Design of Solar Thermal Dryers for 24-hour Food Drying Processes

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Abstract

Solar drying is a ubiquitous method that has been adopted for many years as a food preservation method. Most of the published articles in the literature provide insight on the performance of solar dryers in service but little information on the dryer construction material selection process or material attributes that allow them to be selected as candidates in solar dryer designs. 1-7 Furthermore, if solar dryers can be designed such that the drying process can occur over a 24-hour period, the efficiency of drying can be improved. Thus, if significant improvements can be conducted in the design of solar thermal dryers and exploration of thermal-storage phase change materials that are non-toxic, non-corrosive, stable, possess a long shelf- life, high storage efficiency, and completely reversible, then these materials can have great potential in solar thermal energy systems. In this work, we have used simulations to assess the temperature profiles for solar cabinet dryers, composed of materials with different optical properties, under various conditions to identify suitable phase change material candidates.

The dryer design consisted of an enclosed aluminum multi-layer dryer with an acrylic transparent cover, which is exposed to ambient conditions on a sunny day. Each dryer can hold 15 square feet of food product, but for our initial studies, empty driers were modeled in COMSOL Multiphysics® software and tested to assess baseline performance. Heat enters the system with the conversion of solar energy to heat, increasing the temperature profile within the drying cabinets. Temperature readings were recorded throughout the course of the day, taking into account the solar traverse. Three different material property profiles were tested using the Heat Transfer Module with Surface to Surface Radiation physics interface.

The models indicated that the temperature profiles observed in the cabinets are highly dependent on surface absorptivity and surface emissivity of the radiated surface. Temperatures of 320 K (47oC), a value exceeding that of several PCMs (e.g. Glauber's salt, paraffin wax), can be achieved in a solar thermal dryer designed with an acrylic material that has a solar absorptivity and surface emissivity value of 0.5 and 0.5, respectively (Figure 1). Additional experiments need to be conducted to confirm the emissivity and absorptivity values for materials suitable for use as transparent covers in solar thermal dryers and confirm these results. It is expected that application of the Heat Transfer with Surface to Surface Radiation physics interface of COMSOL Multiphysics® software will have major implications in the design and efficiency of solar thermal food dryers.

Reference

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Figures used in the abstract

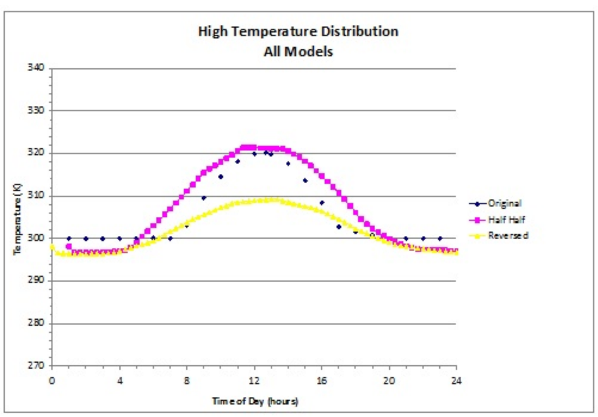

Figure 1: Figure 1. Time dependent maximum temperature (K) distribution for an acrylic material with absorptivity and emissivity values of a) 0.2 and 0.8 (Original), b) 0.5 and 0.5 (Half Half), and c) 0.8 and 0.2 (Reversed), respectively.

Figure 2

Figure 3

Figure 4