Research Journal of Applied Sciences 2 (3): 251-254, 2007

Effect of Dust on the Performance of a Locally Designed Solar Dryer

D.A. Ajadi, G.R. Fajinmi and Y.K. Sanusi
Department of Pure and Applied Physics, Ladoke Akintola University of Technology,
P. M. B. 40000, Ogbomso, Oyo State, Nigeria

Abstract: Dust is one of the limiting factors of solar thermal system in the agricultural sectors area. This resaerch presents the effect of dust on the performance of a solar dryer. Two similar solar dryers were constructed with the same dimensions and materials. One serves as control experiment, which was constantly cleaned up before each daily readings commenced; while the other served as the test dryer for the period of the experiment. The effect of dust on both the absorber temperature T_a and the oven temperature T_0, of each dryer was determined for the two experimental setups. The daily absorber temperature T_a and the oven temperature T_0, were recorded for a period of 25 days; for both dryers simultaneously. The daily maximum temperature of the absorber T_a and the oven temperature T_0, of each dryer were obtained. The results show that, the values of oven temperature of the control dryer are always higher and approximately constant in magnitudes between 42 and 45°C compared with the oven temperature of the test dryer. While the values of the absorber temperatures of the control dryer are between 55 and 65°C. The maximum temperatures of the absorber and the oven of the test dryer were observed to fluctuate in magnitude.

Key words: Dust, solar dryer, dimension, temperature, absorber, magnitude

INTRODUCTION

Various parameters affect the performance of a solar dryer; some of which are environment related, while others are introduced by encapsulations and material interconnection. A few of the climatic factors include solar insolation, wind velocity, relative humidity, dust and temperature which is a determinant that affects the internal working principle of the dryer.

Attenuation of solar radiation due to the effect of dust is very prominent in Nigeria during the hamattan period (November-February). Yahya and Sambo (1991) stated that dust particles affect the amount of solar radiation received per surface area due to the scattering of direct radiation and partial absorption. These dust particles are of various sizes and chemical compositions; their optical properties are dependent on parameters, which affect atmospheric properties such as visibility and scattering. Due to their size (0.05-0.5) μm the particles can remain airborne for considerable periods of time and while airborne, they provide a substantial contribution to the diffuse radiation that reaches the surface of the earth. When the dust particles finally settle on such surfaces as the collector (glass) surface and absorber plate surface, they constitute a means of partial or total blockage to solar radiation capture. Dust settlement is agitated by the intensity and direction of wind. Dust is one of the major reducing agents of solar radiation intensity hence reducing the performance of solar device especially during the hamattan periods.

The effects of dust are difficult to generalize. The data by Dietz (1963) show that at the angles of interest (0- 50°) the influence of dust can be as high as 5%. From long-term experiments on collectors in the Boston area, Hottel and Woertz (1942) found that collector performance decreased by about 1%, due to dusty glass. In a rainless 30-day experiment in India, Grag (1974) found that dust reduced the transmittance by an average of 8% for glass cover tilted at 45°. For design purposes without extensive tests, it is suggested that radiation absorbed by the plate be reduced by a factor of (1-d) where d is 0.02 to account for dust.

The two well known theories for solar radiation scattering due to dust particles or aerosols according to Sayigh (1985) are: The Rayleigh theory and the Mie theory. The Rayleigh theory is limited to spherical particles with a diameter smaller than the light wavelength (λ) while Mie's theory is more general and can be used for any particle size. If D represents the particle diameter in micron (μm) and n is the index of refraction, then the following cases will result:

- If $\pi D/\lambda < 0.6/n$ scattering is governed by Rayleigh's theory

Corresponding Author: D.A. Ajadi, Department of Pure and Applied Physics, Ladoke Akintola University of Technology, P. M. B. 40000, Ogbomso, Oyo State, Nigeria

- If $\pi D/\lambda > 0.6$the scattering is a reflection
- If $0.6/n < \pi D/\lambda < 0.6$ scattering is governed by Mie's theory

The Mie's theory in terms of dust scattering coefficient (k_d) is given as:

$$k_d = 0.08128\lambda^{-0.75} \quad (1)$$

which is valid for a wide range of number of particles per cubic centimeters (m_a) between 1 and 800. An atmosphere with zero particles per cubic centimeter ($m_a = 0$) is a clean atmosphere, while an atmosphere with 800 particles per cubic centimeter ($m_a \neq 0$) is a very dusty one. Therefore the spectral Transmittance (T_d) can be expressed as:

$$T_d = \exp\left[-0.08128\lambda^{-0.75} (d/800)\, m_a\right] \quad (2)$$

According to Sayigh (1985), Angstorn also proposed the following formulae:

$$k_d = \beta\lambda^{-\alpha} \quad (3)$$

$$T_d = \exp(-\beta\lambda^{-\alpha} m_a) \quad (4)$$

where β is turbidity coefficient and α is the wavelength exponent.

The work reported in this article was embarked upon for the sole purpose of studying the effect of dust on the performance of a locally designed solar dryer.

MATERIALS AND METHODS

Two standard solar dryers of the same materials, dimensions and measurements as designed and constructed by Ajadi and Adelabu (2003) are used for this study. The two dryers were placed in an open environment side by side and maximum radiation was allowed to fall on the surface of the glass cover of each dryer. The experiment was performed during the hamattan season for a period of 25 days (between January and February). Two days experimental test was observed before the commencement of the actual experiment. This allows for the cleaning of the control dryer while dust settled on the test dryer.

The absorber Temperature (T_a) and the oven Temperature (T_o) of the two dryers were taken at hourly intervals concurrently. The readings were taken for a period of 10 h (from 8am to 5pm) per day for the whole experimental period of 25 days.

RESULTS AND DISCUSSIONS

The data obtained in this work are presented in Table 1 and 2. Table 1 represents the hourly mean temperature for the 25 days for the two dryers, while Table 2 presents the daily maximum temperature of each dryer. Table 1 show that the temperatures of the control dryer are always higher than the test dryer for both the absorber plate and the oven; with differences between 0.4 to 9.1°C for absorber and 0.2 to 4.5 for oven. These differences were attributed to the deposition of dust particles on the surface of the test dryer's absorber plate and the glass cover. The deposited dust reduced the intensity of the solar radiation that is responsible for the warming up of the air in the absorber and the oven regions of the each dryer. This attenuation of the solar radiation intensity was due to absorption, scattering and reflection by the dust particles.

Table 1: Hourly mean temperature for 25 days

	Absorber temperature T_a/°C		Oven temperature T_o/°C	
Time (h)	Control	Test	Control	Test
8	24.5	24.1	22.9	22.7
9	29	28.5	26.5	26.3
10	38	36.1	29.8	30.3
11	47.1	42.9	34.8	33.3
12	53.8	50.1	37.2	35.0
13	61.3	57.8	39.9	38.6
14	65	58.8	41.3	39.0
15	66.5	61.7	42.1	38.8
16	64.7	57.4	40.8	37.4
17	62.5	57.4	38.8	34.3

Table 2: Daily maximum temperature of each dryer

	Absorber temperature T_a/°C		Oven temperature T_o/°C	
Days	Control	Test	Control	Test
1	70	60	45	44
2	75	67	42	45
3	71	55	42	40
4	70	55	45	41
5	67	62	42	40
6	70	55	45	41
7	64	59	45	41
8	67	55	45	40
9	70	55	41	40
10	65	62	45	42
11	60	55	44	40
12	70	66	45	40
13	65	55	44	40
14	70	59	45	40
15	67	62	45	42
16	67	62	42	39
17	75	66	42	39
18	65	62	44	40
19	70	62	45	40
20	70	60	45	36
21	70	58	45	37
22	71	59	45	36
23	67	58	42	39
24	67	59	45	37
25	70	58	45	39
Mean	68.4±7.5	59.6±6.0	44.0±2.0	39.9±4.5

Table 3: Temperature variation with time for the dryers

		A	B	C	D	E	F	K	R^2
Absorber	Control	0.0019	- 0.0623	0.8212	- 5.5889	20.252	- 27.585	36.65	0.9996
	Test	0.0005	- 0.0144	0.1810	- 1.3240	5.754	- 5.6795	25.15	0.9968
Oven	Control	0.0006	- 0.0204	0.2736	- 1.8375	6.397	- 6.2741	24.41	0.9990
	Test	0.0000	- 0.002	0.0718	- 0.0134	- 0.1967	4.2524	18.63	0.9958

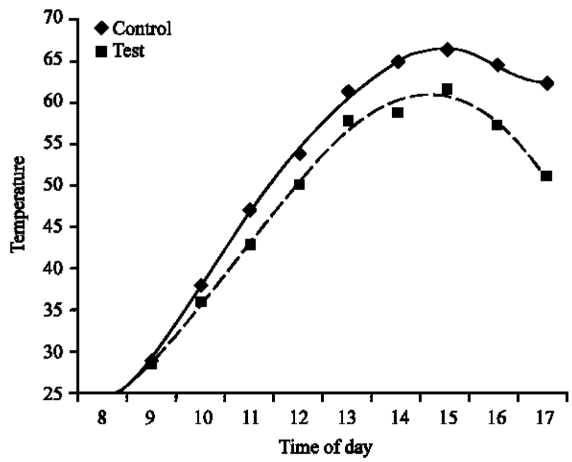

Fig. 1: Hourly mean temperature of absorber for 25 days

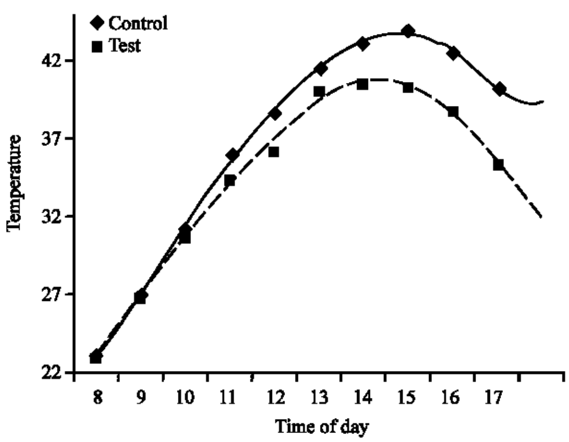

Fig. 2: Hourly mean temperature of oven for 25 days

The graphs illustrated in Fig. 1 and 2are obtained from the data presented in Table 1. These graphs show that as the day progresses, the temperature difference between the control and test dryers increased drastically for the absorber and the oven, respectively. The difference in the absorber temperature was up to 9.0°C and for oven temperature it was up to 4.5°C. This effect could be due to multiple scattering by an increasingly dense deposit of dust on the upper face of the test absorber plate and glass cover, as the day progressed. This significantly reduces the solar radiation emitted to the absorber plate and the oven regions of the test dryer.

Table 2 which show the daily maximum temperature readings, show that the absorber temperature T_a for

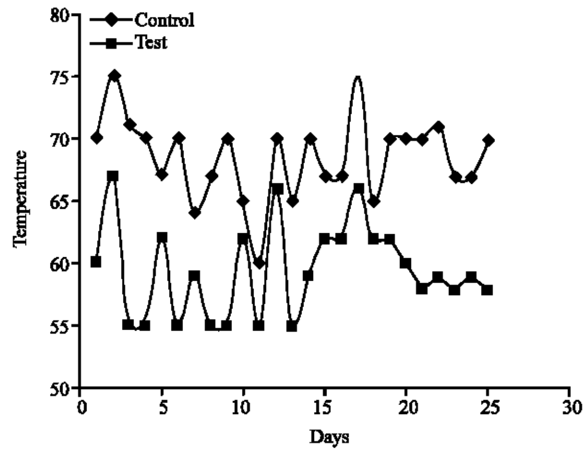

Fig. 3: Comparison of daily maximum temperature of absorber for the two dryers

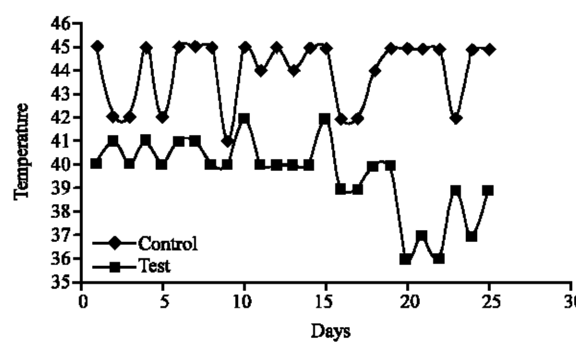

Fig. 4: Comparison of daily maximum temperature of oven for the two dryers

control dryer has a mean value of 68.4°C with 11% variation for the whole period of the experiment; while the test dryer has a mean value of 59.6°C with about 10% variation. The daily maximum temperature readings also show that the oven temperature T_0 for clean dryer has a mean value of 44.0°C with 4.6% variation for the whole period of the experiment; while the unclean dryer, has a mean value of 39.9°C with about 11.3% variation. The mean value of the daily maximum temperature also shows marked difference between the control and the test dryers. For absorber, the temperature difference is about 8°C, while that of oven has temperature difference of about 4°C, which is 50% reduction to that of the absorber. This effect is due to the aggregation of dust particles on the glass cover and the absorber plate, respectively.

Also from Table 2, the absorber's highest temperature recorded for control and test dryers are 75°C and 67°C, respectively; while the oven temperature was constant at 45°C for both control and test dryers. The effect of dust on the glass cover and the absorber plate could be a factor that gives the difference in the absorber temperature. Again from the readings presented in Table 2 show that the oven temperature for both control and test dryers are quite close and are comparable over a range of 36°C to 45°C.

From Fig. 1 and 2, the solid lines illustrate the curve fitting for control dryer; while the dashed lines illustrate the curve fitting for the test dryer. In both control and test dryers the curve fitting of polynomial of degree six fitted perfectly well in the data obtained for both the oven and the absorber plate. The reliability of the curves fitting show 99% with the obtained data. The general curve obtained is given by Eq. 5:

$$T = At^6+Bt^5+Ct^4+Dt^3+Et^2+Ft+K \quad (5)$$

where T is temperature to be determined, t is the local time of the day and the reliability is the Coefficient Of Determination (COD) given by the value of R^2. The corresponding coefficients A to F and the constant of the equations obtained are presented in Table 3.

CONCLUSION

Based on the experimental results, it is concluded that the oven temperature difference is 4.5°C, while the absorber temperature difference is 11.1°C for test and control dryers, respectively. The temperature difference between the control and the test dryers, for both the absorber and the oven increases drastically as the hour of each day progressed. In all the observations the temperature of the control dryer is always higher than the test dryer.

Thus the performance of a dryer requires high temperature and hence high heat energy for drying food items this implies that the dryer should be regularly clean for higher and better performances.

REFERENCES

Ajadi, D.A. and J.S.A. Adelabu, 2003. Performance of a Locally Designed Solar Dryer. Zuma J. Pure and Applied Sci., pp: 5.

Dietz, A.G.H., 1963. Introduction to the Utilization of Solar Energy. Diathermanous Materials and Properties of Materials. New York. McGraw-Hill.

Grag, H.P., 1974. Effect of dirt on Transparent covers in Flat Plate Solar Energy Collectors. Solar Energy, 15: 299.

Hottel, H.C. and B.B. Woertz, 1942. Performance of Flat Plate Solar Heater Collectors Trans. ASMF., 64: 91.

Sayigh, A.A.M., 1985. Dust Effect on Solar Flat Surfaces Devices in Kuwait. Workshop on the Physics of non-conventional energy sources and material science for energy. ICTP, Trieste, Italy.

Yahya, H.N. and A.S. Sambo, 1991. The Effect of dust on the performance of Photovoltaic Modules in Sokoto, Nigeria. Nigerian J. Renewable Energy, pp: 36-42.