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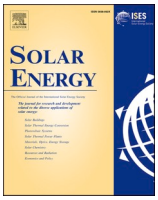

Experimental study and simulation of Hybrid-Active solar thermal cylindrical chamber for Citrus Hystrix leaves drying

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ABSTRACT

This article presents a study of a modular hybrid active solar drying system (MHASD) with parallel collector configuration for the dehydration process of the Citrus Hystrix plant in a cylindrical drying chamber. The system utilized a novel cylindrical drying chamber for solar and low temperature drying integrated into the MHASD system. The experiments were conducted outdoors and exposed to the external environment. The dryer performance was studied by measuring the heat recovered in the drying chamber, the moisture removal capacity, and the efficiency of the MHASD system based on the drying load of Citrus Hystrix sheets. The effectiveness of air flow and temperature distribution in the cylindrical drying chamber was investigated using the computational fluid dynamics (CFD) method. The air temperature in the drying chamber with the hybrid system reached 45 °C to 60 °C on a day with clear skies and variable weather. The drying time of the leaves was 6.5 h when collectors were used, while with the hybrid system it took 4 h to reach the final mass of 16 g. In intermittent weather conditions, the highest drying efficiency of 35.24 % was observed with the hybrid system, while drying with collectors was 17.26 %.

1. Introduction

Technological innovation encourages people to explore more energy sources for industrial processes. In 2030, there is an expected rise of more than 60 % of the world's energy demand, worsening climate damage, and increasing the security issue of energy supplyMoudakkar et al. [7]. Integrating solar thermal technologies into the industrial sector is a promising alternative to replacing fossil fuels since it is environmentally friendly and unlimited. More than 30 % of the energy produced worldwide is used in agriculture, with 3.6 % going toward dry biological wet goods[24].

The leaves of Citrus hystrix are known as one of the most aromatic herbs and are abundantly grown in Asian countries such as Laos, Indonesia, Malaysia, Vietnam, and Thailand. Citrus Hystrix leaves are known to bring many health benefits and are used in cooking. Leaves can help reduce headaches and gout and maintain our health care. Furthermore, cooking with Citrus Hystrix leaves is integral to Southeast Asian cuisine, especially in Thai dishes. Since fresh Citrus Hystrix has a short post-harvest life, they are dried and packed in plastic film before they are exported to other countries such as the United States of America, the United Kingdom, and Australia[13]. A fluidized bed dryer with inert sand particles was used to dry Citrus Hystrix leaves at 50 °C with different air velocities[22]. The findings demonstrated the surface air velocity and drying rate of Citrus Hystrix leaves [9]. The addition of inert particles to the dryer improved the drying process. Phoungchandang et al. [12] analyzed the drying process of Citrus Hystrix leaves using a heat pump-dehumidified and compared it with tray drying. The citronellal content was higher with the heat pump-dehumidified drying used because of the reduced drying time compared to tray drying.

Drying is one of the most determining post-harvest processes, as it discourages enzymatic degradation and microbial growth and preserves agricultural and marine products for longer periodsOliveira et al. [10,26] by reducing the moisture content of the products until it reached a safe limit to prevent the microorganism from spreading (S. [19]. Before modern technologies were widely applied in agriculture, drying activities were traditionally carried out in the open sun. Although this conventional method requires a lower investment cost, open-sun drying requires a large open space since the dried products must be spread to obtain radiation directly from the sun. The approach also causes a longer

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