IJEW 国际工程期刊 International Journal of Engineering Works انجینئرنگ کاموں کا بین الاقوامی جرنل

International Journal of Engineering Works
ISSN-p: 2521-2419
ISSN-e: 2409-2770
Vol. 6, Issue 10, PP. 339-346, October 2019
https://www.ijew.io/
https://doi.org/10.34259/ijew.19.610339346

Extensive Performance Evaluation of a 75Kg Solar-Biomass Hybrid Tunnel Dryer with Several Types of Agricultural Products

Sahibzada Imad ud din[1], Asif Ali[2], Suhail Zaki Farooqui[3]
[1,2,3] Department of Renewable Energy Engineering, U.S.-Pakistan Center for Advanced Studies in Energy, University of Engineering and Technology Peshawar, Pakistan
immiedwardian@gmail.com[1], chemasif85@gmail.com[2], suhail.zaki@uetpeshawar.edu.pk[3]
Received: 26 September, Revised: 01 October, Accepted: 03 October

***Abstract*—**Solar-biomass hybrid tunnel dryer has been designed to dry different kinds of agricultural products.The dryer is comprised of three major parts, solar collector(inside the drying chamber), backup heating stove and an additional collector connected to the drying chamber through PVC pipes. This study presents the performance evaluation of the dryer. Collector average efficiency was found to be 29.7% and the drying efficiency for the system was 22.8%. The tunnel dryer was run on solar energy and solar-biomass energy for different set of tests. Different types of vegetables and fruits were dried in the tunnel dryer. A total of 7 solar-biomass hybrid tunnel dryer were constructed out of which 6 were installed in Swat KP Pakistan (Regions: Chikrae, Tal sar, Badalae, Jarro, Charbagh and Khwazakhela). Swat being the most effective area in respect of producing fruits. The post harvest losses are high. The total capacity of the dryer was found to be 75Kg.

***Keywords*—** Solar drying, Solar-biomass dryer, Hybrid Drying, Temperature, Relative Humidity

I. INTRODUCTION

Solar drying is one of the cheapest method to preserve food. Solar drying systems are reliable and environment friendly [1]. Drying cost of solar dryers are very low compared to other drying techniques [2]. Additionally, drying of food through solar drying systems require generally little space and brief amount of time to dry the food material [3]. Moreover, solar drying is one of the most efficient drying method used worldwide. It is far more advantageous than Open Sun Drying (OSD). In OSD the food is spreaded on the sheets placed on the grounds. Microbacterial and other enivironmental friendly insects can easily attack the food material in OSD [4,5]. The food in OSD needs an intensive labor, because one has to cover the food during night time or rainy days. Quality deterioration occurs when direct UV rays falls on the food material.

Solar dryers are one of the most used food drying systems in 21st century. Food material is well protected inside the drying chamber. Temperature inside the drying chambers are high, so no microorganism can grow on the surface of food material. The moisture inside the drying chamber is carried by the hot air. This moisture is thrown into atmosphere through a chimney or an exhaust fans depending upon the type of the dryer. The optimum temperature for drying is in the range of 40-60 ^{0}C. Solar dryers encourages farmers to overcome the post harvest losses. Because post harvest losses are one of the major issue rural areas farmers are facing [6].

Persimmons, locally known as Amluk, are cultivated in northern areas of KP Pakistan on large scale. According to Small and Medium Enterprises Development Authority (SMEDA) 71,265 tons of Persimmons are produced annually in Swat; 28,000 tons of which are wasted [7]. In Swat KP Pakistan mostly persimmon are dried on customarily methods. The short usability time after harvesting of persimmons makes it a challenge for farmers to reduce the post harvest losses. For this purpose 6 commercial scale 75Kg solar-biomass tunnel dryer was designed, fabricated and installed in Swat.

This paper presents the extensive performance evaluation of the solar-biomass hybrid tunnel dryer. Different tests were performed to find the extensive paramteres of the dryer. A 50Kg of batch of tomatoes, as well as different fruits and vegetables were dried.

II. MATERIALS AND METHODS

A. Description of the Dryer

Solar-biomass hybrid tunnel dryer was designed and fabricated shown in Figure 1. It is composed of three major parts; GI stove, Drying Chamber(contains a solar collector and a heat exchanger) and an additional solar collector. The GI stove is fabricated with a height of 0.72m and width of 0.57m. Drying chamber is supported by a mild steel frame. The height of the drying chamber from the ground is 1.6m. The length and width of the chamber is 2.4m and 1.2m respectively. The additional solar collector is connected to the drying chamber. This collector is fabricated with the length, width and height of 2.4m, 2.4m and 0.2m respectively.

Figure 1: Design of the tunnel dryer

Four DC exhaust fans are installed on the drying the chamber (2 at each opposite ends). These exhaust fans are run a solar PV system shown in Figure 2. Furthermore two blowers are run by the battery. The blowers are connected to GI stove and additional solar collector for different set of experiments.

Figure 2: Solar PV system (Dryer installed in SWAT)

B. *Performance Evaluation of the Dryer*

Performance of the dryer was categorized based on the following sections.

1) *Temperature Measurement*

A digital thermometer logger(Tm-947SD) was used to determine temperature at different points in the dryer. Temperature readings were taken at the top,middle and bottom trays. The ambient temperature readings were also logged.

2) *Humidity Measurement*

A digital hygrometer (Elitech RC-61) was used to measure relative humidity inside and outside of the dryer.

3) *Solar Radiation Intensity*

Solar radiation intensity readings were taken from the meteorological station installed at UET Peshawar Pakistan.

4) *Collector Unit Efficiency*

Collector unit efficiency for the dryer was calculated by using the formula:

$$\eta_c = \frac{\dot{m} C_p (T_c - T_{am})}{I_s}$$

$\dot{m}$; Mass Flow Rate
C_p ; Specific Heat Capacity of Air
T_c ; Collector Temperature
T_{am} ; Ambient Temperature
I_s ; Solar Radiation

5) *Drying Efficiency*

The drying efficiency for the dryer was calculated using the formula:

$$\eta_{\text{drying}} = \frac{W\ L_v}{I_{st} A_e}$$

η_{drying} ; Drying Efficiency
W ; Total Weight Loss
L_v ; Latent heat of vaporization of water
I_{st} ; Total Solar Radiation
A_e ; Effective area of collector receiving I_s

6) *Drying Rate*

Drying rate of the dryer was found using the equation:

$$DR = \frac{W_i - W_f}{t}$$

DR ; Drying Rate
W_i ; initial weight of the sample
W_f ; final weight of the sample
t ; Total Drying Period

III. Results and Discussions

This solar-biomass hybrid tunnel dryer can be operated in four different modes.

- Solar Energy Drying
- Solar Drying with Additional Solar Collector
- Solar-biomass Drying
- Biomass Drying

A. *Solar Energy Drying*

A batch of 50Kg tomotoe was dried using the solar energy. Temperature on top, middle and bottom trays, and solar radiation intensity was recorded throughout the experiment, shown in figure 3. It is noticed that the temperature at the top trays are high, it is because the top trays get both direct and indirect solar radiations. It took only four days to dry the whole batch of tomatoes. Total weight of the tomatoes were reduced to 3.1Kg. The dried tomatoes were kept into closed containers after the drying. Relative humidity was also recorded inside and outside of the drying chamber, shown in figure 4. We observe that relative humidity inside the dryer is very small as compared to outside relative humidity, which makes it easier inside the dryer to capture more and more water molecules from the food product.

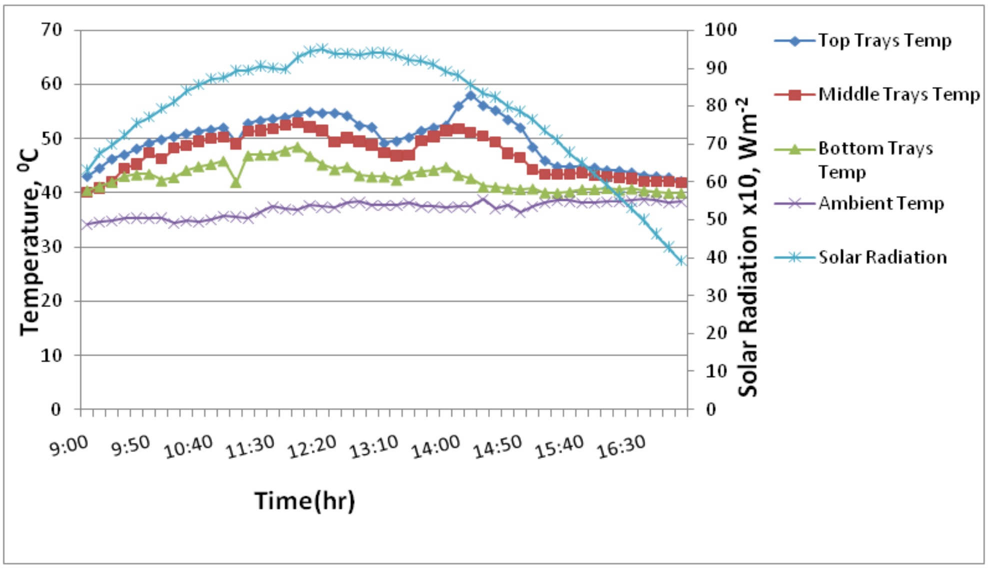

Figure 3: 13th June,2019 Temperature Inside Drying Chamber

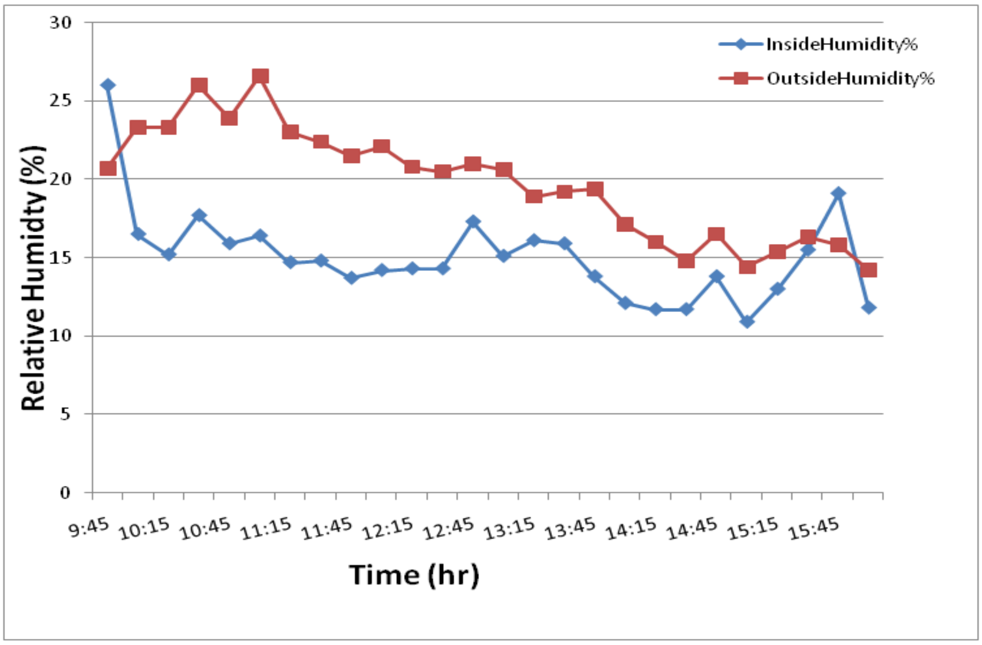

Figure 4: 13th June, 2019 Relative Humidities

B. Solar-Biomass Hybrid Drying

Different types of fruits and vegetatables were dried using solar-biomass drying. Similarly for this drying the temperature and humidity data was logged for three days, shown in figure 5 and 6. The data was logged for continously 24 hours. It is noticed that the drying temperature was controlled for 5 hours after the sunset using the charcoal as a fuel. Total of 5Kg charcoal was burnt in the stove for five hours. It took three days to completely dry the sample of mangoes ,melon, green chilli, bitter gourd and eggplant.

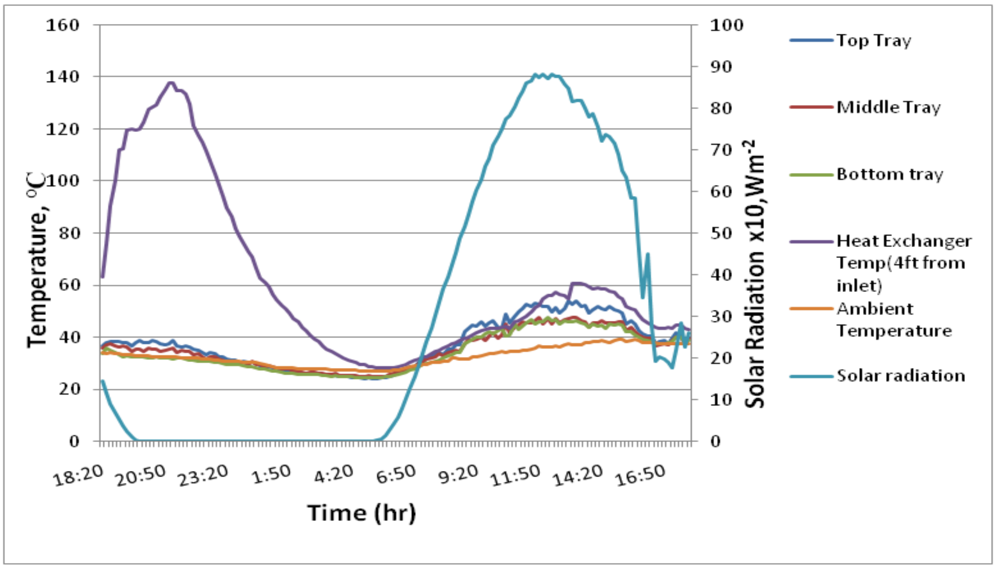

Figure 5: Hybrid Drying 24 hours (18-19June, 2019)

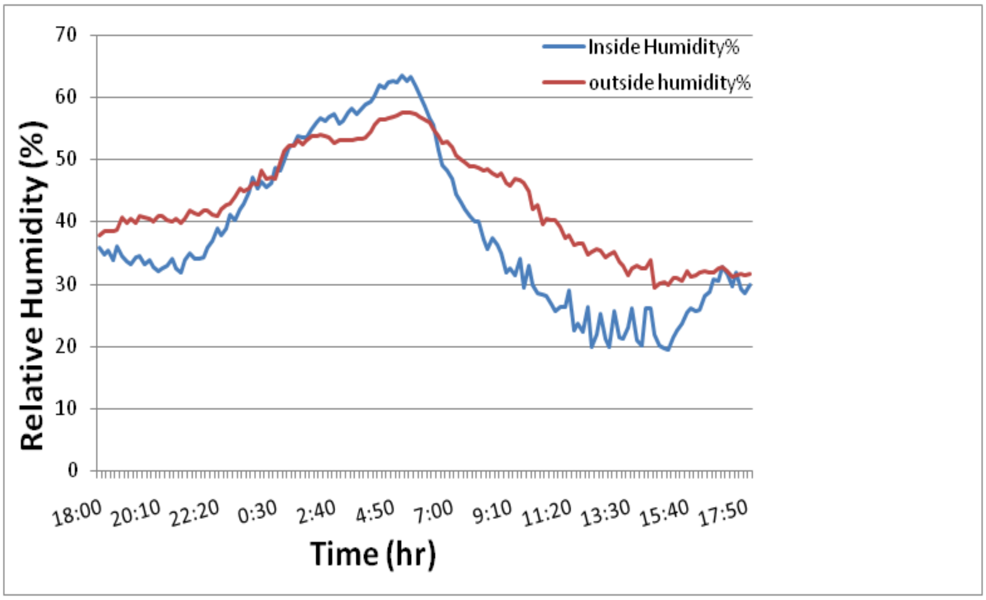

Figure 6: Hybrid Drying Relative Humidity (18-19June,2019)

C. No-Load Biomass Test

This test was performed to find out the temperature gradient of the heat exchanger. Charcoal was burnt in the GI stove. Hot gases were pushed into heat exchanger through a DC blower connected to the bottom of the stove. The temperature readings were recorded on various points throughout the length of the plate surface. We can see from figure 7,8 and 9 the different temperature values at different points of the plate. Figure 10 shows the peak temperatures on different points, while figure 11 shows the temperature gradient of the plate.

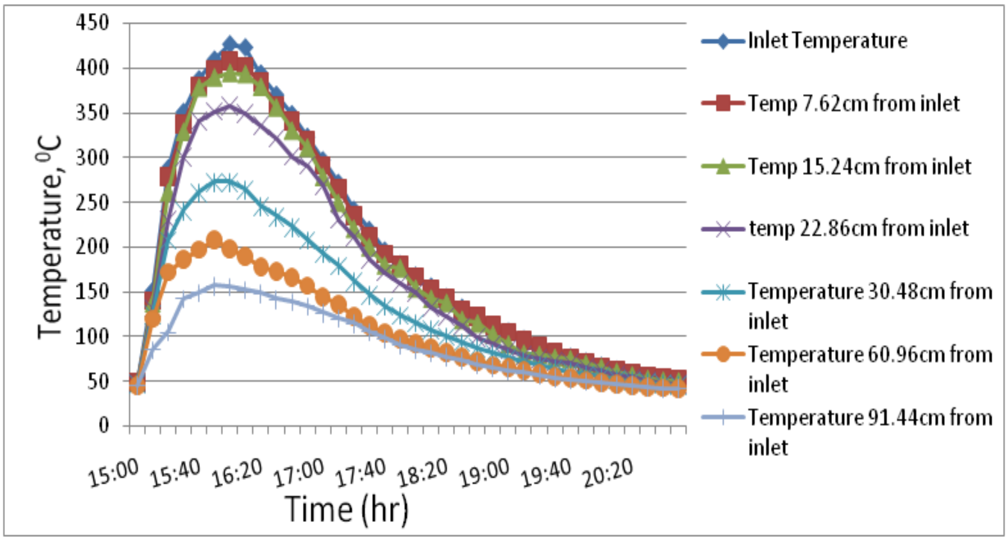

Figure 7: Plate Temperature (0-91.4Cm)

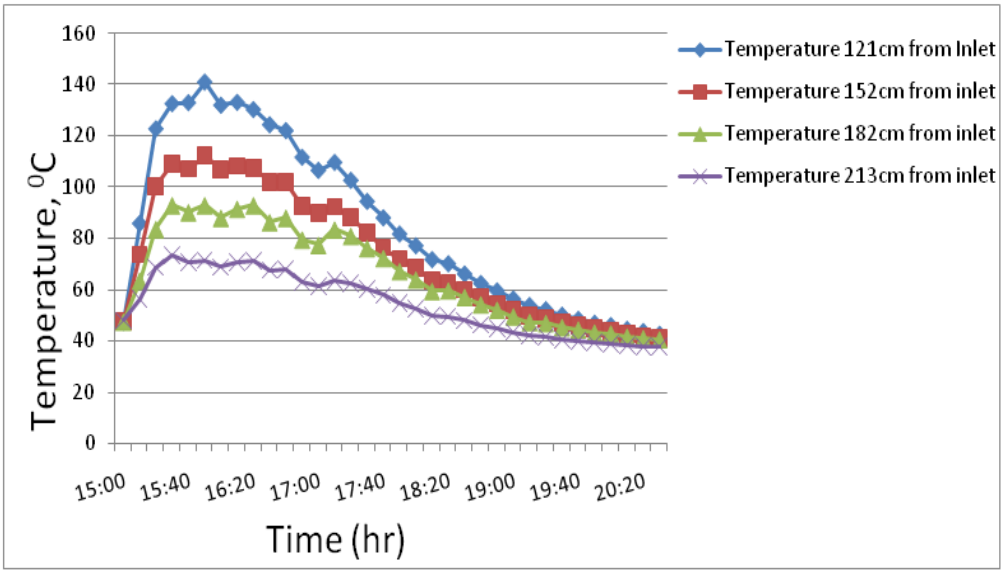

Figure 8: Plate Temperature (121-213Cm)

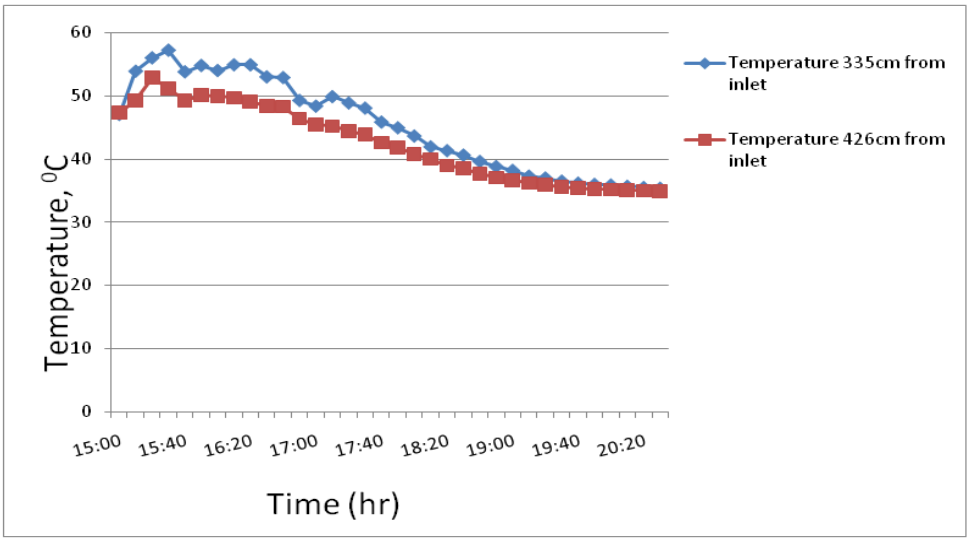

Figure 9: Plate Temperature on 335Cm and 426Cm

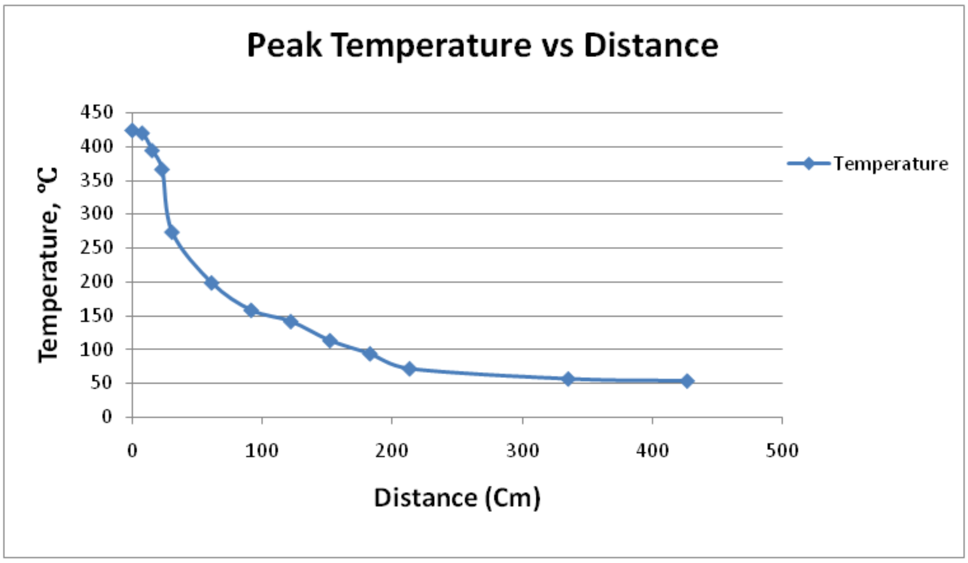

Figure 10: Peak Temperature on Different Points

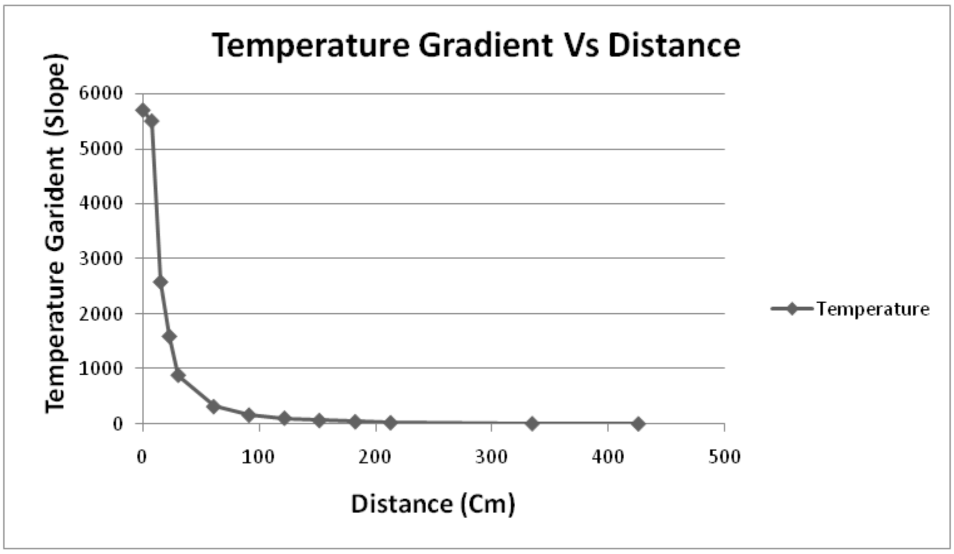

Figure 11: Tempearature Gradient

D. Dryer Performance Evaluation

Collector unit efficiency was calculated on 20th June 2019. From figure 12 we can see that the collector efficiency varies from 8% to 46% throught out the day. Hence the average efficiency of the collector was found to be 29.7%. The drying efficiency for the system was found to be 22.8%. These efficiencies can vary depending on the solar radiation intensity of that area. These experiments were conducted in Peshawar, Pakistan. The drying rate for the 50 Kg batch of tomatoes was found to be 1.48Kg/h. The volumetric flow rate of air going out of the chambers was $0.11m^3/s$.

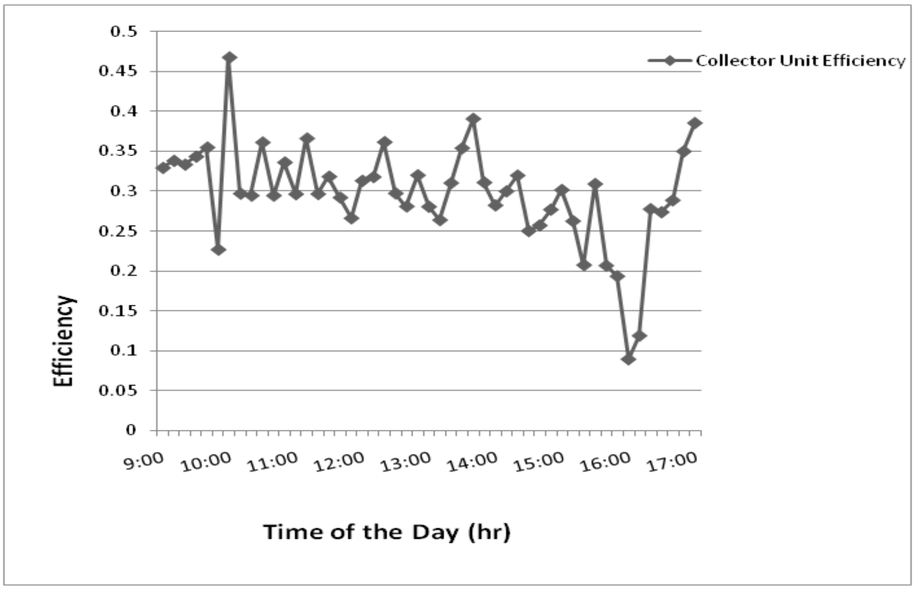

Figure 12: Collector Unit Efficiency

Conclusion

A mixed mode solar-biomass tunnel dryer was constructed from the locally available material in market. The maximum temperature attained inside the dryer was 59.2 ℃. The biomas backup heating system ensures the drying of food products on rainy days or night time. Tomato batch of 50Kg was reduced to 3.1KKg during 32 drying hours. Food inside the dryer is safe from the environmental contaminations. The moisture content is continuously removed by the exhaust fans installed on the drying chamber. Swat being the most productive in respect of fruits; post harvest losses are high. This solar-biomass hybrid tunnel is expected to provide a way for preserving the food for longer periods of time.

References

[1] A, Sharma et. al (2009) Solar-energy drying systems: a review, Renewable and sustainable energy review, 13(67): 1185-1210.

[2] GuttiBabagana, Silas, K and Mustafa, B.G., Design and construction of forced/natural convection solar vegetable dryer with heat storage, ARPN journal of engineering and applied science, 7(10), (2012) 72-77.

[3] Mujumdar, Arun and DevahastinSakamon, Mujumdars practical guide to industrial drying, Montreal: Exergex corporation, (2000).

[4] Joshi, Pallavi and Mehata, Dipika, Effect of drying on the nutritive value of drumstick leaves, *Journal of Metabolomics and Systems Biology*,1(1), **(**2010**)** 5-9

[5] Joshi, Pallavi and Mehata, Dipika, Effect of drying on the nutritive value of drumstick leaves, *Journal of Metabolomics and Systems Biology*,1(1), **(**2010**)** 5-9

[6] Blair R. et. al (2007) Design of a solar-powered fruit and vegetables dryers

[7] SMEDA to establish fruit dehydration unit in swat https://fp.brecorder.com/2017/06/20170623191996/

.