ajfand
SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 4
July 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2020; 20(4): 16029-16045 https://doi.org/10.18697/ajfand.92.18740

PERFORMANCE EVALUATION OF A CHIMNEY SOLAR DRYER FOR HABANERO PEPPER (*Capsicum chinense Jacq*)

Kumi F[1]*, Ampah J[2], Amoah RS[1], Andoh-Odoom HA[2] and M Kodua[1]

Francis Kumi

Jonathan Ampah

Robert Sarpong Amoah

Anthonia H. Andoh-Odoom

Maxwell Kodua

*Corresponding author email: francis.kumi@ucc.edu.gh

[1] Department of Agricultural Engineering, School of Agriculture, College of Agriculture and Natural Sciences, University of Cape Coast, Ghana

[2] Council for Scientific and Industrial Research - Food Research Institute, Ghana

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 20 No. 4 July 2020 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

ABSTRACT

Habanero pepper (*Capsicum chinense Jacq*) is cultivated predominantly in the Volta, Central and Ashanti regions of Ghana and commonly utilised in most local dishes. Majority of consumers prefer the dried form of the pepper. However, farmers are usually confronted with the challenge of obtaining low-cost, locally fabricated dryers that can efficiently dry agricultural produce while mitigating quality and safety concerns. In this study, a model of the newly designed chimney solar dryer by the Horticulture Innovation laboratory of the University of California, Davis, in the United States of America, for crop drying in developing countries was constructed and its performance evaluated in comparison to open sun drying. Habanero pepper was used as a test crop. Subsequently, microbial analysis was carried out on the dried products. The mean chimney dryer temperature (46.4°C) was found to be higher than the ambient temperature (36.2°C). The relative humidity in the chimney solar dryer and the ambient ranged from 25% to 68% and 26% to 83%, respectively. During the period of the drying experiment, mean maximum solar insolation of 823.18 W/m^2 was recorded at 11.30 am while a mean minimum solar insolation of 107.84 W/m^2 was recorded at 4.30 pm. The solar-dried and sun-dried pepper recorded total drying time of 35 h and 55 h respectively. The mean performance coefficient of the chimney solar dryer was determined to be 1.21 which gives an indication of a high dryer performance. The mean yeasts and moulds counts of the solar-dried and sun-dried pepper were 4.30 x 10^4 cfu/g and 2.52 x 10^5 cfu/g, respectively. Also, the *Staphylococcus aureus* and *Escherichia coli* counts were <10 cfu/g for samples in both drying media. In conclusion, the chimney solar dryer was found to have performed better than open sun drying with shorter drying time and better quality of the dried product.

Key words: chimney, habanero pepper, open sun drying, performance, quality, solar dryer

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 4
July 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

INTRODUCTION

Postharvest losses of fruits and vegetables in Africa ranges from 30% to 80% [1, 2]. This is largely due to the lack of effective postharvest systems for handling, processing and storage of the food product, resulting in a deficit in food availability. It is, therefore, important to close this gap by reducing the rate of postharvest losses.

Fruits and vegetables are highly profitable commodities for both small and large-scale farmers in Ghana. However, they are often very perishable and, therefore, postharvest losses can be high. Many fruits and vegetables have production peaks in a short period when high volumes of produce are harvested. Prices are typically low during this glut period but shortly afterwards, prices rise sharply due to poor postharvest systems to maintain quality and extend their shelf-life [3]. In their attempt to mitigate the high postharvest losses, local farmers practice open sun drying by spreading product on mats and exposing them to the sun energy. In as much as this is a cheap method, it tends to be unhygienic and compromises the safety of the food for consumption [4].

During open sun drying, incident solar radiation directly absorbed by the product is used to evaporate the moisture. The rest is reflected back to the atmosphere. The portion of the incident solar radiation that is absorbed and its corresponding wavelength, depends on the colour of the product. However, open sun drying has disadvantages relating to losses in quality and quantity due to loss of essential nutrients and insects and pest infestations [5]. Furthermore, sun drying is not only dependent on the solar intensity fluctuations but also on the environmental air humidity of the location. It characteristically takes place at a slow rate and over a long period from a few days to a month [6].

The use of solar dryers is often preferred to traditional open sun drying of crop products due to their relatively higher drying efficiencies [7]. The use of the solar drying technology for drying vegetables has been recommended in a previous country-wide survey in Ghana [8]. Ghana accounts for about 1% of the world's production of pepper [9] and the commodity has gained significant access to the international horticultural market. Therefore, it is important to follow appropriate preservation procedures to meeting the stringent quality demands. There is abundance of untapped solar energy in the country and using it for solar drying would be a smart and cost-effective approach. Although several types of solar dryers have been introduced into Ghana, there has been slow rate of adoption by local farmers, most likely due to inappropriate designs, high construction costs and non-availability of construction materials. The Horticulture Innovation laboratory of the University of California, Davis, in the United States of America has designed a new chimney solar dryer to overcome this challenge faced by farmers in developing countries [10]. This study aimed at constructing a model of this dryer from local materials and evaluating its performance for drying habanero pepper (a widely preferred and consumed pepper variety in Ghana). Subsequent analysis was conducted to obtain the basic microbial quality parameters of the solar-dried and open sun-dried pepper.

MATERIALS AND METHODS

Design specifications and construction of the chimney solar dryer

The chimney solar dryer constructed for this study is a modification of the dimensions of an original design by the Horticulture Innovation laboratory of the University of California, Davis (UC-Davis), in the United States of America. It was constructed using local materials such as 2 x 4" *Piptadeniastrum africanum* syn. *Piptadenia africana* (known locally as 'dahoma' wood), black fabric, black polythene sheet and plain plastic materials, plastic mesh, thumb pins and wire mesh. The 'dahoma' wood was used for the construction because it is durable and resistant to fungi and termites[11].

The construction of the dryer

The drying table is the main functional structure of the dryer that holds the drying trays and is attached to a chimney (Fig. 1). The table frame was 3 m long, 60 cm high and 45 cm wide. Once the table frame was built, a black fabric and plastic sheet were stretched over the top, bottom and sides and held in position with thumb pins. The black fabric was placed beneath the black plastic sheet. Two narrow strips of wood buttons were attached to the drying table on top of the black materials to hold trays above the surface.

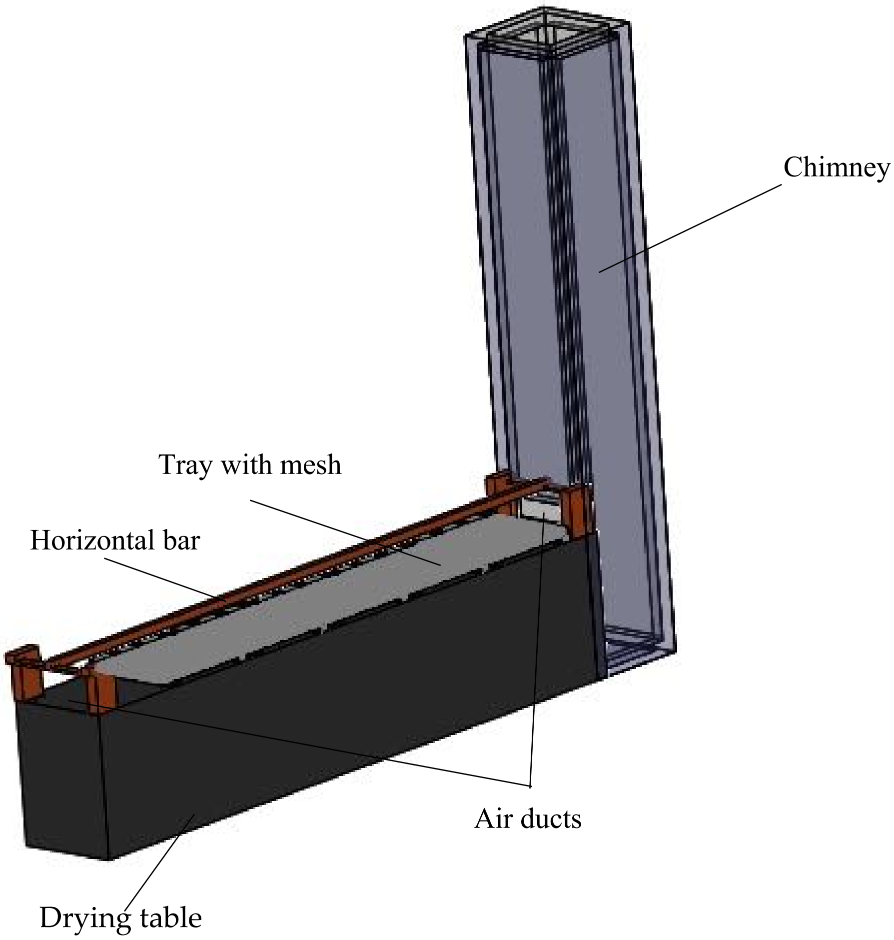
The chimney stood 2.6 m high from the ground. The chimney frame was covered with clear plastic material, securing it to the frame with thumb pins and leaving the top open but covering the bottom. The chimney was attached to the drying table by the aid of two vertical boards. The vertical boards were nailed to the table before fixing the chimney. A horizontal tunnel was created above the drying table by erecting vertical supports from the two ends and fixing a horizontal bar across. The height of the tunnel was equal to the height of two stacked trays plus 5 cm. A rectangular opening was made in the chimney, to allow air to flow out of the it.

After the parts were assembled, a clear plastic sheet was draped over the horizontal bar and the table leaving a tunnel beneath. While doing this, it was important to firmly fix the long ends of the plastic to the ground with stones and other solid materials to minimize the chance of air entering the drying chamber from the sides. Placing the clear plastic material over the tunnel allowed it to be rolled up and lifted off the dryer, providing easy access to the product. It was ensured that the sides of the drying table were air-tight by covering the space between the drying table and the chimney with plastic sheets. This prevented the outside air from short-circuiting the drying table and entering the chimney. Air blew over the product from the open end of the tunnel, picked up moisture from the product and exited through the chimney. Five trays were placed in the tunnel on top of the drying table. Each was made using 4 pieces of wood materials measuring 45 cm x 45 cm. The three (3) dimensional view of the modified design is shown in figure 1(a) while the figure 1(b) shows the constructed chimney solar dryer with pepper samples in it as well as in the open sun.

https://doi.org/10.18697/ajfand.92.18740

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 4
July 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

(a)



(b)

Figure 1: (a) 3-Dimensional drawing of the solar dryer (b) Set-up of the constructed solar dryer with pepper samples in the dryer(left) and the open sun(right)

Performance Evaluation of the Dryer

Freshly harvested habanero pepper was obtained from a Ministry of Food and Agriculture assisted farmer at Jukwa near Cape Coast in the Central Region of Ghana who had harvested at peak maturity. Fruits were sorted to remove defective ones. The dryer was then evaluated by placing five trays on the drying table, each containing 400 g of pepper.

During open sun-drying, the pepper was placed on paper materials of similar dimension to the trays in the dryer and placed on raised platforms of about 20 cm from the ground. After weighing an initial mass of 400 g per sample (for five samples) of the pepper, they were evenly spread on the paper trays to ensure uniformity of drying.

The effectiveness of the chimney solar dryer was compared with that of the traditional open sun drying in a two- sample t-test. The experiment started on 6th March, 2019 and ended on 13th March, 2019. The solar drying lasted up to the 10th of March, 2019 while open sun drying ended on 13th March, 2019. The initial two days recorded 7 h and 4 h of sunlight duration due to unfavourable weather conditions (rainy days) with the rest of the days recording 8 h of full sunlight except the final day (13th March, 2019) for which drying was for only 4 h in the open sun. The initial moisture content (wet basis) of the pepper was determined using the oven drying method at a temperature of 105°C till a constant weight was obtained as reported by Turhan *et al.* [12] and AOAC [13].

The experiment was then set up and at every four (4) hours of drying, the clear plastic covering in the dryer was rolled over to one side. The mass of the pepper in the dryer and that in the open sun were recorded with an electronic weighing balance having maximum value of 2000 g and accuracy level of 0.1 g. The mass loss at each point of drying time was used to calculate the corresponding moisture content. Also, a digital thermohygrometer (HTC-1 temperature/humidity meter) was used to monitor the temperature and relative humidity of the ambient and that of the dryer. One thermohygrometer was placed outside the dryer in the open sun while another was placed at the air exit point of the solar collector table (which also served as the inlet to the chimney). A digital sun meter (Sanpometer LX1010B) was used to measure solar insolation which recorded in lux and the values were converted into watt per square meter (W/m^2) by multiplying by a constant of 0.0079 as proposed by Nouman *et al.* [14]. The temperature, relative humidity and solar insolation were measured on hourly basis during the period of solar drying. The drying time was usually between the hours of 8:30 am and 4:30 pm each day. These parameters are important for determining the performance of a solar dryer.

Determination of the Dryer Performance coefficient

The dryer performance coefficient (DPC) is an effective parameter for assessing the performance of dryers [7]. It is the ratio of the mean relative humidity of the air entering the dryer to the mean relative humidity of the air exiting the dryer during drying. Thus, it is expressed as:

$$DPC = \frac{RH_a}{RH_e} \qquad [1]$$

Where,
RH_a= mean relative humidity of the air entering the dryer (%)
RH_e= mean relative humidity of the air leaving the dryer (%)

Microbial quality of open sun-dried and solar-dried peppers
The analysis was conducted at an accredited laboratory of Food Research Institute, Council for Scientific and Industrial Research of Ghana following standard protocols. *Escherichia coli* and *Staphylococcus aureus* counts were determined using the Nordic Committee on Food Analysis (NMKL) Methods. NMKL 125, 4th Ed. [15] for enumeration of Thermotolerant coliform bacteria and *Escherichia coli* in food and feed and the NMKL 66, 5th Ed. [16], for enumeration of Coagulase positive Staphylococci in foods. Yeast and mould counts were determined using the ISO 21527-1:2008 method.

Microbiological Analysis
Homogenization and Serial Dilution
A one-in-ten dilution of sample solution was prepared using 10 g of dried habanero pepper and 90 ml sterilized Salt Peptone Solution (SPS). The pH of the solution was adjusted to 7.2. Homogenization was conducted for 30 s at normal speed in a stomacher (Lab Blender, Model 4001, Seward Medical, England). Aliquots (1 mL) of diluted sample solutions were pipetted in duplicate into sterile Petri dishes, the appropriate media added and then cultured for enumeration of microorganisms.

Enumeration of Yeast and Moulds
The spread plate technique was used to isolate and enumerate the yeasts and moulds. The media used was Dichloran Rose Bengal Chloramphenicol Agar (Oxoid) at pH 5.6, containing Chloramphenicol supplement. The Chloramphenicol supplement suppresses and prevents bacterial growth. Incubation was carried out at 25°C for 3-5 days in accordance with ISO 21527-1:2008 standard.

Enumeration of *Escherichia coli*
Enumeration of *E. coli* were carried out using the pour plate technique on Tryptone Soy Agar (Oxoid), at pH 7.3. The Tryptone Soy Agar was overlaid with Violet Red Bile Agar (Oxoid), at pH 7.4. Incubation was at 37°C for 24 h for total coliforms and at 44°C for 24 h for *E. coli*. Dark red to purple colonies suspected to be coliforms were confirmed in Brilliant Green Bile Broth (Oxoid), pH 7.4, and incubated at 37°C for 24 h (NMKL No. 44) [15]. Colonies suspected to be *E. coli* colonies were confirmed in EC Broth (Oxoid), pH 6.9. Positive tubes showing gas formation were sub-cultured into Tryptone Water (Oxoid), pH 7.5, and incubated at 44°C for 24 h. The Indole test was then performed for *E. coli* according to the NMKL No. 125 method [16].

Enumeration of *Staphylococcus aureus*
The spread plate technique was used in the determination of *Staphylococcus aureus.* The media used was made up of Baird Parker Agar (Oxoid), Egg Yolk Tellurite Emulsion (SR54), and Blood Agar Base (Oxoid). Incubation was conducted at 37°C for 48 h.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 4
July 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Staphylococcus aureus colonies (grey-black shiny colonies) were further confirmed by biochemical tests in accordance to procedure in the NMKL Method No. 66 standard [17].

Data Analysis

Data with respect to relative humidity, temperature, and moisture content from the experiment were analysed using a two- sample t-test in Minitab version 16 at a significance level of 0.05. For the relative humidity and temperature, there were thirty-five data points for the dryer and ambient conditions, while for the moisture content, there were ten data points for solar drying and fifteen for the open sun drying. All graphs were plotted using Microsoft excel.

RESULTS AND DISCUSSION

Variation of temperature and relative humidity during drying

Figure 2 shows the temperature variation during the drying period in the dryer and the ambient air. During the first 4 h of drying, the temperature of both the ambient air and the exiting air in the dryer tended to rise. In general, the dryer temperature was found to be mostly higher than that of the ambient temperature. The mean dryer temperature was 46.4°C while that of the ambient temperature was 36.2°C. The t-test result (Table 1) shows that there was a significant difference between ambient and dryer temperatures (p=0.000). The presence of the cloth and black polythene covering the drying table provided maximum absorption and transmission of incident solar radiations. Thus, most of emitted radiations were trapped inside the chimney dryer and hence the higher temperature recorded compared to that of the ambient [18]. A similar result was reported by Svenneling [19], for an indirect type of dryer where the temperature rise in the dryer reached a maximum of above 50°C. Tibebu *et al.* [20] also reported a maximum temperature in their constructed solar dryer of 53.3°C as compared to 37.8°C for ambient temperature.

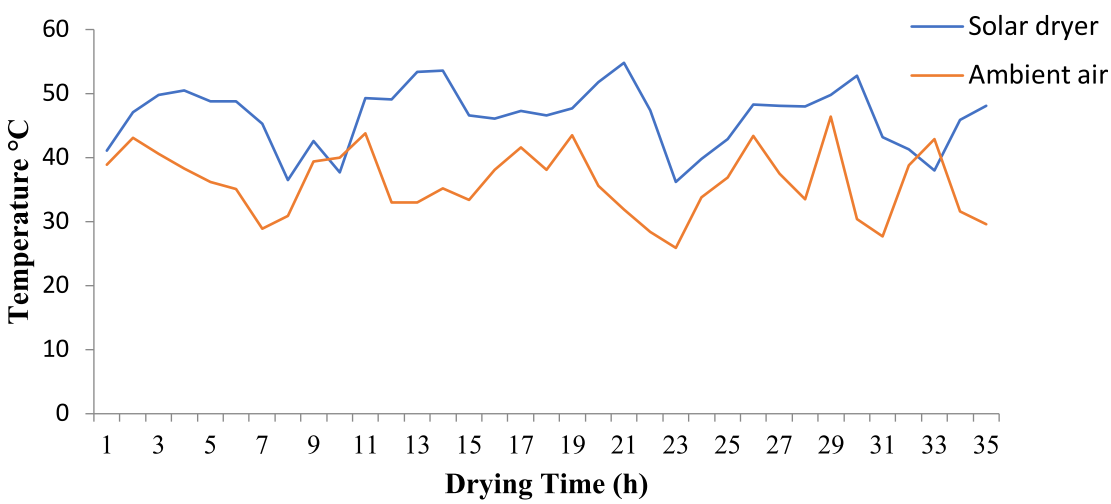


Figure 2: Hourly variation of temperature versus drying time during the drying period in the chimney solar dryer

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 4
July 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Figure 3 shows changes in the relative humidity versus time for the chimney solar dryer and the ambient air. Although there was no significant difference (p=0.054), as shown in Table 1, the average relative humidity inside the chimney solar dryer was mostly lower than that of the ambient. While the ambient recorded between 33% to 83% relative humidity, the dryer recorded between 25% and 68%. This is in agreement with the findings by the Horticulture Innovation Laboratory (UC-Davis) that the new dryer tends to produce a lower humidity compared to the ambient and, therefore, speeds up the drying process [21]. Also, in this work, relative humidity dropped from 68% to 36% within 2 to 3 h of drying on the first day in the solar dryer. Similarly, in the work of Bala *et al.* [22], relative humidity dropped from 70% to 55% after 1 h of solar drying. Also, Jain and Tiwari [23] in their work on cabbage and peas drying recorded relative humidity values of 62% and 71% for open sun and greenhouse drying, respectively at the onset of drying.

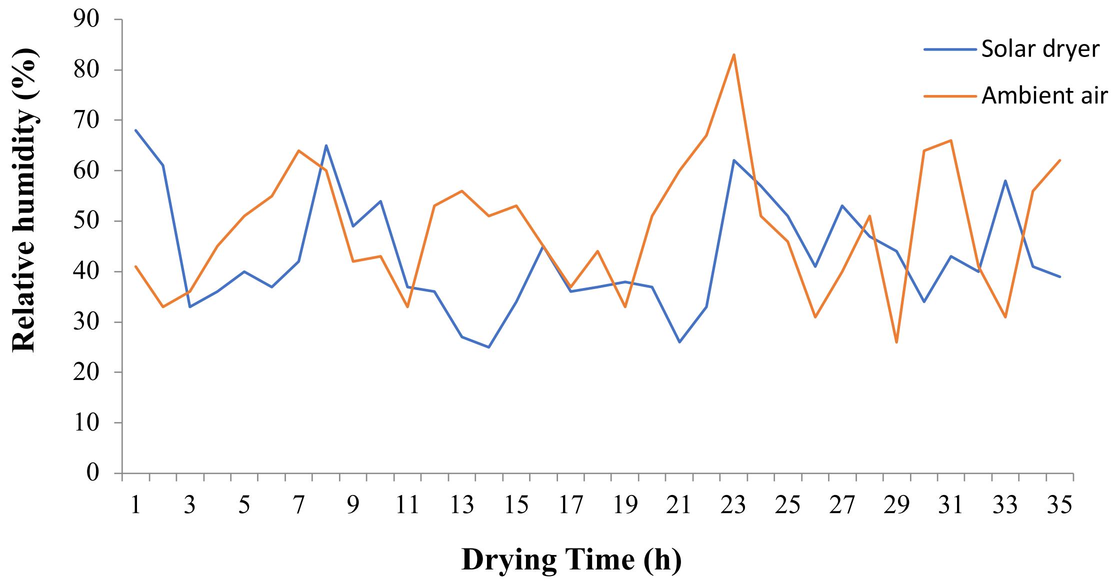


Figure 3: Hourly relative humidity versus drying time over the drying period in the chimney solar dryer

Solar insolation over the solar drying period

Figure 4 shows the trend of solar insolation recorded during solar drying. The trend generally observed was that solar insolation rose to a peak value during the first 3 h of drying (8:30 to 11:30 am). Thus, the mean maximum and minimum solar insolation value were 823.18 W/m^2 at 11:30 pm and 107.84 W/m^2 at 4:30 pm, respectively. The higher insolation values depict high temperature in the surrounding as well as inside the chimney of solar dryer; lower insolation values portray the reverse. Usually, solar insolation has direct effect on the heating of the dryer and how fast it dries the product and, therefore, suggests that drying before 11:30 am could lead to effective and faster drying. This in agreement with the work of Itodo *et al.* [7]. Jadhav *et al.* [24] and Sevda and Rathore [25] also obtained similar results during drying of grapes, green peas and aonla pulp in solar tunnel dryer and cabinet solar dryer, respectively.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 4
July 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

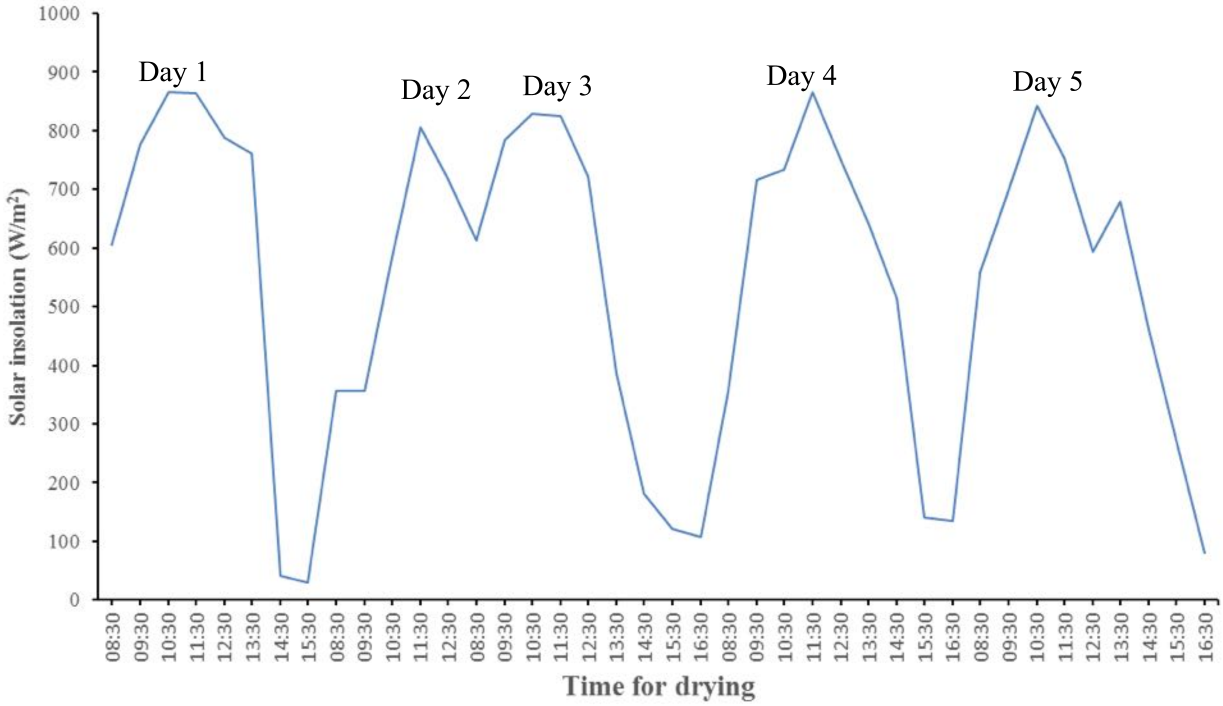


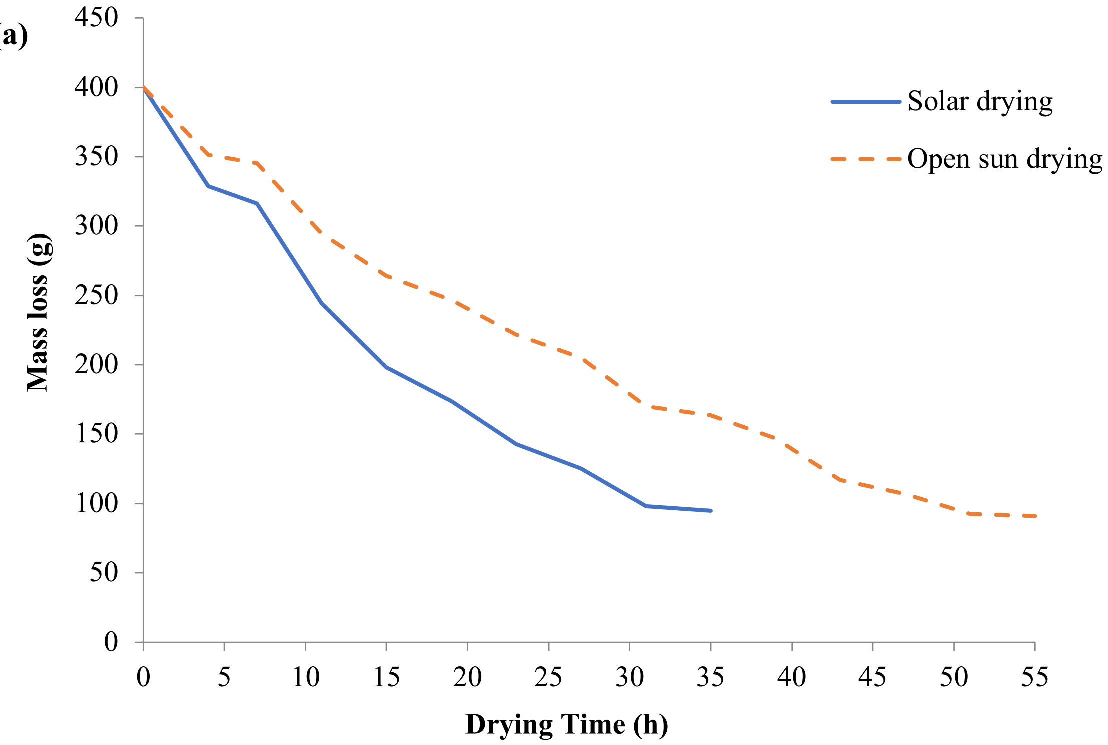
Figure 4: Solar insolation trend during solar drying

Drying performance of the solar dryer

Figure 5 shows the mass loss (a) and moisture content (b) curves of the solar dryer compared to the open sun drying of the pepper. The total drying duration for the chimney solar dryer was 35 h after which there was no appreciable loss in mass of the product. However, for the open sun drying, it took an extra three (3) days (55 h of total drying time) for the drying process to be completed. It could be observed that after 7 h, the moisture content of pepper in the dryer had reduced from 85.25% to 64.3% and from 85.25% to 71.5% for chimney solar drying and open sun drying, respectively. While the chimney dryer dried the pepper down to 8.9% within five days, the open sun drying recorded 7.9 % after the three extra days. This indicates that solar drying tends to increase the rate of moisture removal compared to open sun-drying. Similar reports by Bala and Janjai [22] on the solar drying of fruits, vegetables and spices indicated that the moisture content of mango decreased gradually from 78.87% at the commencement of drying to 22.48% at the end of drying. Koua *et al.* [26] also presented a graph of moisture content of banana against drying time (hours) that showed a steep slope during the first 4 h followed by a gradual decreasing slope towards the end of drying.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 4
July 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

(a)



(b)

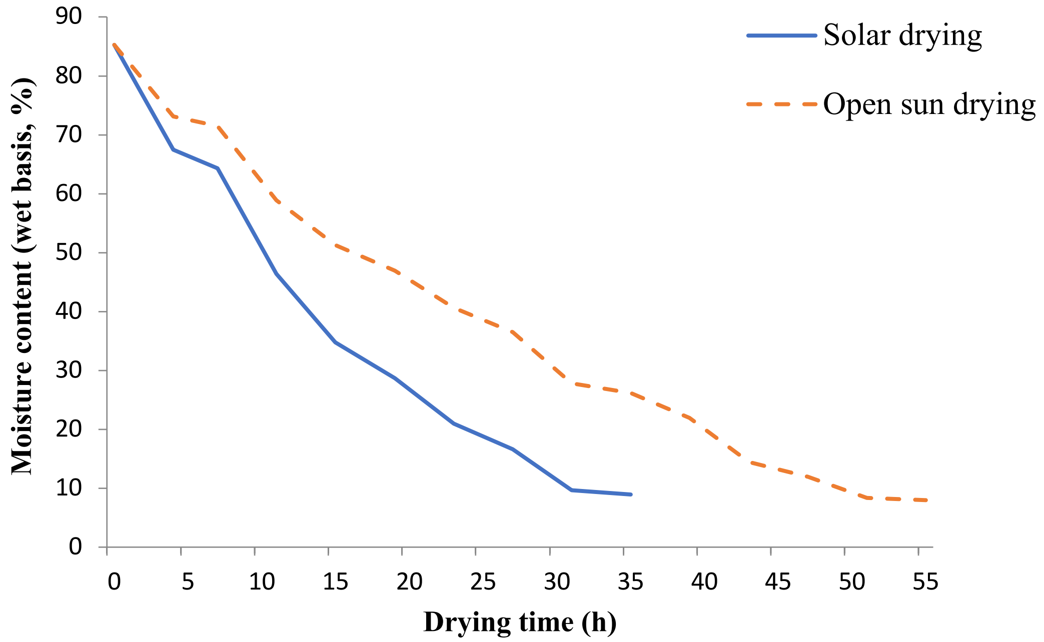


Figure 5: Mass loss (a) and moisture content (b) curves for the solar drying and the open sun drying

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 4 July 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 2 shows the dryer performance coefficients (DPC) per day and its mean value over the first five days of solar drying. This parameter gives an indication of the effectiveness of a solar dryer. A dryer performance coefficient greater than one (1) indicates high drying efficiency as reported by Itodo *et al.* [7]. An average value of 1.21 was recorded for the five-day period of solar drying which was satisfactory and gives a positive indication of the effectiveness of the solar dryer for drying the product.

Microbial and food safety analysis of the dried pepper samples

The microbiological analysis of the solar-dried and open sun-dried peppers (Table 3) shows that, the mean bacterial count for *Escherichia coli* was <10 cfu/g for the two types of drying methods. This result is acceptable and is in conformity with the Ghana standard [27] for ground / whole spices. The yeast and mould counts for solar-dried habanero pepper was 4.30 x 10^4 cfu/g and that for open sun-dried habanero pepper was 2.52 x 10^5 cfu/g. Effectively, it shows that there were more yeast and mould growths in the open sun than the solar-dried pepper, which implies a better quality of dried food product for the latter. The result of the solar-dried pepper is consistent with studies conducted by González *et al*. [28] in Argentina on paprika, where yeast and mould counts ranged from 2 x 10^2 to 1.9 x 10^5 cfu/g. The result reported by Yogendrarajah *et al*. [29] and Hashem and Alamri[30] on spices also confirm the findings of this study.

For *Staphylococcus aureus*, although the Ghana Standard Authority [27] does not specify any microbiological limit, the results of <10 cfu/g are good, in comparison to the generally acceptable criteria of 10^2 cfu/g [31]. According to the Code of hygienic practice for spices and dried aromatic herbs, the safety of species and dried herbs depends on maintaining good hygienic practices along the value chain. Bacteria that are spore formers such as *Clostridium botulinum*, *Bacillus cereus* and *Clostridium perfringens* have also been found in spices as well as non-spore forming bacteria such as Salmonella, *Staphylococcus aureus* and *Escherichia coli*. Codex Alimentarius International Food Standards [32] also indicates that safety of spices and dried herbs are also affected by mycotoxin producing moulds and this is evidenced in the high counts of yeast and mould in the processed pepper samples. Figure 6 shows pictures of the habanero pepper before and after drying in the solar and the open sun drying. It could be seen that at the end of drying, colour, which is a quality parameter of spices like pepper, was found to be more preserved under the solar drying than under open sun drying. This confirms the work of Rodriguez *et al.* [33] that using solar dryers tends to preserve the colour of the product and may enhance its overall consumer acceptability.

Figure 6: Fresh pepper before drying (a), Solar-dried pepper (b), Sun-dried pepper (c)

CONCLUSION

In this study, a model of a new chimney solar dryer was constructed with local materials and its performance evaluated against open sun drying after which basic microbial quality analysis was done on the dried habanero pepper. The performance of the solar dryer was found to be superior to open sun drying. The solar dryer generated mean higher temperatures and lower relative humidity compared to ambient parameters, which effected faster drying and gave a high dryer performance. In addition, the microbial analysis indicated that the solar-dried pepper was of a better quality than the open sun-dried pepper.

Future work could focus on deploying this technology to farmers and food processors through Agricultural Extension Agents and assess its impact on their livelihoods

ACKNOWLEDGEMENT

The authors acknowledge Ms Lauren Howe and her team from the Horticulture Innovation laboratory of the University of California, Davis in the USA for granting us technical advice and permission to construct a model and carry out the performance evaluation of the chimney solar dryer designed by their institution.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 20 No. 4
July 2020
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 1: T-test result for temperature, relative humidity and moisture content

Variable	Mean (Standard Deviation)		Estimate for difference (95 % Conf. Interval)	T-value	P-value
Temperature	*SD (n=35)*	*A (n=35)*	10.25	8.45	0.000
	46.41(4.88)	36.15(5.26)	(7.83, 12.68)		
Relative Humidity	*SD (n=35)*	*A (n=35)*	-5.57	-1.96	0.054
	43.0 (11.0)	48.6(12.6)	(-11.23,0.09)		
Moisture Content	*SD (n=10)*	*OSD (n=15)*	-0.5	-0.05	0.960
	38.3 (26.6)	38.8(25.1)	(-22.8, 21.7)		

n-number of data points, SD- solar dryer, A- ambient, OSD- open sun drying

Table 2: Dryer performance coefficient (DPC)

Day 1	Day 2	Day 3	Day 4	Day 5	Mean
1.03	1.20	1.34	1.03	1.45	1.21

Table 3: Mean bacterial counts for Solar dried and Open sun-dried Habanero peppers

	E.coli **count (cfu/g)**	***Staphylococcus aureus*** **count (cfu/g)**	**Yeast and Mould count (cfu/g)**
Solar dried peppers	<10	<10	4.30×10^4
Open sun-dried peppers	<10	<10	2.52×10^5

REFERENCES

1 **Kitinoja L, Saran S, Roy SK and AA Kader** Postharvest technology for developing countries: challenges and opportunities in research, outreach and advocacy. *J of Sci Food and Agric*, 2011; **91(4)**: 597-603.

2 **Wakholi C, Cho B-K, Mo C and MS Kim** Current state of postharvest fruit and vegetable management in East Africa. *J of Biosys Eng*, 2015; **40(3)**: 238-249.

3 **Arah IK, Ahorbo GK, Anku EK, Kumah EK and H Amaglo** Postharvest Handling Practices and Treatment Methods for Tomato Handlers in Developing Countries: A Mini Review. *Adv in Agric*, 2016; **2016**: 8.

4 **Schiavone DF, Teixeira AA, Bucklin RA and S Sargent** Design and Performance Evaluation of a Solar Convection Dryer for Drying Tropical Fruit. *Appl Eng in Agric*, 2013; **29(3)**: 391-401.

5 **Shitanda D and NV Wanjala** Effect of Different Drying Methods on the Quality of Jute (Corchorus olitorius L.). *Drying Tech*, 2006; **24(1)**: 95-98.

6 **Belessiotis V and E Delyannis** Drying: methods and systems–principles of drying procedures. Book n Greek. Athens: Sideris Publishing Co, 2009, 844.

7 **Itodo IN, Ijabo JO, Charles JA, Ezeanaka NN and SO Akpa** Performance of Desiccant Solar Crop Dryers in Makurdi, Nigeria. *Appl Eng in Agric,* 2019; **35(2)**: 259-270.

8 **Jensen S, Flemming F and E Kristensen** Survey on solar fryers for drying of food and wood in Ghana. 1st ed. 1999: Danish Technological Institute, Energy Division.

9 **Owusu-Kwarteng J, Kori F and F Akabanda** Effect of Blanching and Natural Convection Solar Drying on Quality Characteristics of Red Pepper (*Capsicum annuum L*). *Int J of Food Sci*, 2017: 6pp.

10 **Deltsidis A, Aalia K, Reid M, Thompson J, Mitcham E, Hansen B, Bell M, Dawson B and A Jarman** Chimney Solar Dryer Manual. University of California Davis. 2018, California: Horticulture Innovation Laboratory, UC-Davis.

11 **Bentum A** Properties of Ghanaian timbers: Dahoma (Piptadeniastrum africanum Hook. f.). in Technical Newsletter. 1970, Forest Products Research Institute, Ghana: Accra. 19-21.

12 **Turhan M, Turhan KN and F Sahbaz** Drying Kinetics Of Red Pepper. *J of Food Process and Preserv*, 1997; **21(3)**: 209-223.

13 **AOAC.** Official Methods of Analysis of AOAC International. 15th ed. 1990, Maryland, USA: AOAC International.

14 **Nouman A, Chokhachian A, Santucci D and T Auer** Prototyping of Environmental Kit for Georeferenced Transient Outdoor Comfort Assessment. *Int J of Geo-Info*, 2019; **8(76)**: 1-23.

15 **NMKL 44.** Coliform bacteria. Detection in foods and feed. 6th Ed. 2004. NordVal International, Lyngby.

16 **NMKL 125.** Thermotolerant coliform bacteria and Escherichia coli. Enumeration in food and feed. 4th ed. 2005. NordVal International, Lyngby.

17 **NMKL 66.** Enumeration of Coagulase positive Staphylococci in foods. 5th ed. 2009. NordVal International, Lyngby.

18 **Sodha M** Analytical and experimental study of open sun drying and a cabinet type drier. *Energy Convers. and Man*, 1985; **25(3)**: 263-271.

19 **Svenneling J** Constructing a solar dryer for drying of pineapples: implementing a solar dryer for sustainable development in Ghana, in Faculty of Technology and Science2012, Karlstands University, Netherlands.

20 **Tibebu TB, Obeng G, Mensah E and A Smith** Solar Dryer With Biomass Backup Heater For Drying Fruits: Development And Performance Analysis *J of Sci and Tech*, 2016; **36(2)**: 10-25.

21 **Deltsidis A, Mukherjee A, Islam M, Wheeler L, Mitcham E, Thomasson J and M Reid** New chimney dryer desing results in faster drying due to higher air speeds. In Symposia on Tropical and Temperate Horticulture. 2018. *Acta Hortic*. 1205.

22 **Bala B and S Janjai** Solar drying of fruits, vegetables, spices, medicinal plants and fish: Developments and Potentials. In International solar food processing conference. 2009.

23 **Jain D and GN Tiwari** Effect of greenhouse on crop drying under natural and forced convection. . *Energy Convers and Man*, 2004; **45**: 765-783.

24 **Jadhav D, Visavale G, Sutar N, Annapure U and B Thorat** Studies on solar cabinet drying of green peas(*Pisum sativum*). *Drying Tech*, 2010; **28(5)**: 600-607.

25 **Sevda M and N Rathore**. Experimental investigation of the performance of the solar tunnel dryer for drying aonla pulp. *Int. J of Global Energy Issues*, 2009; **31(2)**: 183-192.

26 **Koua KB, Fassinou WF, Gbaha P and S Toure** Mathematic al modelling of the thin layer solar dryingof banana, mango and cassava. *Energy*, 2009; **34**: 1594-1602.

27 **Ghana Standards Authority**. Ghana Standards GS 955 in Microbiological Analysis of Foods – Sampling Plans and Microbiological Criteria 2019.

28 **Melo González MG, Romero SM, Arjona M, Larumbe AG and G Vaamonde** Microbiological quality of Argentinian paprika,. *Rev Argentina de Microb,* , (2017); **49(4)**: 339-346.

29 **Yogendrarajah P, Deschuyffeleer N, Jacxsens L, Sneyers P-J, Maene P, De Saeger S, Devlieghere F and B De Meulenaer** Mycological quality and mycotoxin contamination of Sri Lankan peppers (*Piper nigrum L.*) and subsequent exposure assessment. *Food Cont*, (2014); **41**: 219-230.

30 **Hashem M and S Alamri** Contamination of common spices in Saudi Arabia markets with potential mycotoxin-producing fungi. *Saudi J of Biol. Sci.,*, 2010; **17(2)**: 167-175.

31 **Microbiological Reference Criteria for Food**. Food Administration Manual Version 2.(1995). Available at https://www.mpi.govt.nz/dmsdocument/32902-microbiological-reference-guide-assess. Accessed on 19/5/2019.

32 **Codex Alimentarius International Food Standards.** Code of hygienic practice for spices and dried aromatic herbs (CAC/RCP 42), 2014.

33 **Rodriguez E, Figueroa I and C Mercado** Feasibility Of Analysis of Drying Process Habanero Chilli Using a Hybrid-Solar-Fluidized Bed Dryer in Yucatan, Mexico. *J of Energy and Power Eng*, 2013; **7**: 1898 - 1908.