

DESIGN AND DEVELOPMENT OF NATURAL CONVECTIVE SOLAR DRYER

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Abstract

Solar drying has emerged as a potential drying solution for agricultural products in many developing nations. The drying behavior of the product to be dried depends on many parameters of the dryer. A box-type natural convective solar dryer was developed to analyze the drying performance of Wood chips. Experiments revealed promising drying results with drying efficiency. The design of the dryer could further be enhanced by hybridization with an external heat source.

Keywords: solar energy, drying, wood chips

1. Introduction

Today, the world is facing a global energy security crisis. Renewable energy sources are now considered as the next generation of energy sources. Solar, among the other sources, has emerged as a significant player in providing user-friendly solutions. Wood has been an age-old source of energy for many developing nations. To make the optimal use of the wood for energy production requires going through pretreatment processes. In the postharvest creation of biomass, the wood or woodchips moisture content plays a significant role. In many thermochemical processes to harvest energy from wood, such as pyrolysis, combustion, or gasification, moisture content needs to be optimal. Drying is the phenomenon of removing the water content from the product such as wood, sometimes also referred to as dehydration. It's observed in the pyrolysis process.[1] The liquid product has inferior quality due to concentrated tar. The prime reason for the formation of tar is the moisture content in the woods, which forms tar and reduces the combustion capacity of the mass. Even in Pellet production, the high water content in the mass can lower energy efficiency and higher carbon emissions. thus to obtain maximum benefits of the energy utilization from wood, it becomes inevitable.[2]

Many times open sun drying is considered the easiest and cheap drying technique. In the field of agriculture and crop production, this method is used for a long time. The major drawback in open sun drying is the longer time taking process due to uncontrollable drying rates.[3] The unequal heat distribution and fluctuating drying rates affect the product quality as well.[4] These undesirable characteristics of open drying are controlled by the Solar dryers of different designs based on the consumer's

exact requirements. The physical parameters such as drying rate, temperature control, heat ventilation, etc., are the major design consideration in designing a solar dryer.

2. Classification of Solar Dryers

In the last few decades, several solar dryers have been designed and developed by various researchers around the world. The design modules of the dryers could be of any shape, size, and facility. [5] Still, the solar dryers are majorly classified based on air movement inside the dryer, the collectors, and the product to be observed for drying. Based on airflow movement, the dryers are classified into the Forced flow and Natural flow dryers. The classification is depicted in Figure 1. as shown below.

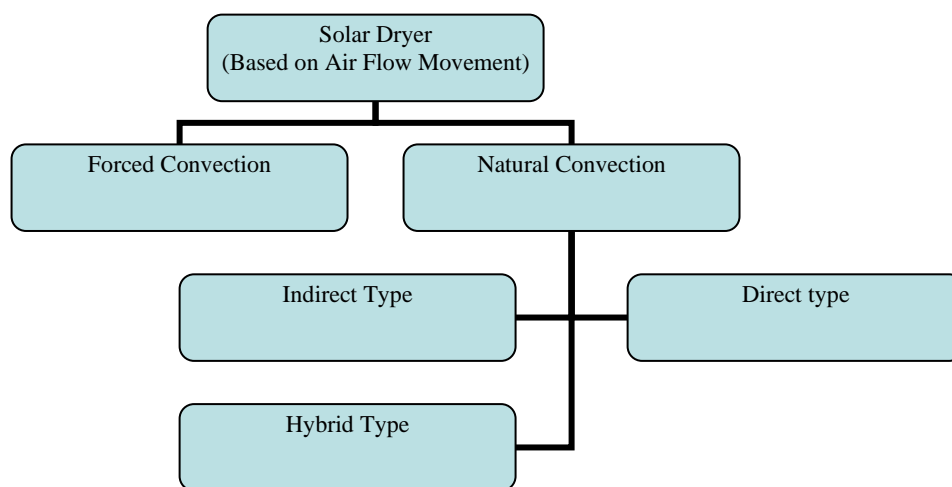


Figure 1. Solar Dryer classification based on airflow movement [6].

If the air movement inside the drying chamber is due to some external force, then the dryer is said to be a forced convection type dryer. On the contrary, if air movement inside the chamber is due to ambient air density, then such dryers are called natural convective dryers. [7] Furthermore, the natural convective dryers could be classified into Direct, Indirect, and Hybrid types based on the design and requirement-based modifications.

In the study, a direct type natural convective lab-scale dryer was designed and developed to understand temperature profiling during different winter seasons. The dryer's air flow is passive in nature and does not require any external fan or blower. The temperature inside the dryer rises during the afternoon and slowly declines with the sunset. This temperature rise gradually increases the dehydration of the product inside the cabinet. The drying efficiency differs for various products and needs different optimal moisture content. There could be dryers also designed on the basis of the size of the agricultural product which needs to be dried. The forced dryers are normally used in cases where a high heat requirement is required for the faster drying process. The airflow increases the heat transfer inside the chamber, which directly affects the drying rate. The cabinet dryer is mostly used to dry small items such as spices, grapes, banana chips, potatoes, chilly flakes, wood chips, etc. In most of the cases, it was observed that the drying rate was mostly 2 to 5 times faster than open sun during models in the field of agricultural products.[8]

3. Materials and Method

The lab-scale cabinet dryer was developed at the institute laboratory of the University of Miskolc. Figure. 2 below depicts the 3D view of the dryer (all mentioned dimensions are in millimeters).

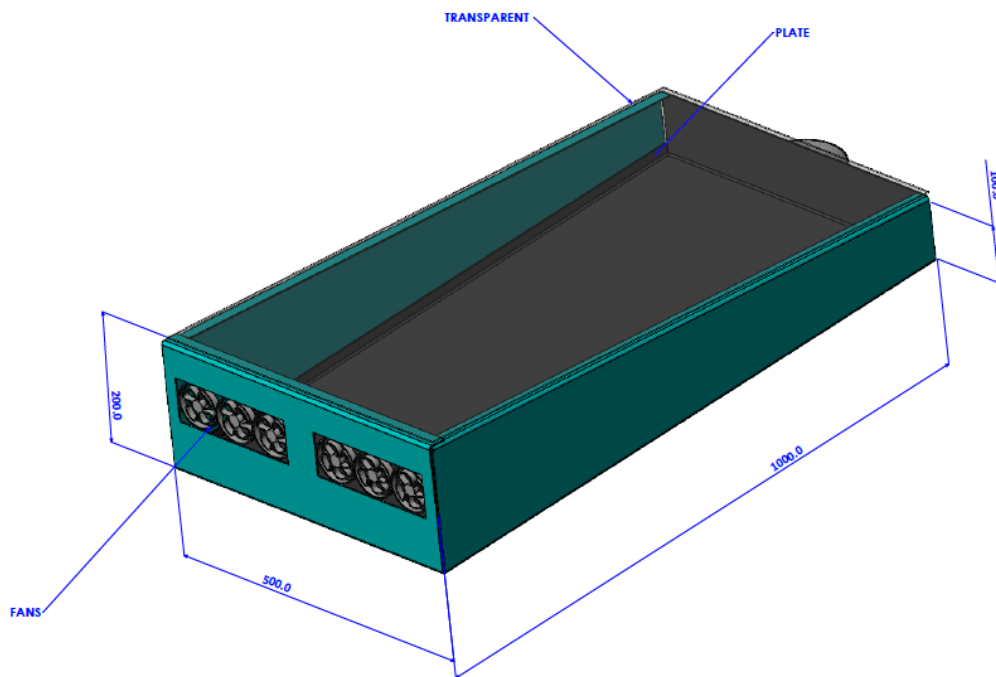


Figure 2. 3D view of the solar dryer developed for experiments.

The dryer's upper part is a transparent glass cover to maximize the heat trap inside the dryer. The inlet and outlet ventilation was provided on the two sides. These ventilation outlets were used to measure the temperature variation inside the dryer. The experiment intended to trap the sensible heat inside and its behavior during the day's different times. The energy conservation analysis could be performed with the equation mentioned as[9]:

$$Q_{ac} + Q_{sc} = Q_{ab} - Q_l$$

where Q_{ac} is the accumulated energy, Q_{sc} is the energy absorbed, Q_{ab} is the absorbed energy and Q_l is the energy lost.

The useful energy can be calculated as:

$$Q_u = mC_p(T_{out} - T_{in})$$

where Q_u is the useful heat, m is the air mass flow rate, C_p is the specific heat of the air, and (T_{out}, T_{in}) are the outlet and inlet temperatures inside the dryer.

4. Observations

To understand the wood chips' drying nature, different sizes of the wood chips were kept under observation. The experiments were conducted in november when the ambient temperature at the city of Miskolc fluctuated between 10 °C to 25 °C. The observations were made only for days when the sunshine was good with a clear sky. It was recorded that the maximum temperature reached during the tests was 35 °C at the outlet on Day1. The temperature profiles reveal that the maximum temperature attained inside the dryer was in the afternoon from 12 PM to 2 PM. The temperature drops fast as the sun gets down in the evening. Hourly change of solar radiation also affects the drying phenomena.

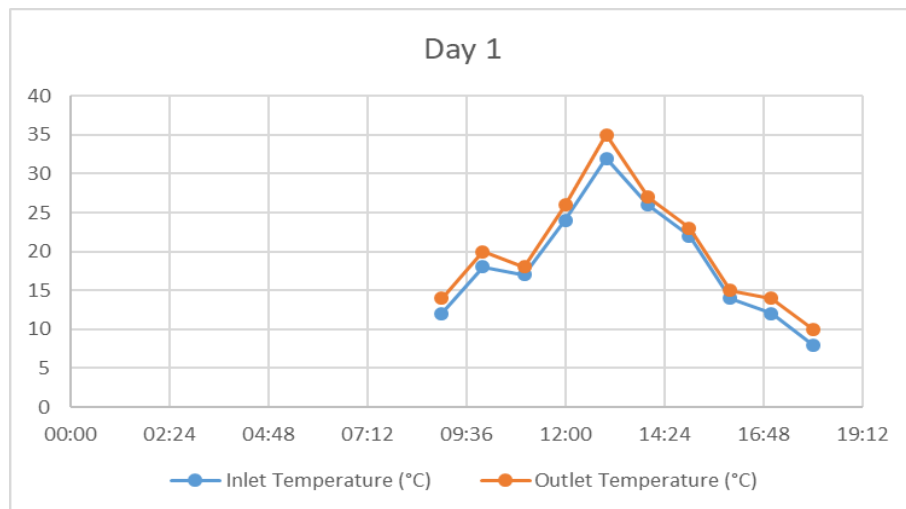


Figure 3. Temperature profiles of the inlet and outlet temperatures at the different days of the experiment (day 1).

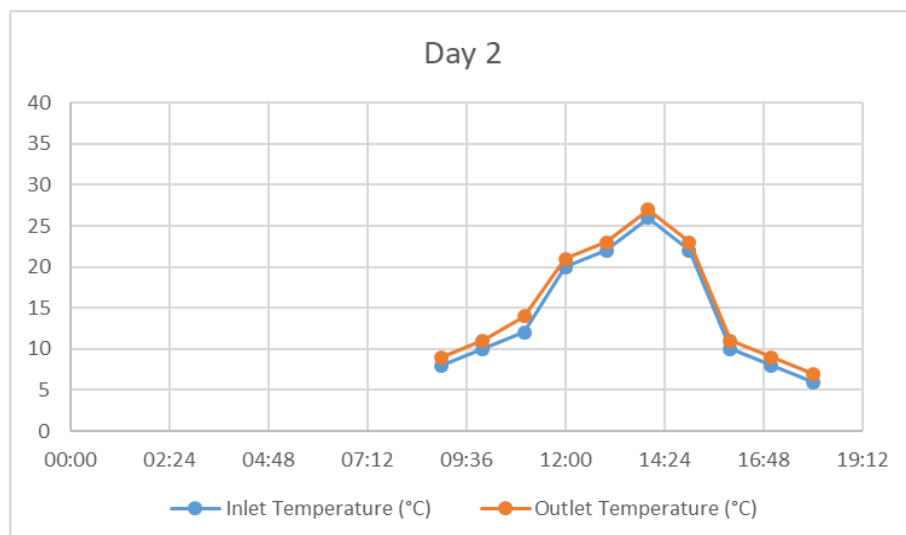


Figure 4. Temperature profiles of the inlet and outlet temperatures at the different days of the experiment (day 2).

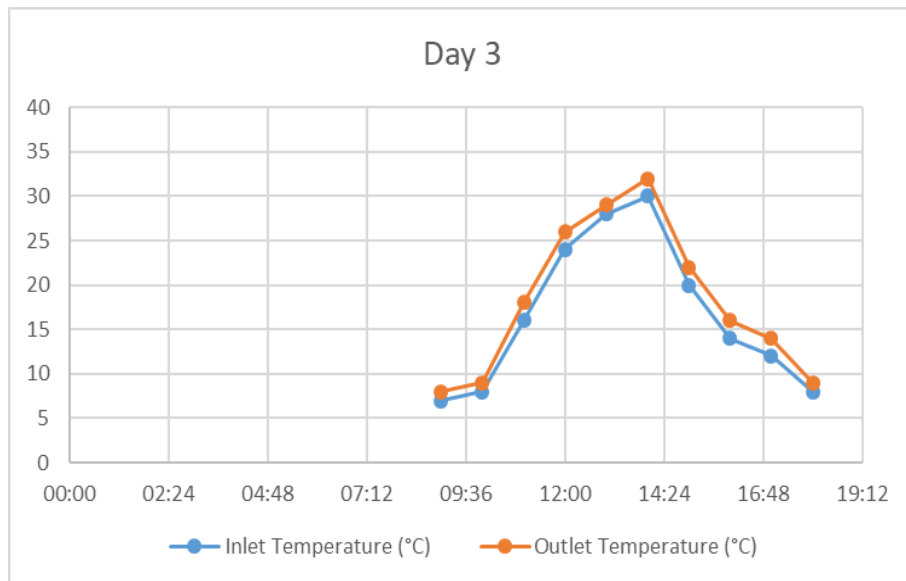


Figure 5. Temperature profiles of the inlet and outlet temperatures at the different days of the experiment (day 3).

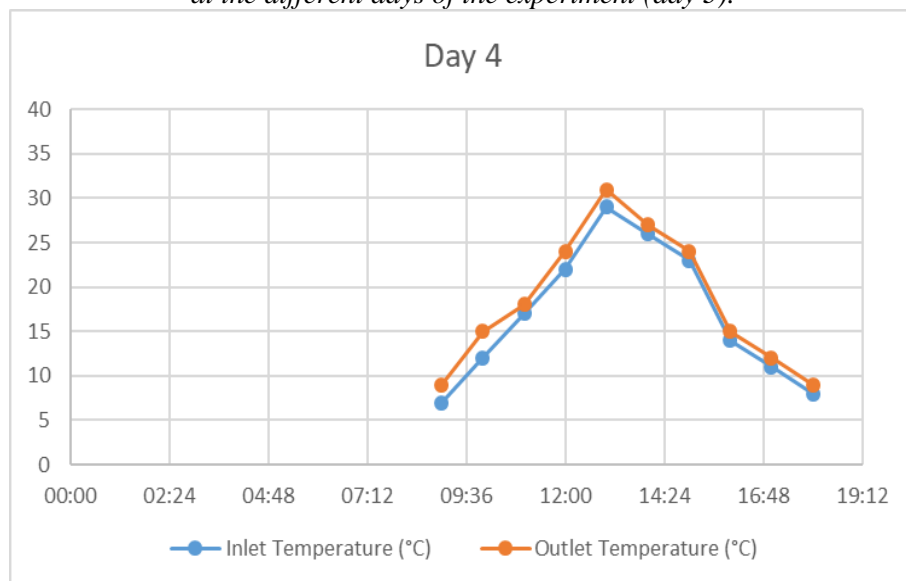


Figure 6. Temperature profiles of the inlet and outlet temperatures at the different days of the experiment (day 4).

Previous to the experiment, the wood chips the moisture measuring device measured moisture content. As shown in Figure 7. the dryer was monitored for temperature readings through thermocouples. The wood chips' initial moisture content was recorded as 45%, and during the experiments, it went down from 45% to 36%, 28%, and finally 24% on the fourth day. The optimal moisture content for the chips for pyrolysis or combustion is somewhere is considered to be near 15%.



Figure 7. Set up of the Solar Dryer for investigation.

The results obtained could be considered much better than open sun drying. Understanding the drying parameters needs a thorough understanding of energy conversion systems.[10] The thermal performance of the dryer could also be enhanced by hybridization. [11]Some studies revealed that in the case of wood drying, the time consumed could be reduced by 24-52% with the use of an external combined heat source such as heat pumps.[12]

In order to further enrich the investigations, summertime would be more suitable for conducting the experiments with higher temperature profiles. The concept of hybridization with an external heat source for continuous drying with latent heat storage, e.g., phase change materials, could be attempted in the next level of studies. [13]Case studies with a computational approach recommend that the size and the diameter of the wood chips could be a substantial drying parameter.[14] Thus the investigation of woody biomass moisture removal also depends on the size, and it affects the economic feasibility of the dryer when operated for a large-scale setup.[15] Mathematical modeling could be another helping tool in understanding energy conversion and finding optimal values.

5. Conclusion

The article contributes to understanding the solar drying behavior of wood chips in the winter season on bright sunny days. The reduction of moisture content proved to be promising to an extent, with a drop from 45% to 25% on winter days in Miskolc. The temperature maximum reached 35°C at the outlet on a given day afternoon. Better results are expected in the summer months, with higher temperature profiling possible. Other aspects of drying and related parameters will be approached for further experiments. This study requires validation of other parameters such as airflow measurement and solar irradiance effects on the drying time.

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