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# Evaluation of PAU Domestic Solar Dryer

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**A solar dryer (PAU domestic model) was evaluated with sapota, chilli and bitter-gourd. It is a natural convection type with a capacity of 15 kg (Aperture area - 0.36 m², No. of trays -3, 620(w) x 620(l) x 350(h) mm and weight 17 kg). Sapota, chilli and bitter- gourd were dried and comparison was made on moisture content, drying time and drying efficiency. Results show an initial moisture contents of the three products with 74.0, 56.0 and 89.0 per cent reduced to 6.10-6.50 percent in 19, 27 and 16 hours on an average global radiation plane of solar collector 550 W/m², 580 W/m² and 580 W/m² respectively. Over all efficiency of the system while drying the sapota, chilli and bitter-gourd was found to be 25, 28 and 26 per cent respectively. Solar dried food produce will fetch higher value due to its quality compared to traditionally (open sun) dried produce**

**Key words:** Domestic solar dryer, sapota, chilli, bitter-gourd, moisture content, drying time

Drying is one of the important post harvest operations, required for agricultural commodities in farm and house hold level. Reduction of moisture to the desired level is an essential function of the drying operation. Based on the needs of drying of agricultural farm products in house hold level smaller size driers are commonly used. Drying of sapota, chilli and bitter-gourd needs low temperatures and products can be dried even at home. The expected low temperature is obtained by employing various solar energy gadgets. Available large numbers of solar dryers like direct, indirect and natural circulation and forced circulation have been reviewed by (Ekechukwa and Worton 1999). Drying of different types of food products by different dryers has been reported by (Prakash, *et al.,* 2004), (Forson, *et al.,* 2003), (Panagavhane, *et al.,* 2002), (Condori, *et al.,* 2001), (Negi and Roy 2001) and (Ahmad, *et al.,* 1996). Based on different types of dryers, Punjab Agricultural University (PAU) has developed a natural convection type domestic level solar dryer for house hold level to dry of agricultural produces. Hence, the present work was undertaken to evaluate drying performance of the PAU natural convection type domestic solar dryer with sapota, chilli and bitter-gourd.

## Materials and Methods

The performance trails were carried out for the PAU domestic solar dryer (Fig. 1) at laboratory and field conditions. The specification of the dryer is as follows:

| | |
|---|---|
| Capacity | : 15 kg |
| Aperture area | : 0.36 m² |
| No. of trays | : 3 |
| Overall dimensions of dryer | : 620 x 620 x 350 mm |
| Weight of the dryer | : 17 kg |
| Inclination of the dryer | : Fixed / variable |

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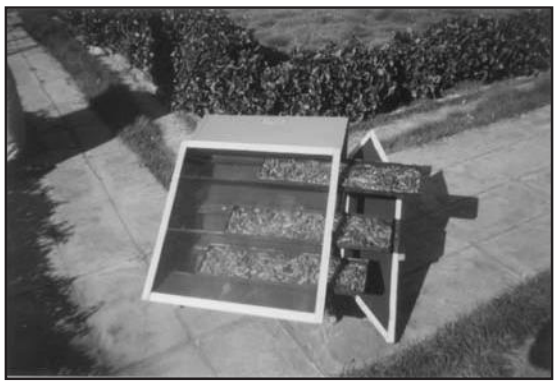

**Fig.1. View of PAU domestic solar dryer**

Three different horticultural products *viz*. sapota, chilli and bitter-gourd were selected for the evaluation. Fresh product of 1 kg (depending on density of the product) was loaded in batch mode.

### *Sapota*

The fully matured cricket ball variety of sapota fruits were cleaned and sliced before spreading over the trays of the dryers.

### *Chilli*

The fully matured, bright shiny red Chilli of variety “Nylon” was used for the study. Unripe Chillies and foreign materials were removed and spread over the trays of dryers.

***Bitter-gourd***

The fully matured bitter-gourd of 'CO1' variety was blanched for 7 min. and suspiring with 0.1 per cent KMS for 5 min. The blanched bitter-gourds were spread over the trays of the dryers.

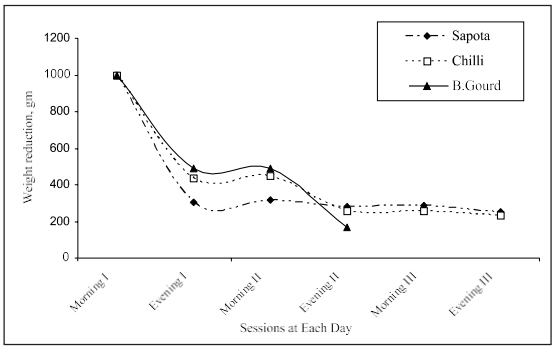


**Fig. 2. Weight reduction during drying in PAU domestic solar dryer**

**Results and Discussion**

***Performance evaluation of PAU domestic solar dryer***

The PAU domestic solar were loaded with selected products of 1 kg each. The tests were carried out under sunny condition with no load and full load.

**Table 1. Temperature and RH variation in PAU domestic solar dryer at no load test**

| Time | Solar intensity ($W/m^2$) | Ambient Temp. (°C) | Atmo spheric RH (%) | RH(%) inside the dryer | Temperature inside the dryer (°C) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Tray1 | Tray2 | Tray 3 |
| 10:00 | 648 | 29.0 | 49.9 | 42.4 | 33.4 | 32.6 | 32.4 |
| 11:00 | 738 | 30.1 | 33.3 | 34.3 | 41.6 | 41.2 | 37.4 |
| 12:00 | 868 | 30.1 | 29.4 | 45.8 | 49.5 | 46.3 | 55.2 |
| 13:00 | 891 | 31.2 | 34.6 | 35. | 37.4 | 45.5 | 51.2 |
| 14:00 | 850 | 32.0 | 35.0 | 35.2 | 37.4 | 42.0 | 45.2 |
| 15:00 | 848 | 36.8 | 34.4 | 30.5 | 41.5 | 40.6 | 39.4 |
| 16:00 | 838 | 31.5 | 41.1 | 35.5 | 36.6 | 36.4 | 35.0 |
| 17:00 | 766 | 30.6 | 43.7 | 41.5 | 31.6 | 32.4 | 33.9 |

***No load test***

No load experiments were conducted with a view to find out temperature profile at different trays in the dryer at sunny day. The results are presented in the table1. It was observed from the table, the maximum temperature attained in the PAU domestic solar dryer in sunny day at no load test was 55.2°C at 1:00 PM in the top tray. The minimum RH of 30.2 per cent was observed at 2:00 PM in the top tray. The ambient temperature varied from 29.0-36.0°C during the drying test period.

**Table 2. Temperature profile of PAU domestic solar dryer with sapota fruit after first day of drying**

| Time | Solar intensity ($W/m^2$) | Ambient Temp. (°C) | Atmo spheric RH (%) | RH(%) inside the dryer | Temperature inside the dryer (°C) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Tray1 | Tray2 | Tray 3 |
| 10:00 | 589 | 30.2 | 44.0 | 53.0 | 32.0 | 32.6 | 34.0 |
| 11:00 | 686 | 30.2 | 44.1 | 53.6 | 32.4 | 34.0 | 36.0 |
| 12:00 | 857 | 31.8 | 38.0 | 47.6 | 40.0 | 43.0 | 46.0 |
| 13:00 | 860 | 32.0 | 41.3 | 52.3 | 44.0 | 48.0 | 51.0 |
| 14:00 | 889 | 35.8 | 36.6 | 38.0 | 51.0 | 66.0 | 76.0 |
| 15:00 | 879 | 34.8 | 35.4 | 36.3 | 50.0 | 68.0 | 70.0 |
| 16:00 | 790 | 33.0 | 40.3 | 42.3 | 43.0 | 55.0 | 62.0 |
| 17:00 | 758 | 33.0 | 40.9 | 41.9 | 42.5 | 55.3 | 62.3 |

**Table 3. Temperature profile of PAU domestic solar dryer with sapota fruit after second day of drying**

| Time | Solar intensity ($W/m^2$) | Ambient Temp. (°C) | Atmo spheric RH (%) | RH(%) inside the dryer | Temperature inside the dryer (°C) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Tray1 | Tray2 | Tray 3 |
| 10:00 | 540 | 28.9 | 58.3 | 52.8 | 48.0 | 61.0 | 63.0 |
| 11:00 | 671 | 30.0 | 60.3 | 57.2 | 40.0 | 49.0 | 53.0 |
| 12:00 | 698 | 32.0 | 50.8 | 54.0 | 60.0 | 62.0 | 65.0 |
| 13:00 | 824 | 33.0 | 50.4 | 52.0 | 50.0 | 60.0 | 60.0 |
| 14:00 | 769 | 32.1 | 48.3 | 68.8 | 54.0 | 66.0 | 73.0 |
| 15:00 | 908 | 38.0 | 32.0 | 49.0 | 50.0 | 61.0 | 72.0 |
| 16:00 | 780 | 32.5 | 38.2 | 39.2 | 47.0 | 65.0 | 70.0 |
| 17:00 | 586 | 32.0 | 38.0 | 40.4 | 46.5 | 64.3 | 70.5 |

**Table 4. Temperature profile of PAU domestic solar dryer with sapota fruit after third day of drying**

| Time | Solar intensity ($W/m^2$) | Ambient Temp. (°C) | Atmo spheric RH (%) | RH(%) inside the dryer | Temperature inside the dryer (°C) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Tray1 | Tray2 | Tray 3 |
| 10:00 | 497 | 28.2 | 66.1 | 62.0 | 29.0 | 31.0 | 32.0 |
| 11:00 | 680 | 31.1 | 62.0 | 54.8 | 38.0 | 41.6 | 42.0 |
| 12:00 | 809 | 31.6 | 54.8 | 48.4 | 39.0 | 47.0 | 48.0 |
| 13:00 | 823 | 33.2 | 48.4 | 52.0 | 44.6 | 50.2 | 56.4 |
| 14:00 | 756 | 33.6 | 44.5 | 68.8 | 42.0 | 52.0 | 59.0 |
| 15:00 | 765 | 32.9 | 40.6 | 49.0 | 47.0 | 55.0 | 62.0 |
| 16:00 | 769 | 33.4 | 40.9 | 39.2 | 44.0 | 56.4 | 66.2 |
| 17:00 | 552 | 33.0 | 39.2 | 40.4 | 45.0 | 60.0 | 68.0 |

***Load test***

***Sapota***

The sliced sapota fruits of initial moisture content of 73.7 %.were spreaded over the trays. The ambient temperature, atmospheric RH, RH inside the dryer and temperature inside at different trays were measured and presented in the table 2, 3 and 4.

**Table. 5. Temperature profile of PAU domestic solar dryer with chilli after first day of drying**

| Time | Solar intensity ($W/m^2$) | Ambient Temp. (°C) | Atmo spheric RH (%) | RH(%) inside the dryer | Temperature inside the dryer (°C) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Tray1 | Tray2 | Tray 3 |
| 10:00 | 651 | 32.0 | 45.0 | 57.0 | 34.0 | 35.0 | 36.0 |
| 11:00 | 756 | 33.6 | 46.0 | 58.0 | 35.8 | 36.6 | 61.0 |
| 12:00 | 740 | 32.0 | 44.5 | 53.0 | 50.0 | 61.0 | 62.0 |
| 13:00 | 759 | 32.9 | 45.3 | 52.0 | 52.0 | 68.0 | 69.0 |
| 14:00 | 679 | 31.2 | 41.5 | 56.3 | 45.0 | 68.0 | 52.0 |
| 15:00 | 800 | 33.0 | 38.5 | 46.0 | 48.0 | 51.0 | 54.0 |
| 16:00 | 835 | 33.5 | 38.4 | 48.0 | 44.0 | 53.0 | 46.0 |
| 17:00 | 709 | 32.0 | 38.2 | 45.4 | 45.5 | 46.0 | 45.5 |

**Table 6. Temperature profile of PAU domestic solar dryer with chilli after second day of drying**

| Time | Solar intensity ($W/m^2$) | Ambient Temp. (°C) | Atmo spheric RH (%) | RH(%) inside the dryer | Temperature inside the dryer (°C) Tray1 | Tray2 | Tray 3 |
|---|---|---|---|---|---|---|---|
| 10:00 | 534 | 30.7 | 52.5 | 57.4 | 33.1 | 33.2 | 33.4 |
| 11:00 | 635 | 31.3 | 49.6 | 58.0 | 40.0 | 46.0 | 45.0 |
| 12:00 | 678 | 32.0 | 45.2 | 60.3 | 37.0 | 43.5 | 44.0 |
| 13:00 | 609 | 30.1 | 47.2 | 55.0 | 43.0 | 50.0 | 51.0 |
| 14:00 | 835 | 33.5 | 43.2 | 52.3 | 40.0 | 47.0 | 48.0 |
| 15:00 | 830 | 32.4 | 38.7 | 50.4 | 40.0 | 47.0 | 46.0 |
| 16:00 | 756 | 31.8 | 37.3 | 61.6 | 44.0 | 43.0 | 41.0 |
| 17:00 | 680 | 32.0 | 37.0 | 60.9 | 41.0 | 46.0 | 46.0 |

During the first day of drying of sapoto, it was observed that the maximum temperature of 76°C at 2:00 PM. The ambient temperature, atmospheric

**Table 7. Temperature profile of PAU domestic solar dryer with chilli after third day of drying**

| Time | Solar intensity ($W/m^2$) | Ambient Temp. (°C) | Atmo spheric RH (%) | RH(%) inside the dryer | Temperature inside the dryer (°C) Tray1 | Tray2 | Tray 3 |
|---|---|---|---|---|---|---|---|
| 10:00 | 489 | 26.4 | 55.4 | 62.7 | 34.0 | 36.0 | 30.0 |
| 11:00 | 547 | 27.5 | 53.9 | 66.9 | 33.0 | 37.0 | 30.0 |
| 12:00 | 702 | 30.5 | 48.5 | 41.7 | 40.0 | 45.0 | 40.1 |
| 13:00 | 874 | 34.0 | 35.8 | 42.3 | 38.0 | 40.0 | 41.0 |
| 14:00 | 820 | 33.2 | 37.4 | 56.3 | 40.0 | 46.0 | 46.0 |
| 15:00 | 857 | 34.0 | 36.2 | 60.4 | 58.0 | 58.0 | 59.0 |
| 16:00 | 725 | 31.9 | 40.5 | 61.0 | 46.0 | 49.0 | 50.0 |
| 17:00 | 745 | 31.6 | 40.2 | 61.0 | 45.0 | 48.0 | 49.0 |

Similar results were observed for second and third day of drying. The moisture content was reduced from 73.7 to 6 per cent at the end of drying operation with 19 hours of drying time.

**Table 8. Temperature profile of PAU domestic solar dryer with bitter-gourd first day of drying**

| Time | Solar intensity ($W/m^2$) | Ambient Temp. (°C) | Atmo spheric RH (%) | RH(%) inside the dryer | Temperature inside the dryer (°C) Tray1 | Tray2 | Tray 3 |
|---|---|---|---|---|---|---|---|
| 10:00 | 387 | 28.5 | 63.8 | 65.2 | 34.0 | 44.0 | 45.0 |
| 11:00 | 547 | 30.0 | 42.1 | 49.3 | 52.0 | 65.5 | 65.0 |
| 12:00 | 653 | 32.8 | 34.8 | 41.5 | 63.0 | 70.0 | 71.0 |
| 13:00 | 768 | 34.5 | 35.0 | 34.4 | 65.0 | 73.0 | 74.0 |
| 14:00 | 872 | 35.1 | 32.6 | 30.2 | 65.0 | 68.0 | 75.0 |
| 15:00 | 806 | 34.1 | 37.8 | 28.3 | 62.0 | 66.5 | 70.0 |
| 16:00 | 743 | 32.0 | 34.8 | 28.9 | 61.0 | 65.0 | 69.0 |
| 17:00 | 550 | 31.5 | 37.0 | 28.5 | 57.0 | 63.0 | 66.0 |

RH, RH inside the dryer and solar intensity were varied from 28.5 to33.5°C, 32.0 to 60.3 per cent, 39.2 to 68.8 per cent and 497-823 $W/m^2$, respectively.

**Table 9. Temperature profile of PAU domestic solar dryer with bitter gourd second day of drying**

| Time | Solar intensity ($W/m^2$) | Ambient Temp. (°C) | Atmo spheric RH (%) | RH(%) inside the dryer | Temperature inside the dryer (°C) Tray1 | Tray2 | Tray 3 |
|---|---|---|---|---|---|---|---|
| 10:00 | 458 | 26.7 | 53.8 | 61.2 | 34.0 | 47.0 | 47.0 |
| 11:00 | 608 | 30.2 | 34.3 | 33.3 | 50.0 | 67.0 | 65.0 |
| 12:00 | 786 | 33.8 | 37.8 | 36.5 | 62.0 | 74.0 | 74.0 |
| 13:00 | 842 | 34.2 | 32.8 | 31.4 | 67.0 | 73.0 | 78.0 |
| 14:00 | 734 | 32.8 | 33.6 | 32.2 | 64.0 | 66.0 | 67.0 |
| 15:00 | 758 | 32.2 | 39.3 | 28.3 | 60.0 | 67.0 | 68.0 |
| 16:00 | 798 | 34.3 | 28.7 | 27.7 | 61.0 | 69.0 | 70.0 |
| 17:00 | 680 | 34.2 | 28.0 | 27.5 | 56.0 | 65.0 | 66.0 |

***Chilli***

The chillies were spreaded over the trays with initial moisture content of 56 per cent. The ambient temperature, atmospheric RH, RH inside the dryer

**Table 10. Weight reduction during drying of sapota, chilli and bitter-gourd in PAU domestic solar dryer**

| Day | | Weight of the product in each tray (gm) Tray 1 (Bottom) | Tray 2 (Middle) | Tray 3 (Top) | Total weight of the product (gm) |
|---|---|---|---|---|---|
| Sapota | | | | | |
| First day | Morning | 333 | 333 | 334 | 1000 |
| | Evening | 108 | 100 | 96 | 304 |
| Second day | Morning | 114 | 103 | 100 | 317 |
| | Evening | 97 | 96 | 90 | 283 |
| Third day | Morning | 98 | 96 | 92 | 286 |
| | Evening | 85 | 83 | 83 | 251 |
| Chilli | | | | | |
| First day | Morning | 333 | 333 | 334 | 1000 |
| | Evening | 152 | 145 | 138 | 435 |
| Second day | Morning | 158 | 151 | 141 | 450 |
| | Evening | 89 | 84 | 81 | 254 |
| Third day | Morning | 90 | 84 | 82 | 256 |
| | Evening | 85 | 83 | 83 | 230 |
| Bitter-gourd | | | | | |
| First day | Morning | 333 | 333 | 334 | 1000 |
| | Evening | 165 | 162 | 160 | 487 |
| Second day | Morning | 168 | 162 | 161 | 491 |
| | Evening | 58 | 56 | 51 | 166 |

and temperature inside at different trays are presented in the table 5, 6 and 7.

During the first drying day of chillies, it was observed that the maximum dryer inside temperature as 69°C at 1:00 PM. The ambient temperature, atmospheric RH, RH inside the dryer and solar intensity were varied from 31.2 to 33.6°C, 38.2 to 46.0 per cent, 46.0 to 58.0 per cent and 651 to 835 W/m$^2$, respectively. Similar results were observed for second and third days of drying. The moisture content reduced from 56 to 10 per cent at the end of drying operation with 27 hours of drying time.

***Bitter-gourd***

The bitter-gourd was spreaded over the trays with initial moisture content of 89 per cent. The ambient temperature, atmospheric RH, RH inside the dryer and temperature inside at different trays are presented in the Table 8 and 9.

During the first drying of bitter-gourd, it was observed that the maximum temperature of dryer was 75°C at 2:00 PM. The ambient temperature, atmospheric RH, RH inside the dryer and Solar intensity were varied from 28.5 to 35.1°C, 34.8 to 63.8 per cent, 28.3 to 65.2 per cent and 387-872 W/m$^2$, respectively. Similar results were observed for second day of drying. The moisture was content reduced from 89 to 6.50 per cent at the end of drying operation with 16 hours of drying time.

***Drying time***

The weight reduction of sapota, chilli and bitter-gourd during morning and evening are presented in the table 10 and plotted in figure 2. To attain the final weight, sapota, chilli and bitter-gourd required 19 h, 27 h and 16 h, respectively in PAU domestic solar dryer.

The dryer was taken to evaluate the performance at users' site for the drying of house hold products. Based on the performance at users' site, the feed back received from the users are the dryer can be adopted for household level, easy to operate, no special skills are required for drying and uniform drying takes place when compared to conventional open sun drying.

## Conclusion

Drying of sapota, chillies, and bitter-gourd could be produced using PAU domestic dryer. The time required to dry the sapota, chillies and bitter-gourd were comparatively lower in PAU domestic dryer when compared to open sun drying method. The time required to obtain final required moisture content 6,10 and 6.49 for sapota, chilli and bitter-gourd was 19, 27, and 16 hours, respectively.

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