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Research Article

Comparative study of Performance of Open, Direct and Indirect Solar Dryer in Drying Tomatoes

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Abstract

Solar drying system is essentially important for the preservation of agricultural crops for future use. In this work, the comparative study of performance of three different dryers was investigated. This was done by using the dryers in drying tomatoes crops. From the observation obtained, the daily maximum moisture content evaporated curves indicate decrease in the water contents of the drying material with number of days exposed to solar radiation. The trend of decrease is an exponential decay with the curves varying for the three dryers. The evaporated mass of the moisture content shows that the direct dryer perform higher than the indirect and open drying. The daily average moisture content evaporated graphs follow polynomial curves of degree 6 with coefficient of reliability of 90%. The direct dryer shows the highest daily average moisture content evaporated value follow by the indirect dryer then the open drying dryer. The hourly temperature variations for the three dryers are of polynomial curves of degree 6 with coefficient of reliability of 98 %. The daily maximum temperatures for the three dryers and the daily average temperatures for the three dryers show similar features and follow polynomial curves of degree 6 with coefficient of reliability of 85 %. Generally for all the dryers, direct dryer shows the highest temperature variation, follow by indirect dryer then open drying dryer.

***Keywords**: Open Drying, Active dryer, Passive dryer (Direct Solar Cabinet and Indirect Solar Dryer).*

Introduction

Solar energy is one of the most promising renewable energy sources in the world because of its abundance, inexhaustible and non-pollutant in nature compared with higher prices and shortage of fossil fuels. The concept of dryer powered by solar energy is becoming increasing feasible because of the gradual reduction in price of solar collectors coupled with the increasing concern about atmospheric pollution caused by conventional fossil fuels used for drying crops. However, conversion technologies differ from region to region, due to the variation in the solar intensities. 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 much better color and texture as compared to open sun dried products rapidly, uniform and hygienically, the traits inevitable for industrial food drying processes. Since, they are more effective than sun drying, but have lower operating costs than mechanized dryer (Diamente and Munro, 1993; Condor et al., 2001), more importance is given now to use solar dryer.

The traditional method for crop drying in the tropics is sun drying. Drying is essentially important for preservation of agricultural crops for future use. It preserves crops by removing enough moisture from it to avoid decay and spoilage (Eze and Agbo, 20011). While water content of most agricultural produce is greater than 50%, that of properly dried food varies from 5 – 25%, depending on the food (Bhandary et al, 1997). One of the main problems facing Nigerian farmers has remained lack of convenient method of preserving the agro – produce which is usually produced in larger quantities during harvest (Eze and Agbo, 20011). The traditional open sun – drying widely practiced by rural farmers has inherent limitations; of high crop losses due to inadequate drying fungi attacks, insects, birds, rodent encroachment and unpredictable weather effects (Ebewele and Jimoh, 1981). The implication of this improper handling and drying is far reaching. For instance, it is reported that yearly, millions of dollar worth of gross national products are lost through spoilage (Fumen et al, 2003). Open – air and uncontrolled sun drying is still the most common method used to preserve and process agricultural products in most tropical and subtropical countries. However, being unprotected from rain, wind – borne dirt and dust, infestation by insects, rodents and other animals, products may be seriously degraded to the extent that sometimes become market valueless and inedible and the resulted loss of quality in the dried

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products may have adverse economic effects on domestics and international markets (Diemuodeke and Momoh, 2011).

Different types of solar dryers for drying of biological materials have been reviewed by Ekechukwa and Norton (1998) and Farkas (2004). Although for commercial production of agricultural products, forced convention solar dryer provides a better control of drying operation. Hence, natural convention solar dryer is highly preferred for drying food products especially when in thin layer. Various investigations have also shown that solar drying can be effective means of food preservation since the product is completely protected during drying against rain, dust, insects and animals; (Parkas 2004). All drying systems can be classified primarily according to their operating temperature ranges into two main groups of high temperature dryers and low temperature dryers. However, dryers are more commonly classified broadly according to their heating sources of fossil fuel more commonly known as conventional dryers and solar energy dryers, further, solar-energy drying systems are classified primarily according to their modes and manner in which the solar heat is utilizes. Generally solar dryers can be divided into two main categories: active and passive. The passive solar dryer can be sub divided into direct and indirect solar dryers. Passive dryers use only the natural movement of the heated air. They can be constructed easily with inexpensive, locally available materials. Direct passive solar dryer is one in which the food is directly exposed to the sun's rays for drying. Direct passive solar dryers are best used for drying small batches of food stuffs. Indirect passive solar dryer is one which the sun's rays do not strike the food items for drying directly. Indirect passive dryers vary in size from small home dryers to large scale commercial units. The active solar dryers require an external power source like fans or pumps for moving the solar energy in the form of heated air from the collector to the drying bed where the food is spread for drying. These dryers can be built in almost any size, from small units to very large units, but the larger units are the most economical. In view of its requirement this work is limited to research on passive solar dryers. The figure 1 below shows the breakdown of the drying methodology.

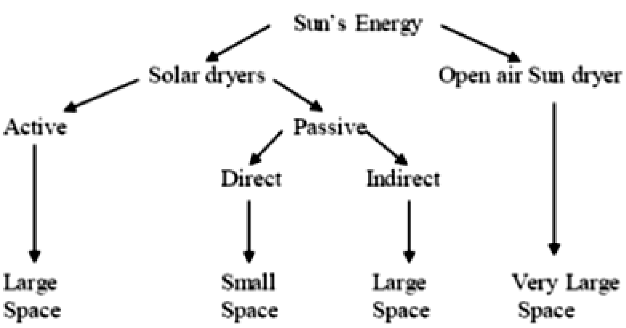

Figure 1: Breakdown of the Drying Methodology

However, it is a serious concern that drying at higher temperature may cause damage to the flavor, color and nutrients of the dehydrated product. Further, undesirable quality changes in the dehydrated product may also be due to the presence of oxygen in the drying medium. Dehydration of food materials containing antioxidants is a difficult food process operation, mainly because of undesirable changes that occur in the quality of dehydrated products. Vacuum drying is one of the efficient means of drying food materials having oxidative and heat sensitivity properties. Since, the lower pressure (vacuum) in the system allows the use of lower drying temperature in order to achieve similar moisture content of the end product. Generally, processing of tomatoes to final moisture of < 15% often involves high temperature in the presence of oxygen and therefore, the product show oxidative damage. It is reported that the quality of vaccum dried coconut was superior to the conventionally dried products. Therefore, a vacuum assisted solar dryer could be a better alternative for drying food materials susceptible for oxidation and heat sensitivity, since solar radiation can pass through vacuum and the moisture in the product can be driven out at lower temperatures. Drying kinetics is generally affected by air temperature, relative humidity, air velocity and material size. Generally, the drying phenomena can be describe using thin layer drying models mainly to estimate the drying times and moisture content of the food materials at time after they are subjected to a known temperature and relative. Many research studies have been reported on mathematical modeling and experimental studies conducted on thin layer drying process of various food products such as onion and pepper, carrot (Doymaz, 2004) tomato (Gould., 1983). In modeling, the investigators have tested various models and reported the best model that fit the experiment data. Since, solar energy sustainable and any research work m this line help to produce quality dried products. Although, for commercial production of dried agricultural products, forced convection solar dryer provide a better control of drying air; natural convection solar dryer does not require any other energy during operation.

In this work, the rate at which water is removed from the tomato in the three drying methods was studied. This is worthwhile because at the end of the day, the rural farmers are concerned with getting their excess product very well preserved. With the three methods carried out under the same conditions and time, it is hoped that the rate at which water is removed from the drying material in each case would be justified.

Materials and Methodology

Tomatoes sample was selected as the product to be dried, because the consideration is on passive solar dryer, which is meant for drying smaller agricultural produce. The materials used in this work were: passive solar dryers; mercury in glass thermometer; stop watch; weighing machine. The first quantities of tomatoes which are solids were divided into three equal portions of 400 grams and each placed on the open air, direct, and indirect solar dryer. Readings were taken at an interval of one – hour from 8:00am to 6:00 pm daily for 11 days. The masses and the temperatures were recorded for the open air, direct and indirect solar dryers. The second quantities of tomatoes were sliced into two halves to compare its rate of drying to that of solid tomatoes. The results were tabulated below

Results

Table 1: Daily Maximum mass (g) of moisture content Evaporated from material in the month of January

Days	open	indirect	direct
1	10.8	12.71	17.05
2	9.1	8.7	10.4
3	8	10.1	12.8
4	2.4	3.3	4.4
5	6.2	8.9	10
6	3.3	3.5	2.2
7	3.4	2.5	2.2
8	0.8	1	1
9	1	1.8	0.4
10	1	0.2	0
11	0.5	0	0

Table 2: Daily Maximum mass (g) of moisture content evaporated from material in the month of February

Days	open	indirect	direct
1	12.8	12.71	17.05
2	9.1	8.7	10.4
3	7	5.1	2.8
4	2.4	3.3	4.4
5	2.2	2.9	3
6	3.3	3.5	2.2
7	3.4	2.5	2.2
8	0.8	1	1
9	1	0.8	0.4
10	1	0.2	0
11	0.5	0	0

Table 3: Daily Average mass (g) of moisture content evaporated from material in the month of January

Days	open	indirect	direct
1	0.45	0.64	0.91
2	1.36	1.45	1.54
3	1.46	1.15	1.91
4	1	1.19	1.26
5	0.91	1.55	1.89
6	3.09	2.64	2.18
7	2.37	3.19	3.56
8	2.53	3.09	3.6
9	1.64	3	2.28
10	1.82	2.99	1.36
11	0.45	1.45	1

Table 4: Daily Average mass (g) of moisture content evaporated from material in the month February

Days	open	indirect	direct
1	2	4	2.03
2	4.05	3.04	3
3	3.02	2.05	3.05
4	3.1	4.04	2.98
5	2.05	3.05	3.96
6	5.94	6.03	7
7	4.97	6.01	6.04
8	3.97	5.98	8.02
9	3.1	8.05	10.05
10	3.05	5.05	3.07
11	2	3.55	3

Table5: Hourly Temperature of each dryer in the month of January

Time	open	indirect	direct
8	22	23	24
9	24	25	26
10	26	28	30
11	30	31	32
12	31	32	34
13	32	34	37
14	37	38	42
15	35	40	45
16	33	42	41
17	32	39	39
18	29	36	37

Table 6: Hourly Temperature of each dryer in the month February

Time	open	indirect	direct
8	25	27	28
9	27	29	30
10	29	34	35
11	33	40	42
12	36	43	45
13	38	48	50
14	39	49	50
15	38	49	50
16	37	49	50
17	36	40	41
18	36	39	40

Table 7: Daily maximum temperature of each dryer in the month of January

Days	open	indirect	direct
1	39	47	48
2	36	39	41
3	39	47	49
4	40	45	48
5	40	43	44
6	40	43	44
7	40	42	47
8	36	41	45
9	40	45	48
10	35	45	48
11	32	41	43

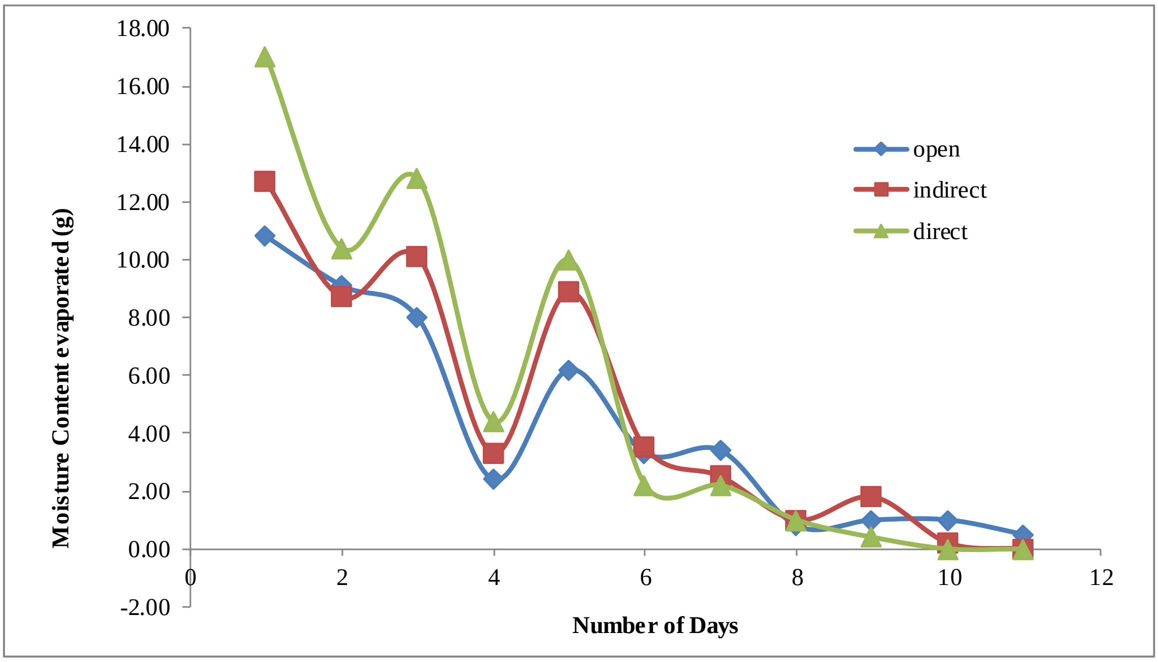

Figure 1: Daily Maximum mass (g) of moisture content evaporated from material in the month of January

Table 8 Daily Maximum Temperature of each dryer in the month of February

Days	open	indirect	direct
1	39	43	45
2	35	45	45
3	39	47	48
4	39	48	49
5	39	49	50
6	39	48	49
7	35	44	46
8	37	46	47
9	39	48	49
10	42	49	50
11	37	42	45

Table9: Daily Average Temperature of each dryer in the month of January

Days	open	indirect	direct
1	35.38	38.5	44.13
2	30.27	33.45	34.91
3	33	37.91	39
4	33.27	37.1	38.82
5	36.9	35.1	36.7
6	32.64	35.27	36.45
7	31.82	31.64	38.1
8	31	35	37
9	32.1	35.36	41.64
10	27.27	31.45	33.18
11	26.36	34.27	38.45

Table 10: Daily Average Temperature of each dryer in the month of February

Days	open	indirect	direct
1	34.3	37	39
2	31.64	38.36	39.78
3	34.1	39.18	41
4	34.45	39.91	41.1
5	31.18	40	41.36
6	33.82	40	41.64
7	28.36	34.91	36.82
8	32	38	39
9	33.1	38.1	39.64
10	36.2	40.18	41.64
11	30.72	40.18	41.64

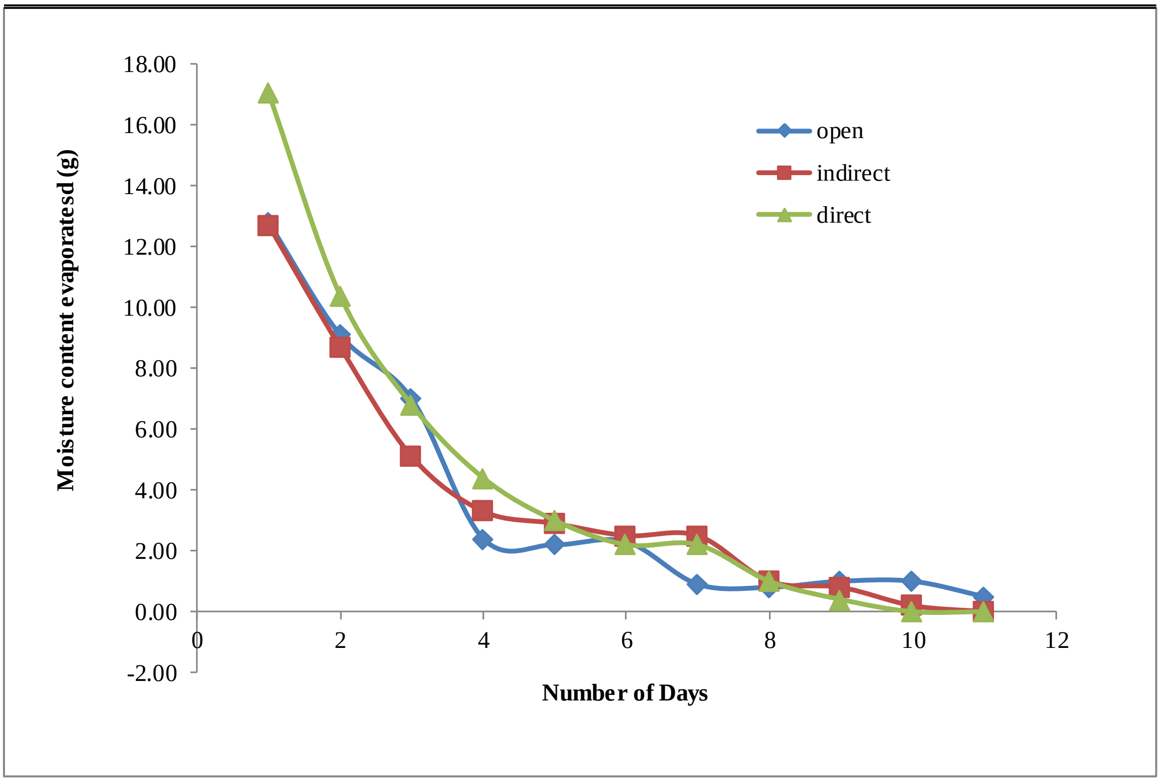

Figure 2: Daily Maximum mass (g) of moisture content evaporated from material in the month of February

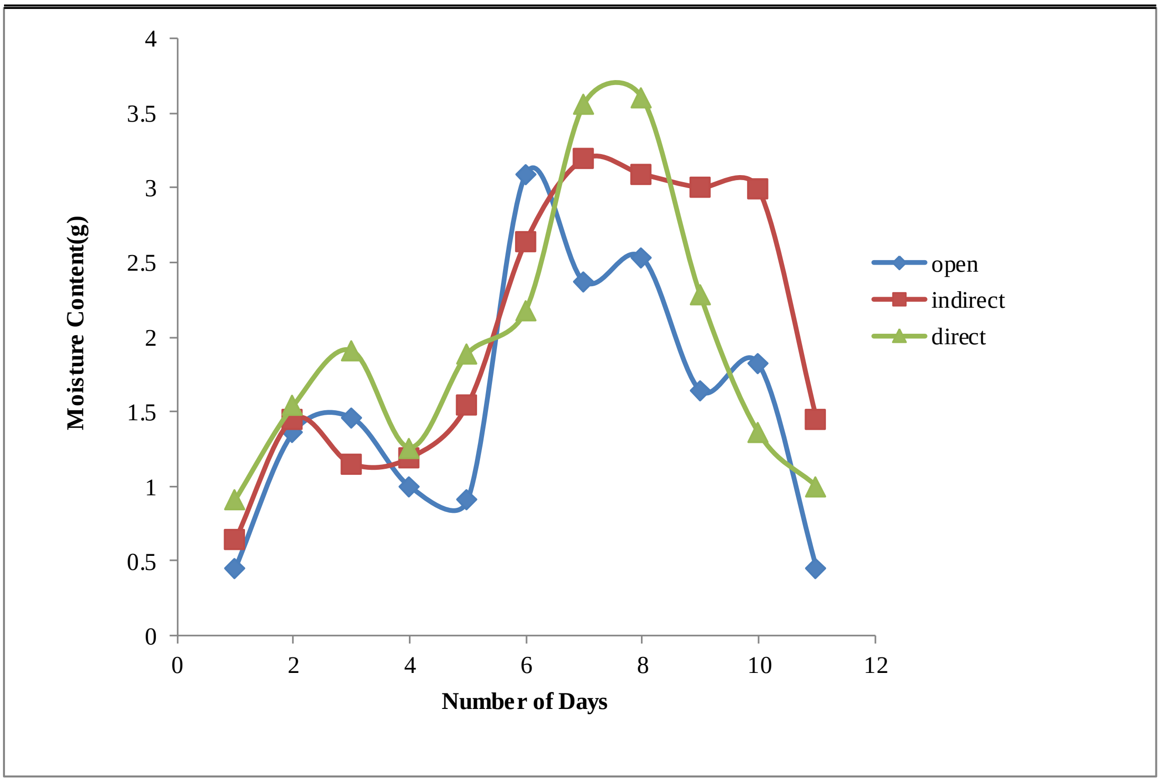

Figure 3: Daily Average mass (g) of moisture content evaporated from material in the month of January

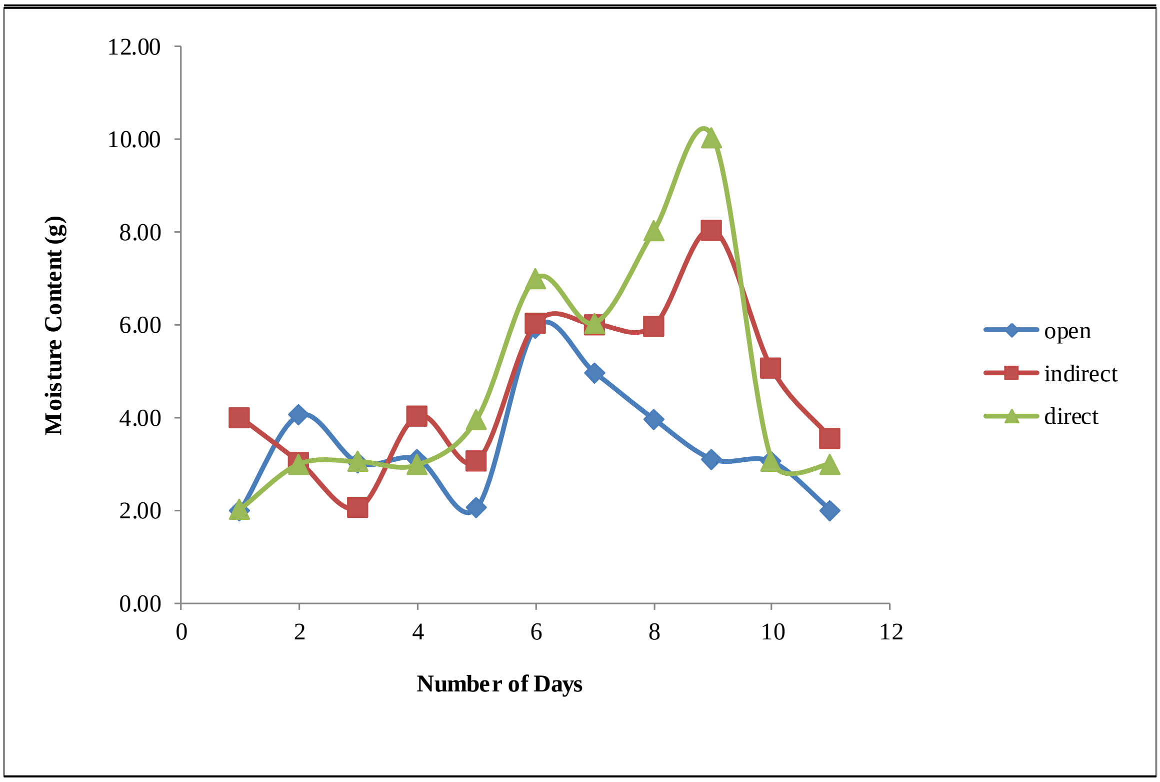

Figure 4: Daily Average mass (g) of moisture content evaporated from material in the month of February

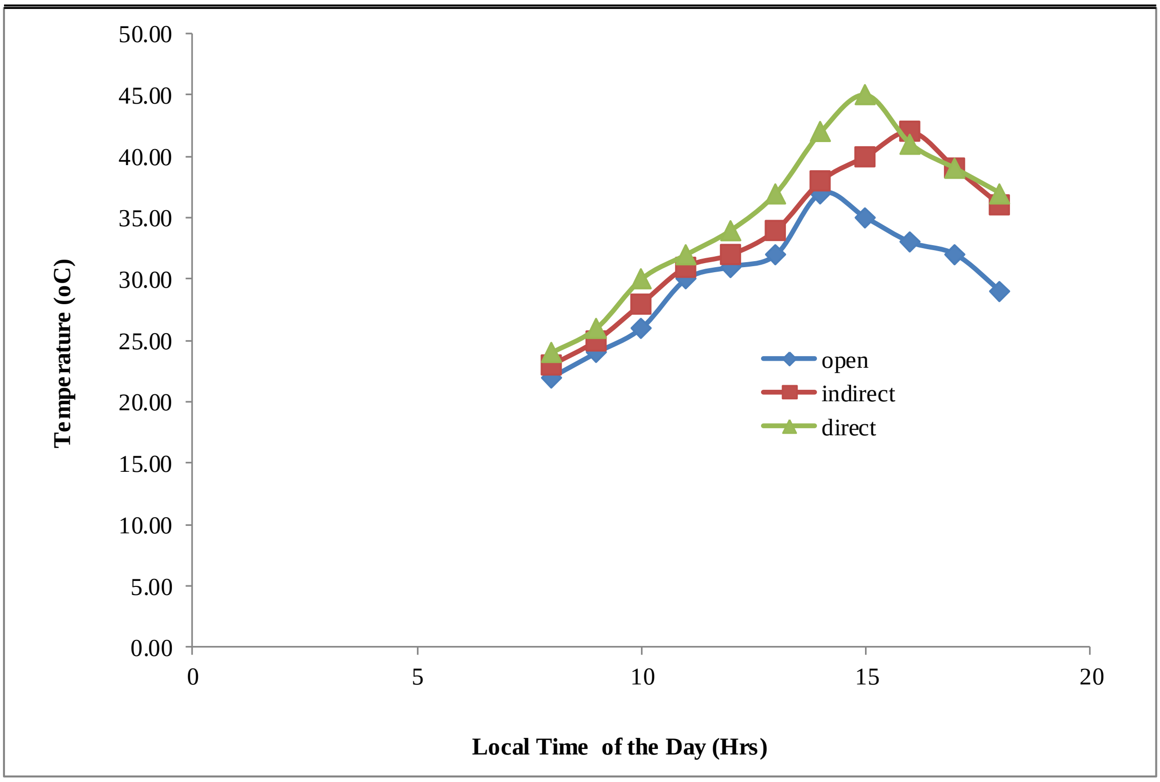

Figure 5: Hourly Temperature (^{o}C) of each dryer in the month of January

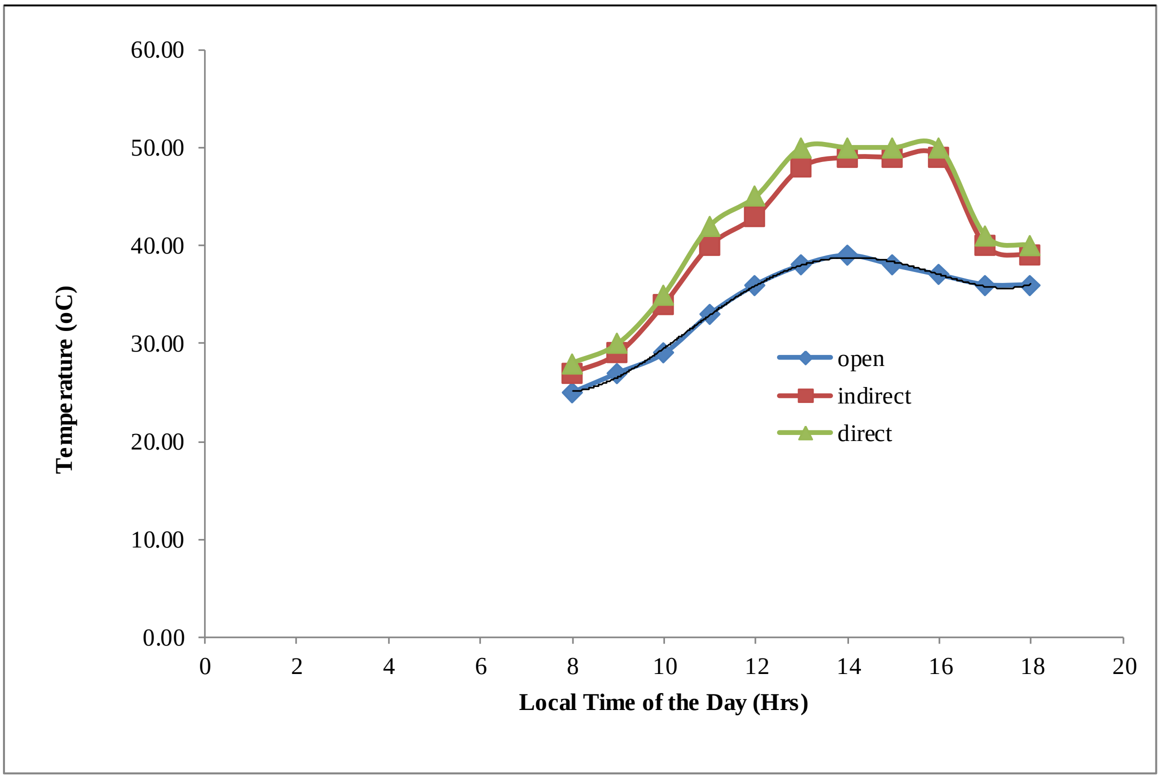

Figure 6: Hourly Temperature (^{o}C) of each dryer in the month of February

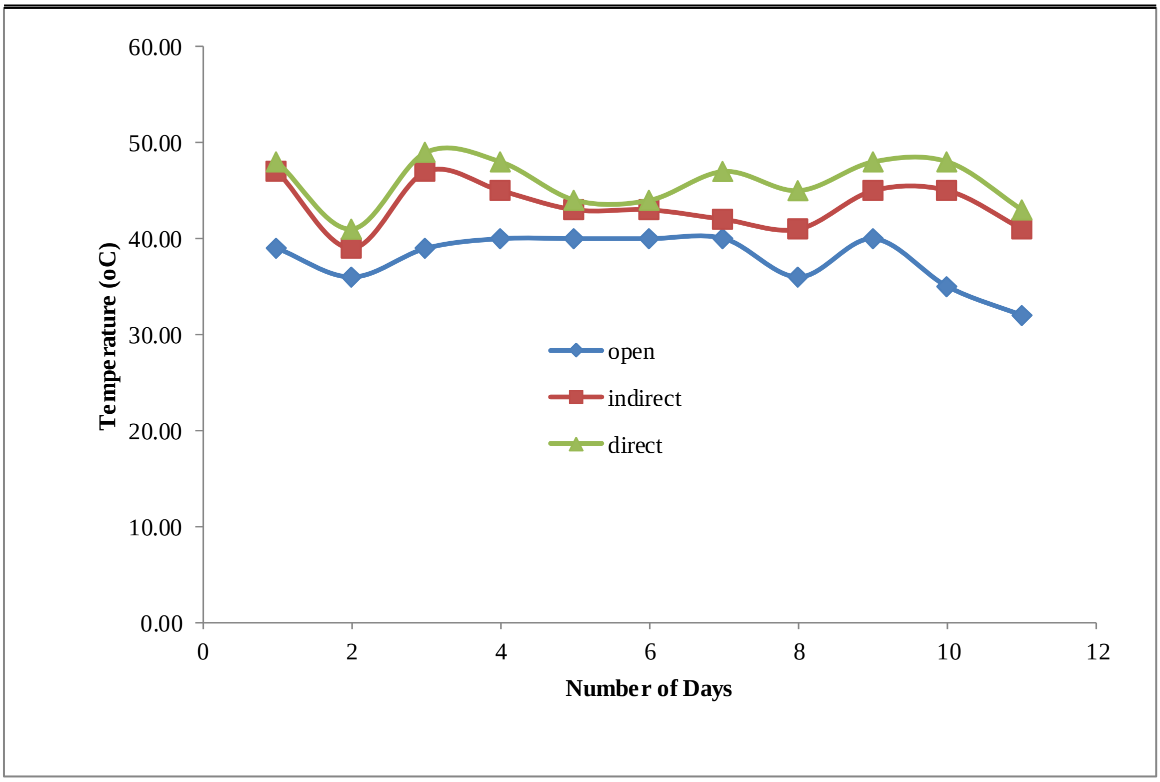

Figure 7: Daily Maximum Temperature (^{o}C) of each dryer in the month of January

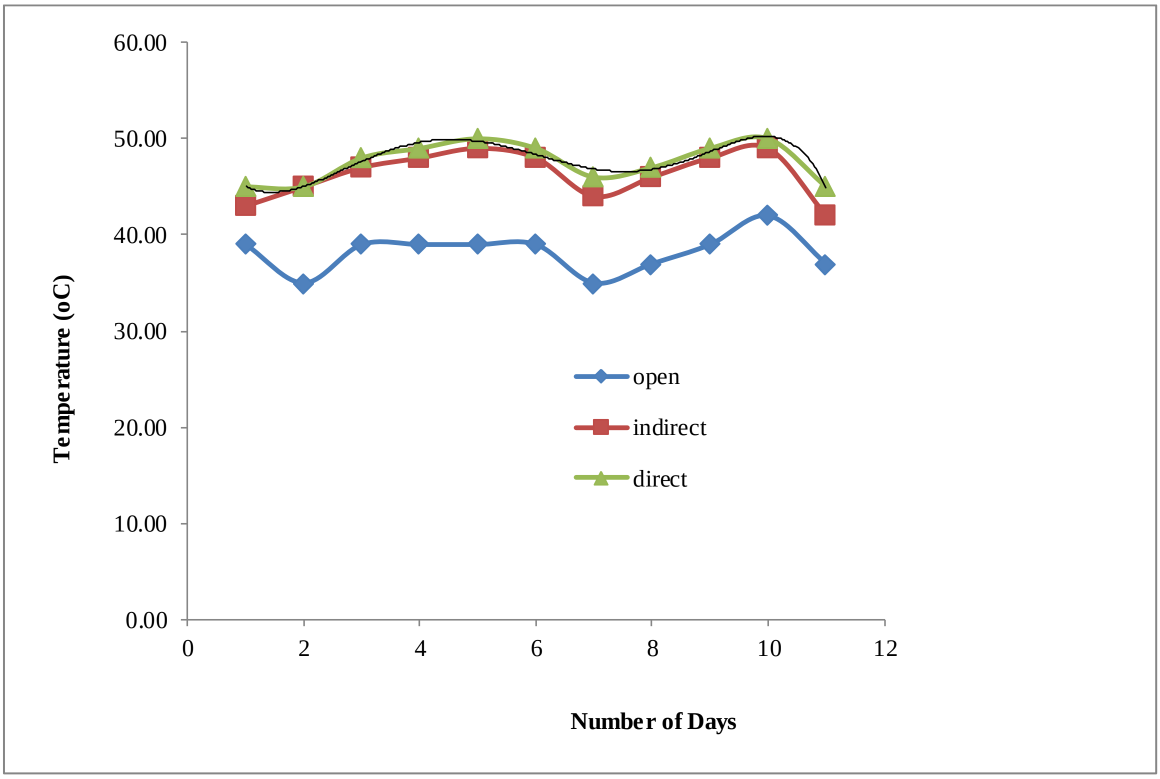

Figure 8: Daily Maximum Temperature (^{o}C) of each dryer in the month of February

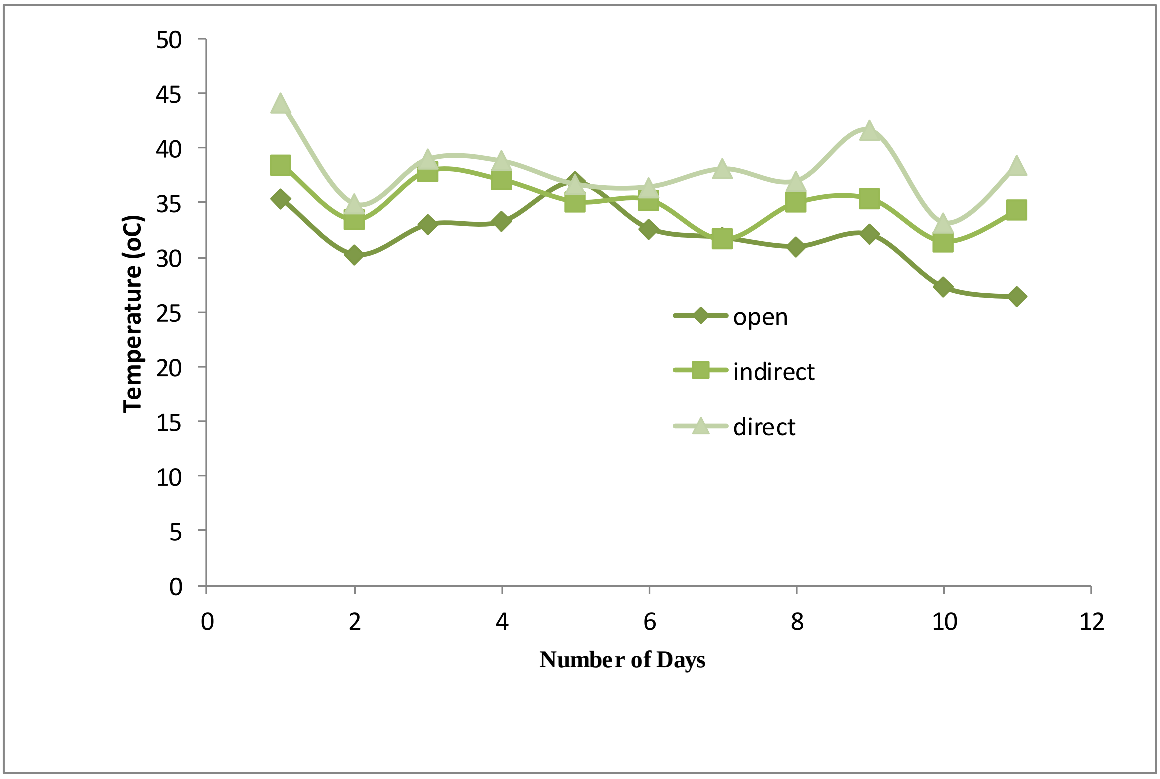

Figure 9: Daily Average Temperature of each dryer in the month of January

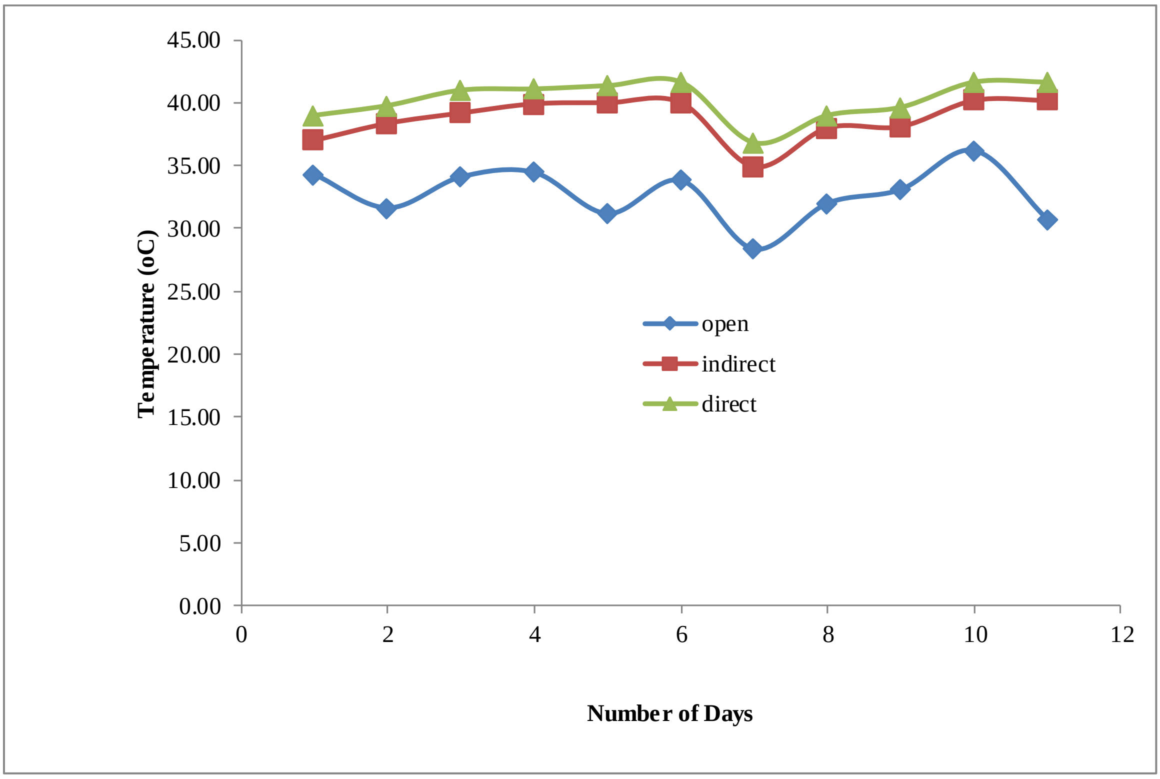

Figure10: Daily Average Temperature of each dryer in the month of February

Discussion

Moisture Contents

The mass of the moisture content removed by each of the dryer were plotted against the number of days as shown in figures 1, 2, 3 and 4. Generally the curves in figures 1 and 2 for the month of January and February respectively indicate decrease in the water contents of the drying material with number of days exposed to solar radiation. The trend of decrease is an exponential decay with the curve varying for the three dryers. The trend of the graphs indicate that the drying rate was not uniform, that is, it is higher at the onset of the drying and lower towards the end of the drying period. In both graphs the evaporated mass of the moisture content shows that the direct dryer perform higher than the indirect and open drying. Figures 3 and 4 illustrate the daily average moisture content evaporated for the month of January and February respectively. Both graphs follow polynomial curves of degree 6 with coefficient of reliability of 90%. The direct dryer shows the highest average moisture content evaporated value follow by the indirect dryer then the open drying dryer.

Temperature of the dryers

The graph of temperature recorded in each dryer against number of days was plotted for the month of January and February respectively. From these graphs it was observed that both temperatures in the direct and indirect dryers are always higher than the temperature of in the open drying dryer. This is due to the greenhouse effect inside the direct and indirect dryers. Figures 5 and 6 illustrate the hourly temperatures for the three dryers for the month of January and February respectively. The graphs are of polynomial curves of degree 6 with coefficient of reliability of 98 %. Figures 7 and 9 illustrate the daily maximum temperatures for the three dryers for the month of January and February respectively; Figures 9 and 10 illustrate the daily average temperatures for the three dryers for the month of January and February respectively. The four graphs show similar features and follow polynomial curves of degree 6 with coefficient of reliability of 85%. Generally for all the dryers, direct dryer shows the highest temperature variation, follow by indirect dryer then open drying dryer.

Conclusion

The performance of three different types of dryers were studied, investigated and compared. The moisture content evaporated curves of the tomatoes show that the direct solar dryer has the highest loss of moisture content followed by the indirect solar dryer then the open drying dryer. It was also observed that direct solar dryer shows the highest temperature variation followed by the indirect solar dryer, then open drying dryer.

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