# INVESTIGATION TOWARD DIRECT SOLAR DRYERS WITHOUT THERMAL ENERGY STORAGE AND WITH THERMAL ENERGY STORAGE

**VIVEK G[1*], PRAKASH P[2], SURENDAR G[1] and SAKTHI S[1]**

[1]*Assistant Professor, Department of Mechanical Engineering, Arifa Institute of Technology, Nagapattinam, Tamilnadu, India.*

[2]*Assistant Professor, Department of Mechanical Engineering, Krishnasamy College of Engineering and Technology, Cuddalore, Tamil Nadu, India.*

---

**Abstract:**

In this experiment, a direct solar dryer frame that is made up of a rectangular steel grid is used. The direct solar dryer is well-insulated with a suitable insulating material. The experiment is carried out by using thermal energy storage using sensible heat, which is implemented inside the copper tube presented in the experimental setup, which involves storing heat in a solid or liquid. The performance of the direct solar dryer with thermal energy storage will be evaluated in terms of the drying rate, energy efficiency, and quality of the dried produce. The results of this study will be useful in developing a low-cost and sustainable drying system for small-scale farmers to improve their income and reduce food waste

**Keywords:** solar drying system, thermal energy storage, ANN, Mass flow rate of air.

## INTRODUCTION

The project aims to design and develop a direct solar dryer with thermal energy storage to address the challenges faced by small-scale farmers in drying their agricultural produce. The direct solar dryer utilizes solar energy to dry crops, and the thermal energy storage system ensures that the dryer operates even during cloudy or non-sunny days. The design of the direct solar dryer involves solar radiation directly radiating inside the cabinet and heating the product inside the cabinet tray. The thermal energy storage system, on the other hand, is composed of a sensible heat storage material that stores the excess heat during the day and releases it at night or during cloudy periods.

In agricultural drying processes such as drying fruits and vegetables, elimination of product spoilage, heat preservation processes, etc. So, the direct solar drying system is well suited for these applications because it is simple, compact, weightless, quiet, does not use open drying or other conventional dryers, and also requires little maintenance.

**The main objective of this project work is**

1. To make the experimental setup of the direct solar drying system with the necessary components and measuring instruments.
2. To experiment with different temperatures for drying rate.
3. To find the maximum temperature as well as moisture content, the efficiency of the system, and the performance of the direct solar drying system.
4. To compare the efficiency by using without and with the thermal energy storage.
5. To analyze the system efficiency with the help of an artificial neural network (ANN) in MATLAB software.

**Formulation and Experimental Methods**

The main source of solar energy is radiated from the sun, and the solar radiation is allowed to fall on the solar dryer. The direct solar dryer consists of an insulating chamber that traps the solar radiation inside the drying chamber, and the top surface of the dryer is covered with toughened glass to facilitate easy entry of radiation. This leads to an increase in temperature at the drying cabinet. Inside the drying cabinet, the trays are arranged one by one to place the drying product, which is made of aluminum. At the drying chamber, an inlet port and an outlet port are provided for easy airflow with the help of a DC fan. This solar drying system uses the forced convection airflow system. The DC fan works with the help of solar panels without any external power source. In the direct solar dryer, thermal energy storage is included at the bottom of the trays; in this experimental setup, sensible heat storage plays an important role in drying the product. Sensible heat storage is an energy storage medium that absorbs solar radiation in the daytime and releases heat at night. The sensible heat storage system consists of a thermal energy storage material. In this experiment, engine oil is used as TES, which is included in the copper tube. Then the experiment was conducted in the method of with and without thermal energy storage, and the direct solar dryer experiment was conducted by including with load and without load. The drying sample is used as 1 kg of onion slices, and the tabulation readings are noted and calculated for the moisture content, drying rate, and system efficiency.

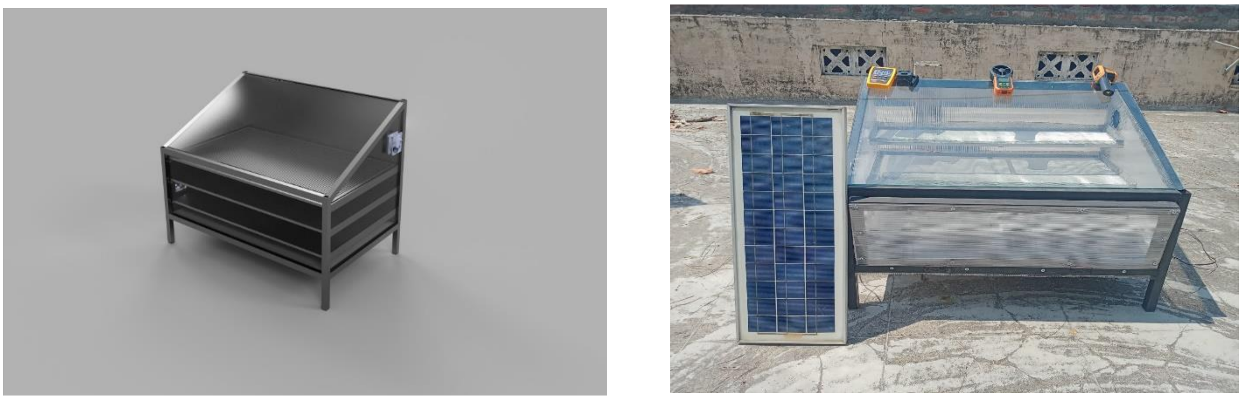

**Figure 1. Computerized representation and photographic view of the direct solar dryer.**

**FORMULA'S USED:**

**HEAT AVAILABLE PER UNIT AREA IN (KJ/hr.m$^2$)**

Heat available per unit area (KJ/hr.m$^2$) = $\frac{Pyranometer\ reading}{Pyranometer\ constant} \times 3600$ (1)

**HEAT AVAILABLE IN THE SOLAR DRYER (KJ/hr)**

Heat available in the solar dryer = Heat available / unit area × Area of the collector (2)

**TOTAL HEAT GAINED BY THE AIR (KJ/hr)**

Total heat gained by the air = $m C_P \Delta T$ KJ/hr (3)

where,

m – Mass flow rate of the air (kg/hr)

$C_P$ – Specific heat of air = 1.005 (kJ/kg. K)

$\Delta T$ – Temperature difference (K)

**MASS FLOW RATE OF AIR (kg/hr)**

Mass flow rate of the air = $\rho \times A \times V \times 3600$ (4)

where,

ρ – Density of the air (kg/m$^3$)

A – Area of the drying chamber (m$^2$)

V – Velocity of the air (m/s)

**EFFICIENCY (%)**

$$\text{Efficiency} = \frac{\textit{Heat gained by the air}}{\textit{Heat available in the solar dryer}} \times 100 \quad (5)$$

**RESULTS AND DISCUSSION**

In this study, artificial neural networks have been used to model the effects of three important parameters, namely, solar intensity, inlet temperature, and outlet temperature, to predict the performance of the direct solar dryer.

In this approach, experimental data have been used to train and validate the neural network model with MATLAB (R2021) with the neural network fitting toolbox software. In this model, the input is solar intensity, and inlet and outlet temperature are building the neural network structure. Based on experimental data, the efficiency performance of the direct solar dryer has been predicted by three input parameters. That contains up to a few hundred weights, and the Levenberg-Marquardt (LM) algorithm attains the fastest convergence and the highest accuracy. Therefore, LM was chosen as the network training method. Fig 2. shows the structure of the neural network.

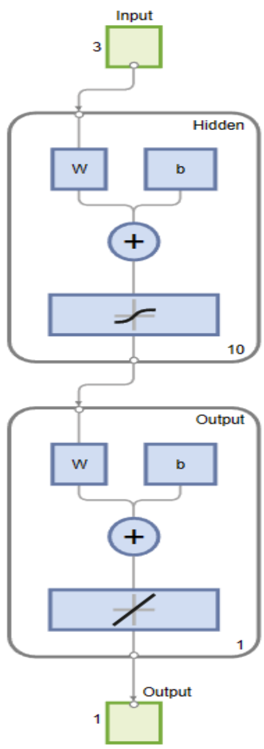


**Figure 2. Structure of neural network**

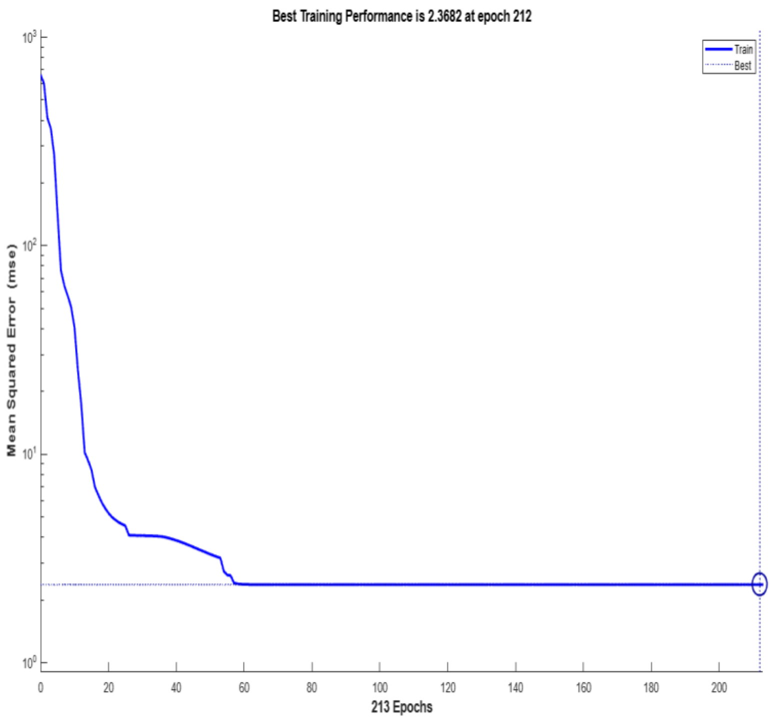


**Figure 3. Performance curve of neural network**

Figure 3. shows the performance curve of the neural network. The best training performance is 2.3682 at epochs 212.

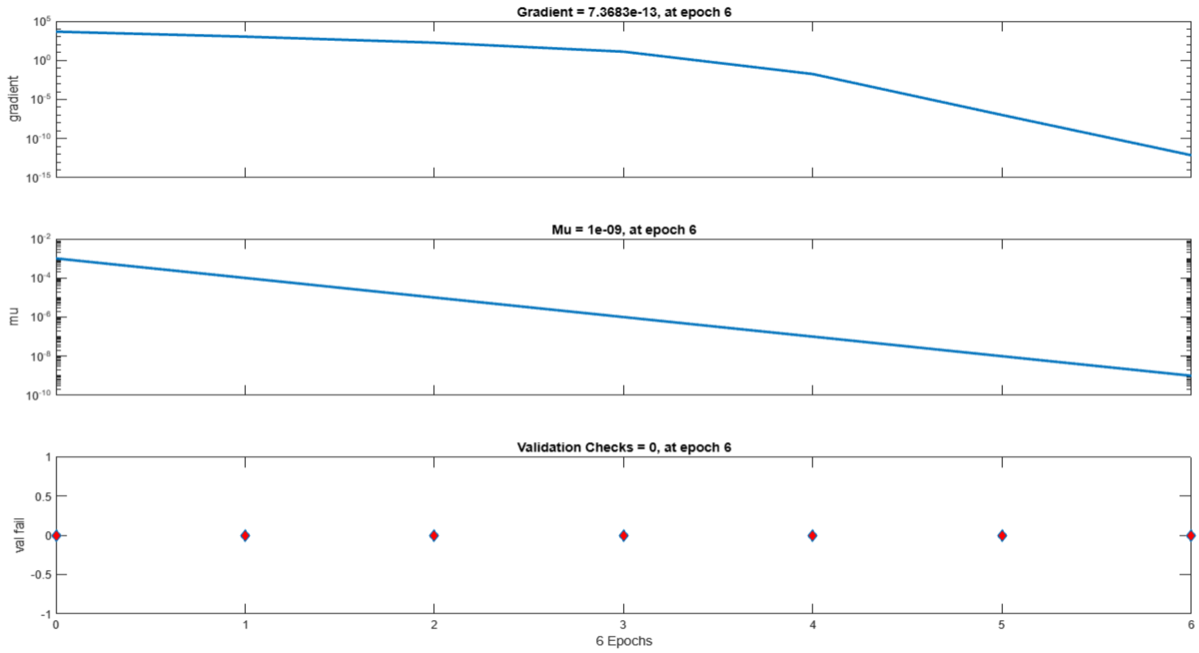


**Figure 4. Training state of neural network**

In this study, ANN has been used to investigate the effects of three important parameters (I, Ti, and To) on the drying efficiency performance of the direct solar dryer. Figure 5. shows the linear regression curve of the neural network. The overall R-value of 0.99736 shows that this ANN model fits with the experiment value.

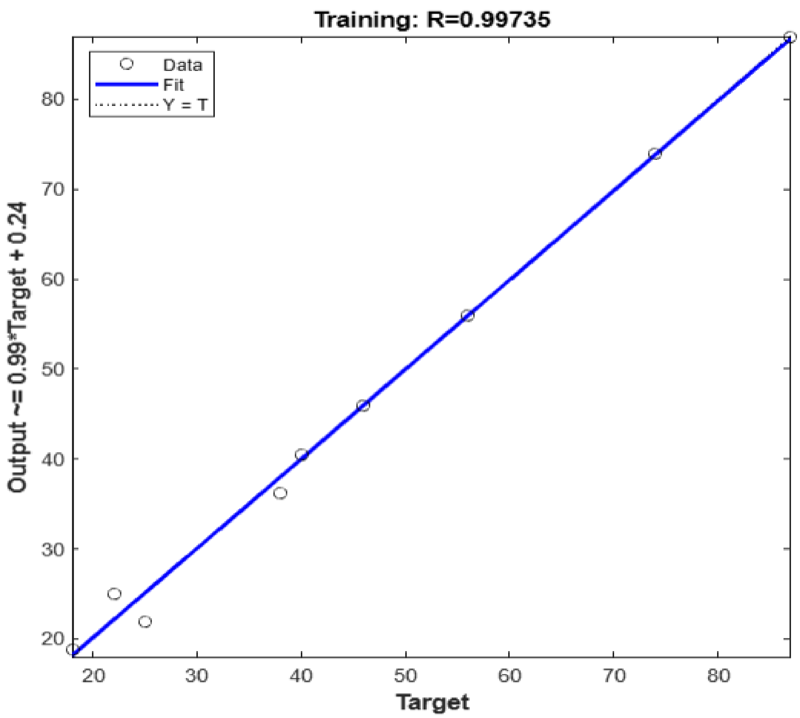


**Figure 5. Linear regression curve of the neural network**

From Fig 6. and Fig 7. The graphical representation was used to analyze the efficiency and comparisons of the different times in this design. And also compared with experimental and ANN working model simulation values.

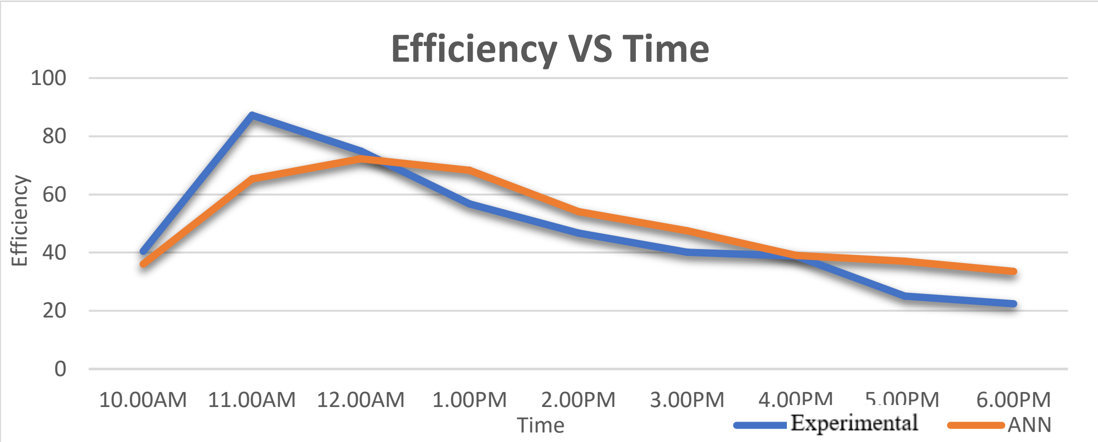


**Figure 6. Without Thermal energy storage**

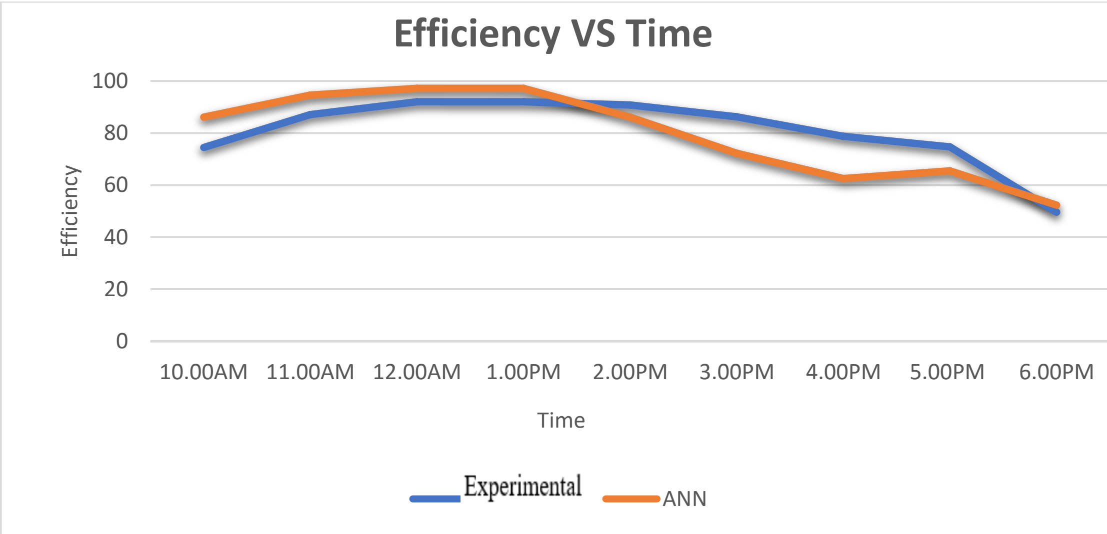


**Figure 7. With Thermal energy storage**

## CONCLUSION

As a result, the drying time is reduced, leading to higher throughput and improved productivity. Additionally, the performance evaluation may reveal that the direct solar dryer with thermal energy storage exhibits superior drying performance compared to traditional drying methods. The controlled heat source and optimized airflow within the system ensure uniform drying, preservation of product quality, and prevention of spoilage or degradation. These factors make it a suitable solution for various applications, including food processing, agricultural products, and timber drying. In this experimental setup, we know that the usage of TES (87.25) and non-usage of TES material (87.27) differ more at the peak hours. So, we conclude that efficiency, which is compared with the help of MATLAB (R2021) software to compare the efficiency and data prediction value, is (65.29) & (94.60).

## REFERENCES

1. Jain, D., and Tiwari, G.N. (2003), 'Thermal aspects of open-sun drying of various crops', Energy, Vol. 28, pp. 37–54.

2. Mekhilefa, S., Saidurb, R., Safari, A., 2011. A review on solar energy use in industries Renewable and Sustainable Energy Reviews, 15, pp. 1777–1790.

3. Abene A, Dubois V, Le Ray M, Ouagued A. Study of a solar air flat plate collector: use of obstacles and application for the drying of grape. Journal of Food Engineering 2004; 65(2004):15–22.

4. Sharma AK, Adulse PG. Raisin production in India. Pune: NRC for Grapes; 2007.

5. Eissen W, Muhlbauer W, Kutzbach HD. Solar drying of grapes. Drying Technology 1985; 3(1):63–74.

6. S. Dhanushkodi, Vincent H. Wilson, K. Sudhakar, Mathematical modeling of drying behavior of cashew in a solar biomass hybrid dryer, Resource-Efficient Technologies (2016), doi: 10.1016/j.reffit.2016.12.002.

7. P. Murugan, S. Dhanushkodi, K. Sudhakar, and Vincent H. Wilson. Tech Science Press, EE, 2021, vol. 118, no. 3. DOI: 10.32604/EE.2021.013491.

8. Abhishek Gautam, R.P. Saini. A review on sensible heat-based packed bed solar thermal energy storage systems for low-temperature applications. Solar Energy 207 (2020) 937–956.

9. El-Sebaii AA, Aboul-Enein S, Ramadan MRI, ElGohary HG. (2002) Experimental investigation of an indirect type natural convection solar dryer. Energy Convers Manage, 43(16):2251–66.

10. Avesahemad Husainy, P.R. Kumari, Design development and performance evaluation of an indirect forced convection solar dryer for grapes, International Journal of Scientific Research and Development, Vol. 3, Issue 03, 2015 (ISSN: 2321-0613).