Research Journal of Applied Sciences 2 (3): 246-250, 2007

Determination of the Optimum Distance Between Glass Cover and the Absorber (Collector) Plate of a Solar Dryer

D.A. Ajadi
Department of Pure and Applied Physics Ladoke Akintola,
University of Technology, P.M.B. 4000, Ogbomoso. Oyo State. Nigeria

Abstract: The importance of the oven temperature used for drying agricultural products cannot be overemphasized. This is determined by the amount of intensity of the radiation which passes through the glass and the absorbed by the collector plate that is converted into heat energy. The solar dryer used has its absorber (collector) plate adjustable to the glass cover at intervals of 1 cm varying from 3.0 to 10.0 cm. The experimental results show that the optimum distance between the glass cover and the absorber (collector) plate for maximum performance of the dryer is about 4.00 cm. This value was obtained when maximum temperature of the absorber and the glass cover occur simultaneously.

Key words: Determination, optimum, absorber, temperature, solar dryer

INTRODUCTION

Solar energy obtained from the sun is inexhaustible and renewable. Unlike fossil fuels, it has no problem of depletion and pollution. However, its science is not fully developed yet (Okujagu and Adjepong, 1989), hence the relatively expensive nature of solar equipments. One of the most common solar applications is the drying of agricultural products; that is the use of flat plate collector as solar dryer.

A flat plate collector is a form of solar thermal energy collector device. It is so called because the part of it, which that absorbs solar radiation is typically a flat metal surface with a black coating. The performance of a flat plate collector at any location depends on a number of factors such as (Okujagu and Adjepong, 1989).

- Climatological factors like: solar insolation, ambient air temperature and wind speed.
- Geographical factors such as: Collector site and altitude of the sun.
- Geometry of the collector such as: Absorber plate area, oven size, distance between the glass cover and the absorber plate.
- Collector orientation, the position of the collector surface relative to the direct sun rays.
- The nature and flow rate of the heat transfer fluid.

The performance of any solar device as stated depends on the available solar radiation falling on it amongst many other design factors (Wolf, 1979; Malnotra *et al.*, 1980).

Optimization of the insolation received by the collector is achieved if the collector is placed in the full tracks of the sun's radiations completely. Thus to predict how a given solar device may thermally perform at a place, it is imperative to have an idea of the intensity of solar energy at that place.

The research reported here, is concerned with determination of the optimum distance between one glass cover and the absorber (collector) plate; of a solar dryer in maximizing the drying rates (that produce high temperature for drying) of agricultural products.

MATERIALS AND METHODS

The solar dryer used in this work was designed by Ajadi and Adelabu (2003). The modification made to the design was the creation of slots calibrated in 1 cm for the absorber plate to vary the height between it and the fixed glass cover seat. The oven size below the absorber plate was fixed throughout the experiment.

The experiment was carried out for 11 h between 7.00 hrs and 18.00 h for each day at various heights. For each height the ambient temperature T, the absorber temperature T_a and the oven temperature T_o were determined and recorded.

In order to minimize heat losses the following precautions were taken during the experimental set up; insulating foam was placed round the glass seat in order to absorb shock and thus prevent the glass from cracking or breaking; each morning the glass and the absorber plate were properly cleaned to remove dust deposits, thus avoiding scattered radiation and finally the solar dryer was placed in open air where shade or shadows could not affect it. The results obtained are presented in Table 1.

Table 1: Data generated from the experiment.

Height cm^{-1}	3.0			4.0			5.0			6.0		
Time h^{-1}	T	T_a	T_o	T	T_a	T_o	T	T_a	T_o	T	T_a	T_o
7.00	25	27	23	30	30	26	30	31	28	30	28	26
8.00	25	28	27	31	30	27	35	36	28	29	34	27
9.00	28	30	28	33	48	33	34	49	33	32	40	30
10.00	34	59	35	34	53	34	35	64	36	33	59	34
11.00	33	59	34	38	60	37	37	72	37	36	80	40
12.00	37	71	38	34	74	42	37	78	39	38	74	40
13.00	36	60	37	37	80	43	38	79	42	37	76	39
14.00	38	74	40	38	65	40	38	60	38	38	70	43
15.00	40	73	42	35	54	38	38	69	41	38	68	42
16.00	38	62	41	34	45	36	38	68	40	38	66	41
17.00	39	57	40	24	37	32	36	48	37	38	59	39
18.00	35	45	36	24	36	30	33	42	35	35	51	37
Height cm^{-1}	7.0			8.0			9.0			10.0		
Time h^{-1}	T	T_a	T_o	T	T_a	T_o	T	T_a	T_o	T	T_a	T_o
7.00	25	27	26	27	28	26	28	29	26	29	28	27
8.00	28	29	26	29	30	28	31	34	29	30	31	28
9.00	30	34	28	31	34	30	33	37	31	31	35	29
10.00	31	56	32	32	39	32	35	40	34	32	39	31
11.00	36	76	37	34	47	36	38	47	40	34	44	34
12.00	36	79	38	38	60	41	40	55	42	37	51	38
13.00	38	74	39	40	65	42	41	57	43	38	53	40
14.00	36	76	40	40	67	44	40	56	44	38	57	41
15.00	41	82	44	39	66	42	39	56	42	37	56	40
16.00	35	63	37	36	50	42	39	55	40	36	56	39
17.00	35	63	37	35	59	39	37	54	39	35	53	37
18.00	33	61	35	33	39	36	36	53	37	34	52	34

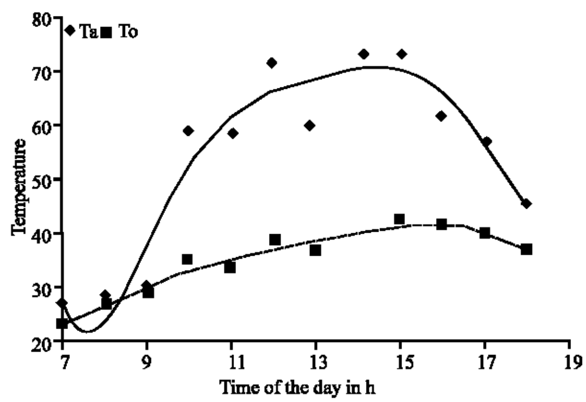

Fig. 1A: Graph of the hight 3 cm

Table 2: Temperature for each Height at Mean Solar Time 13.00 h local time

Height (h) cm^{-1}	T_a /°C	T_o/°C
3.0	60	37
4.0	80	43
5.0	79	42
6.0	76	39
7.0	74	39
8.0	65	42
9.0	57	43
10.0	55	40

RESULTS AND DISCUSSION

The data obtained presented in Table 1, shows that the time for which the maximum temperatures occur for each height is different for absorber and the oven respectively. The various curves of each height are shown in Fig. 1 A to 1H. These curves are different even though the shapes are similar. The shapes of the curves of the oven for all the heights are very much the same, whereas the shapes of the curves of absorber for all the heights are very much dissimilar.

The oven temperature, hence the heat energy obtained for drying is constant irrespective of the height, with an average value of 40.6°C with 5.5% variation. The absorber temperature varies considerably with an average value of 68.3°C with 13.2% variation. There is a difference of 28°C between the input (absorber or collector) temperature and the output (oven) temperature of the dryer.

From Table 2 which presents the temperatures of the absorber and the oven for all the heights at 13.00 h local time, the graphical illustrations were compared in Fig. 2. This indicate that the highest temperature for both the absorber and the oven are 80.0 and 43.0°C, respectively occurring at a height of about 4.0 cm simultaneously.

According to Sayigh (1974), the best design of a solar dryer will take into consideration the optimum air gap between the absorber (collector) plate and the glass cover seat. The results obtained by Sayigh show that the best air gap was over 4.0 cm and owning to the side-shading effect caused the collector box less than 8.0 cm.

Table 3: Summary of the curve fittings of the graphical illustration with Eq 1

Heigh cm^{-1}	T	A	B	C	D	E	R^2
3.0	T_a	6.5044	-109.31	1013.4	-4894.2	9608.4	0.9181
	T_o	0.0758	-1.7277	19.056	-98.187	209.16	0.9643
4.0	T_a	0.0627	-3.124	55.152	-403.87	1075.8	0.9516
	T_o	-0.7378	11.623	-98.823	433.49	-747.78	0.9663
5.0	T_a	3.7711	-66.364	639.89	-3183	6386.3	0.9223
	T_o	1.4547	-24.288	223.37	-1067.6	2092.1	0.9451
6.0	T_a	-0.3117	-2.846	99.170	-796.67	2116.9	0.9632
	T_o	1.3806	-23.361	218.14	-1059.6	2107.8	0.9699
7.0	T_a	3.3421	-59.227	581.29	-2965	6121.1	0.9501
	T_o	1.6009	-26.076	235.69	-1116.2	2180	0.9461
8.0	T_a	-8.1504	130.31	-1141.3	5189.8	9552.8	0.9478
	T_o	-1.515	24.534	-216.94	994.6	-1825.2	0.9923
9.0	T_a	-3.8738	62.313	-54900	2514.6	-4656.1	0.9947
	T_o	-1.5413	24.438	-211.41	949.1	-1708.1	0.9924
10.0	T_a	0.0094	-0.5218	10.078	-77.104	230.78	0.9942
	T_o	0.0064	-0.3676	7.3546	-59.254	192.61	0.9905
T_{max} at	T_a	-12.667	114.96	-570.54	1468.9	-1453.2	0.9981
13 h	T_o	5.2153	-39.324	153.62	-287.67	234.13	0.9999

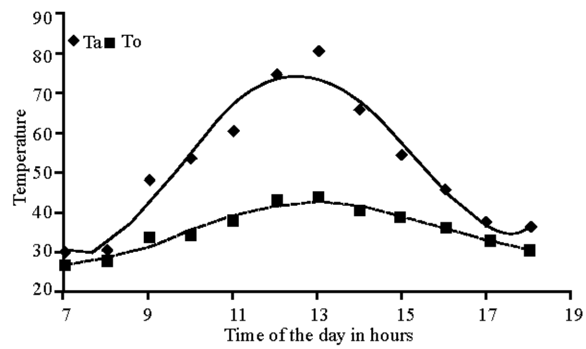

Fig. 1B: Graph of the hight 4 cm

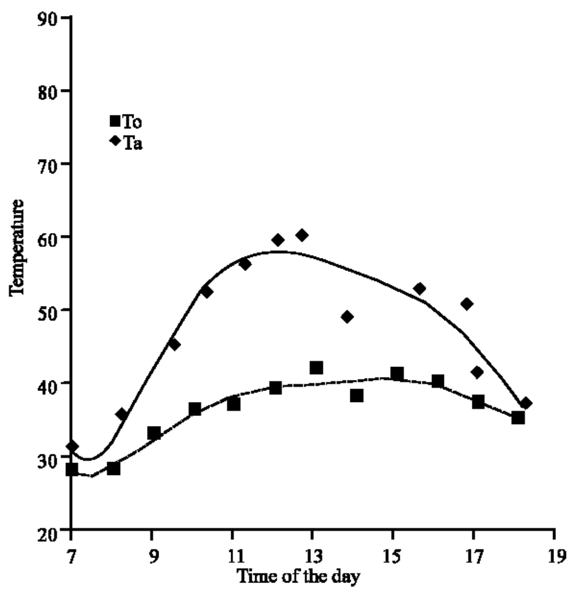

Fig. 1C: Graph of the hight 5 cm

Analyses of the graphs show that curve fitting of the data obey a polynomial equation of degree four and

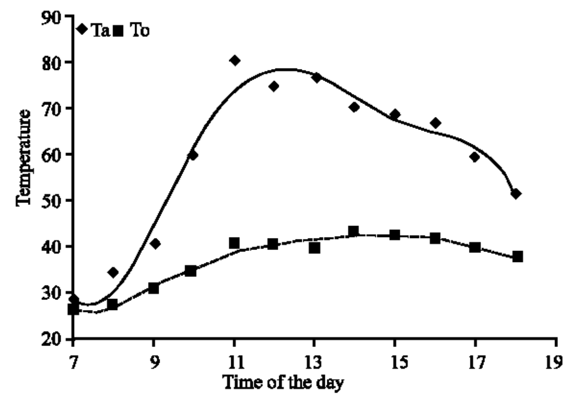

Fig. 1D: Graph of the hight 6 cm

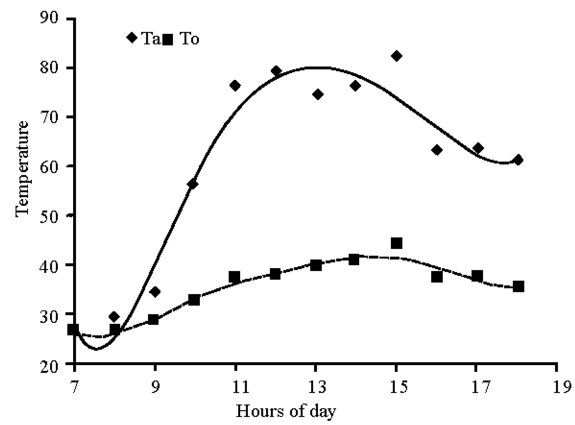

Fig. 1E: Graph of the hight 7 cm

is presented in Table 3. The general polynomial equation is given as

$$T = Ax^4 + Bx^3 + Cx^2 + Dx + E \quad (1)$$

where T is the observed temperature, A, B, C, D and E are constants. For Fig. 1A to 1H, x represents the local time in h; while in Fig. 2, x represents the height.

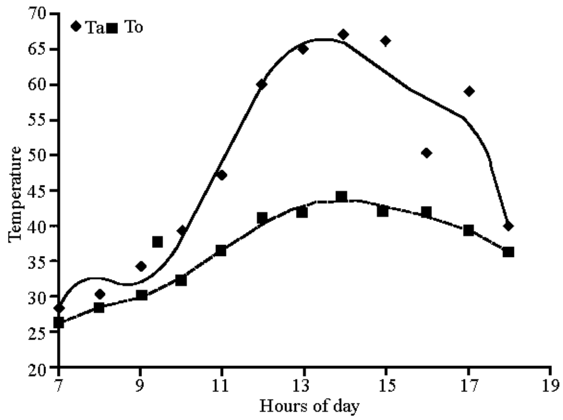

Fig. 1F: Graph of the hight 8 cm

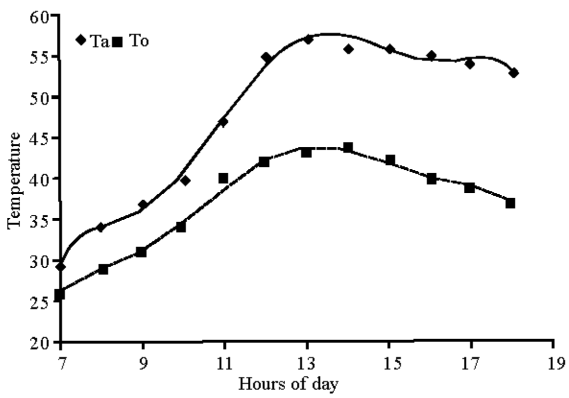

Fig. 1G: Graph of the hight 9 cm

The graphs at height 3.0 cm indicate that the points are more scatted in the absorber than in the oven. Both maximum temperatures of the absorber and the oven skewed towards the right and occur beyond 15 h local time.

At height 4.0 cm, the graphs of both the absorber and the oven show normal distribution curves, with the two maximum temperatures occurring at 13 h local simultaneously.

The heights 5.0 and 6.0 cm produced similar curve fittings. The absorber graphs skewed to the left where the maximum temperatures were obtained at about 12h local time. But the oven graphs skewed to the right with the maximum temperatures occurring at about 15 h local time.

For heights 7.0 and 8.0 cm, the points are more scattered in the absorber curves, while the curve fitted well for the oven curves. The maximum temperatures for both the absorber and the oven occurred at different times of the day.

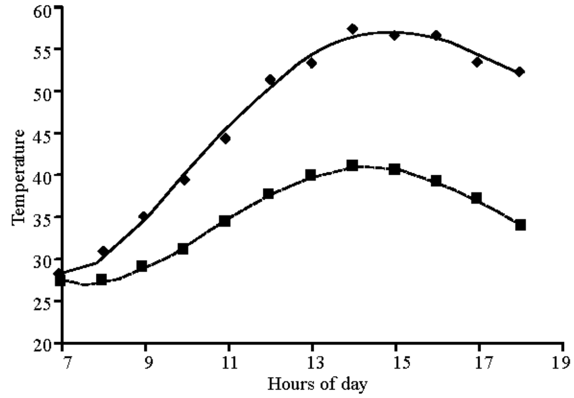

Fig. 1H: Graph of the hight 10 cm

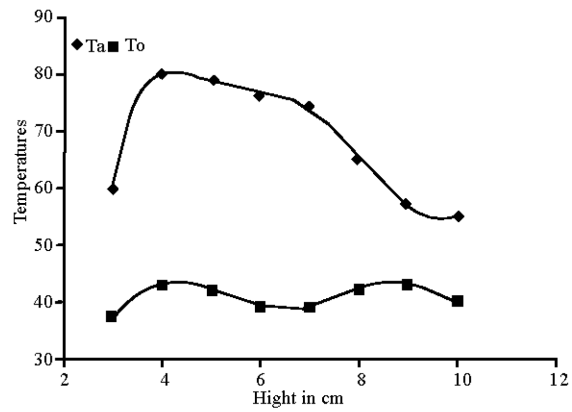

Fig. 2: Maximum temperature for each hight at 13 h local time

Both graphs of the absorber and the oven for the heights 9.0 cm and 10.0 cm all have good curve fittings for the data obtained, but the maximum temperatures occurred at different times of the day. The curves produced are not normal. The graphs skewed to the right.

Figure 2 shows that the points are perfectly fitted in the curves for both the absorber and the oven and that the curves show that maximum temperatures for both the absorber and the oven can only occur simultaneously at a distance of 4.0 cm between the glass cover and the absorber plate.

CONCLUSION

In conclusion one of the factors affecting the performance of solar dryer is the optimum distance between the absorber plate and the glass cover. At this distance the maximum temperatures of the absorber and the oven must occur simultaneously at a particular time. Thus to obtain a high temperature for drying agricultural products, the optimum distance between the glass cover seat and the absorber plate must be considered. This optimum distance is found to be 4.0 cm in this research with a reliability of 99.9%.

REFERENCES

Ajadi, D.A. and J.S.A. Adelabu, 2003. Performance of a Locally Designed Solar Dryer. Zuma J. Pure. Sci., pp: 128-132.

Malnotra, A., H.P. Garg and U. Rani, 1980. Minimizing Convective Heat losses in Flat Plate Solar Collectors. Solar Energy, pp: 521-526.

Okujagu, C.U. and S.K. Adjepong, 1989. Performance of a simple Flat Plate solar Collector at an Equatorial Location. Solar and Wind Tech., Vol.6.

Sayigh, A.A.M., 1974. Solar Flat Plate collectors: The uses of solar energy. Paper presented to the cultural activity programme, College of Engineering University of Riyadh, Saudi Arabia.

Wolf, R.E., 1979. Solar Collector Performance, Dependence upon Coating. J. Coating Tech., 51: 49-53.