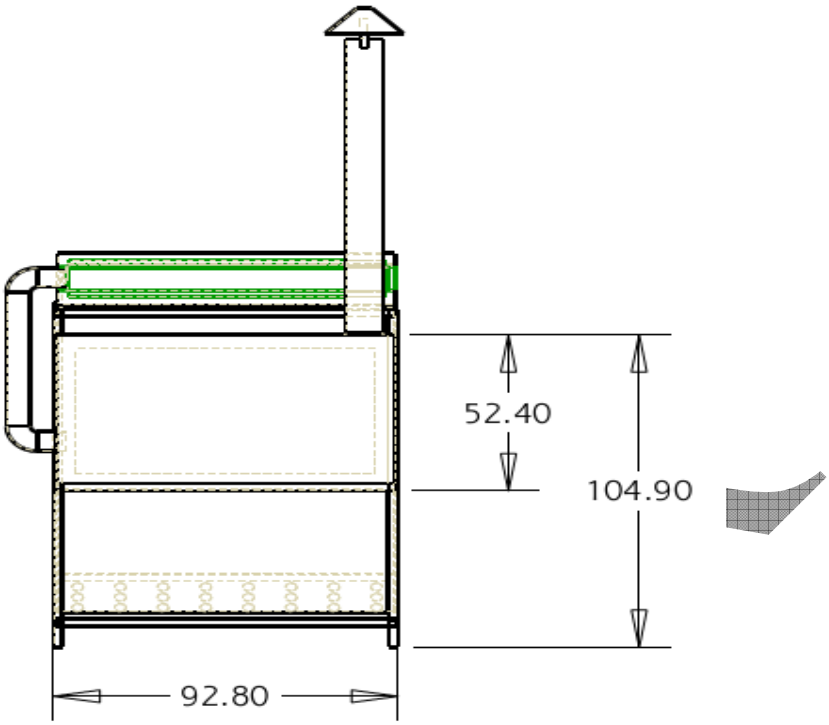

Fig 2: Natural convection solar dryer (Front view)

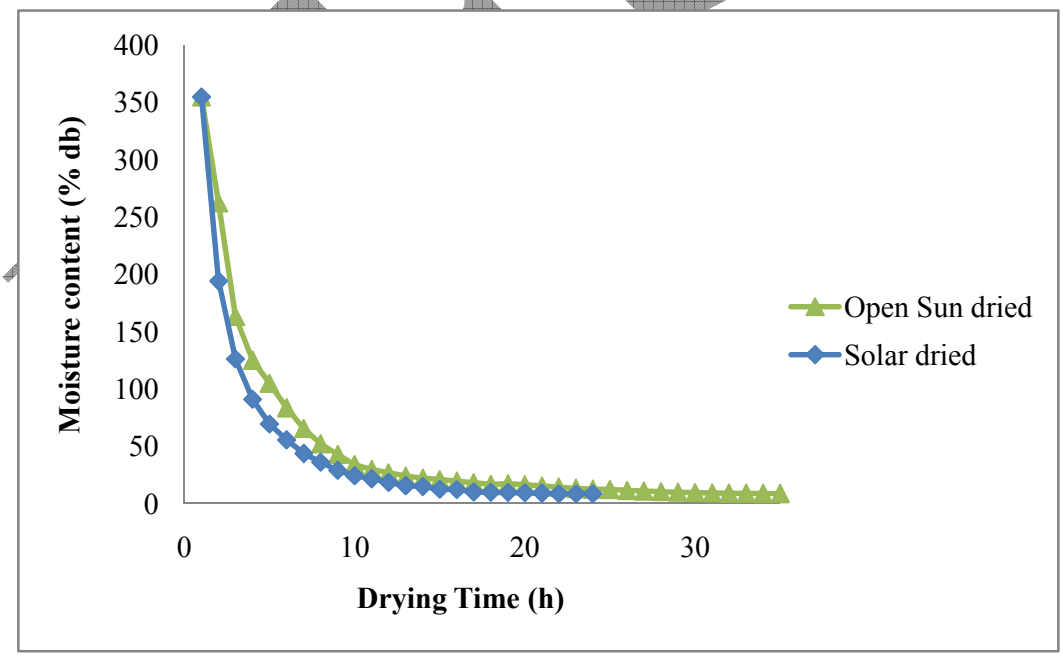

Fig 3: Moisture content versus drying time of solar dried and open sun dried Sapota

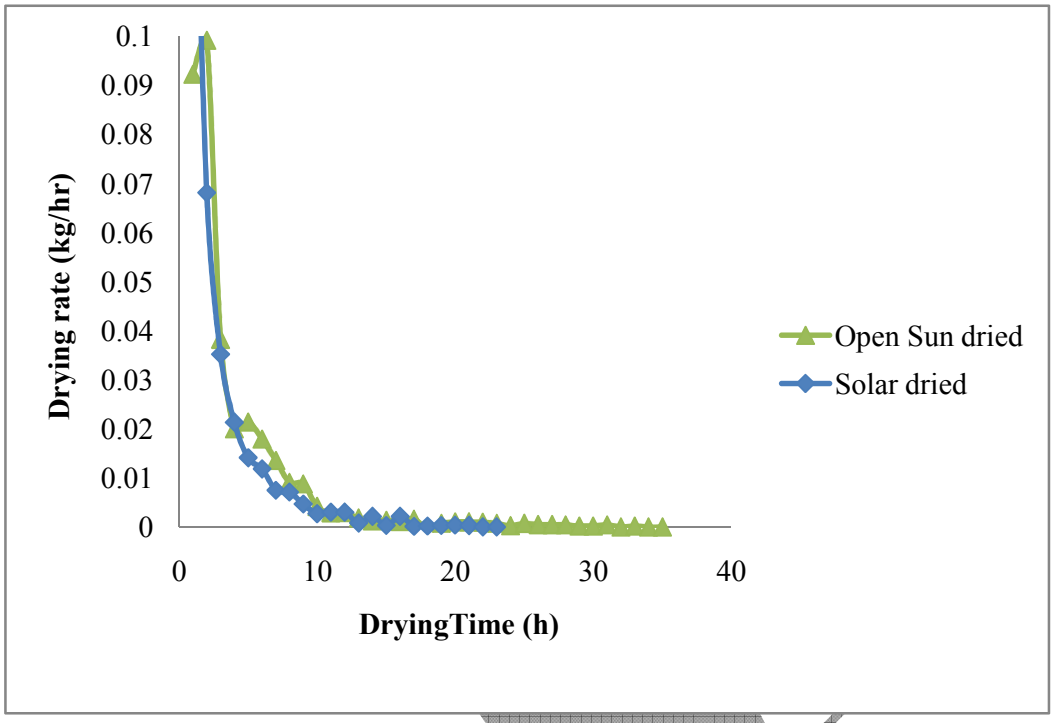

Fig 4: Drying rate versus drying time of solar dried and open sun dried Sapota

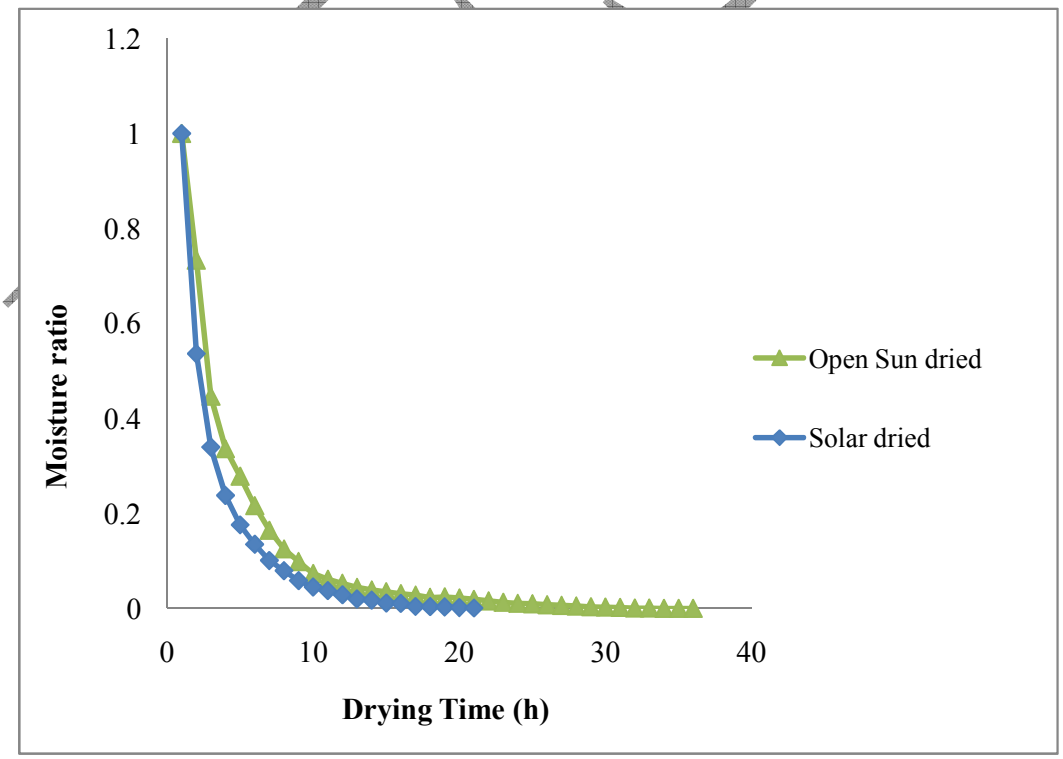

Fig 5: Moisture ratio versus drying time of solar dried and open sun dried Sapota

