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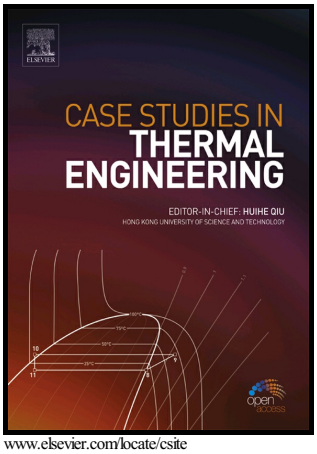

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Mathematical Modeling and Simulation of a Solar Agricultural Dryer with Back-Up Biomass Burner and Thermal Storage

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Abstract

Solar drying is a cost-effective and environmentally friendly method for drying agricultural products. To design a proper solar dryer for specific products, thermodynamic relations for the dryer system need to be considered. Numerical simulations are commonly used for the design and operational control of dryers. This study presents the mathematical modeling and simulation of a solar agricultural dryer with back-up biomass burner and thermal storage. Thermodynamic and numerical simulations of the solar collector and drying chamber are performed, while back-up heater (biomass burner) operation is simulated with a computational fluid dynamics (CFD) simulation. For the solar collector, it was found that the presence of a glass cover significantly increases the temperature of the collector; however, increasing the number of glass covers from one to two does not significantly affect the temperature. Variation in thickness of the back insulation has negligible effects, especially for thicknesses over 3 cm. The results show that there is a small difference in temperature between the bottom three trays, while the temperature on the top tray is significantly higher. The CFD simulation showed that the average drying air temperature in the drying chamber was 56 °C, which is suitable for the drying of agricultural products.

Keywords: solar dryer, solar drying, mathematical modeling, CFD, simulation.

1. Introduction

Drying is an effective method of food or agricultural product preservation for long periods. In general, farmers face problems in having their products dried fast, efficiently, economically, and in a correct environmental fashion. Sun drying on the ground is currently the most used method. Most farmers, especially in developing countries, cannot afford to import expensive drying equipment, which is either electrically or diesel-engine driven. This causes additional financial burdens of maintenance, fuel, electricity, and other running expenses in addition to environmental problems. Solar drying has been well-known as a cost-effective drying method; it is widely used worldwide and is environmentally friendly.

Solar dryer systems can be classified into direct and indirect dryers. For direct dryers, solar radiation is absorbed directly by the product to be dried, while indirect dryers use solar radiation to heat the air, which then flows through the space containing the product [1]. Indirect solar dryers employ a separate solar collector that absorbs solar radiation, converts it into thermal energy that in turn heats the flowing air, and then supplies the heated air to a chamber. A combination of direct and indirect methods is called a mixed-type dryer [2].

Based on the auxiliary energy used to operate the system, dryers are classified into active and passive dryers. Active dryers employ an external means such as fans or blowers to move the heated air from the solar collector to the drying bed, while passive dryers use only the natural movement of heated air. The drying of agricultural products involves two

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