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

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Introduction: In agricultural processes such as solar drying (dehydration of fruits and vegetables), short-term thermal energy storage would be beneficial: thermal energy could be stored during the day and then harnessed in the evening when solar radiation is limited or during overcast weather conditions. In this work, we have used simulations to assess the temperature profiles for solar thermal cabinet dryers fabricated using materials with different optical properties.

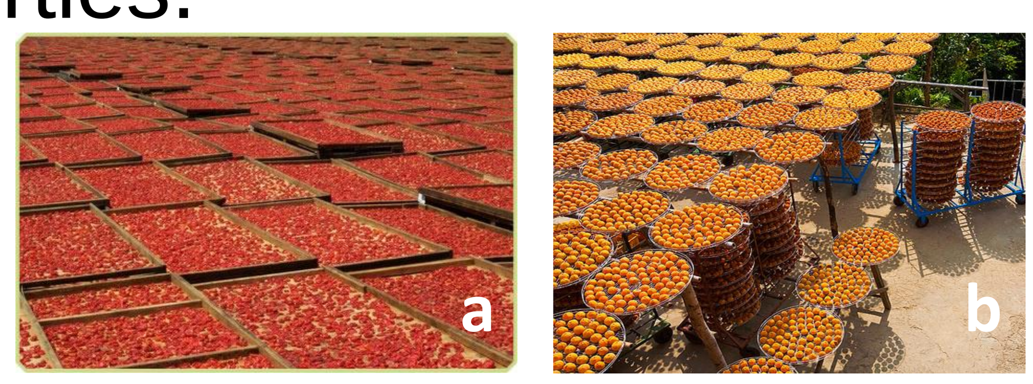

Figure 1. (a) Single layer and (b) multi-layer solar drying on a farm.

Computational Methods: The Heat Transfer Module, with Surface to Surface Radiation, was employed to solve the 1) conduction and (2) radiation equations below for our system.

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p \mathrm{u} \cdot \nabla T = \nabla \cdot (k \nabla T) + \mathrm{Q} \quad \textbf{(1)}$$

$$-n \cdot (-k \nabla T) = \sum_{i=1}^{N} \varepsilon_{\mathrm{Bi,u}} \left(G_{\mathrm{Bi,u}} - \mathrm{e_b}(T) \mathrm{FEP}_{\mathrm{Bi,u}}(T) \right)$$

$$+ \sum_{i=1}^{N} \varepsilon_{\mathrm{Bi,d}} \left(G_{\mathrm{Bi,d}} - \mathrm{e_b}(T) \mathrm{FEP}_{\mathrm{Bi,d}}(T) \right) \quad \textbf{(2)}$$

To identify the desired material properties of candidate materials for solar thermal dryers, the emissivity and absorptivity values were modified. This data will be used to assess the incorporation of phase change materials in our solar thermal dryers.

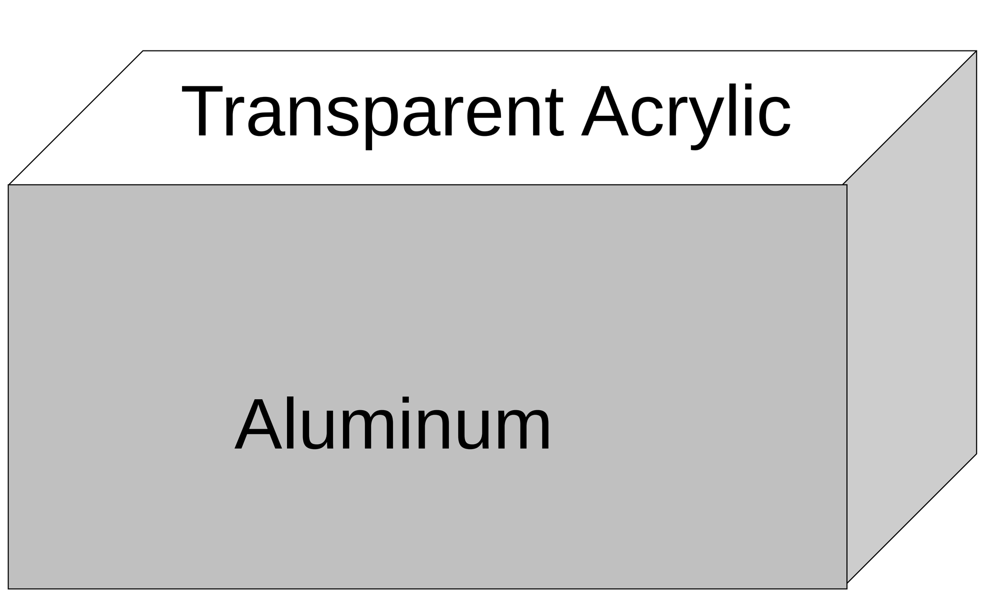

Figure 2. Proposed simple box-type solar thermal dryer.

Results: Results of this work reveal that modifications in optical properties have significant influence on temperature profiles of solar thermal dryers.

Surface to Surface Radiation			
Variable	Original	Half-Half	Reverse
Solar Absorptivity (ε_{B1})	0.2	0.5	0.8
Surface Emissivity (ε_{B2})	0.8	0.5	0.2

Table 1. Experimental Parameters.

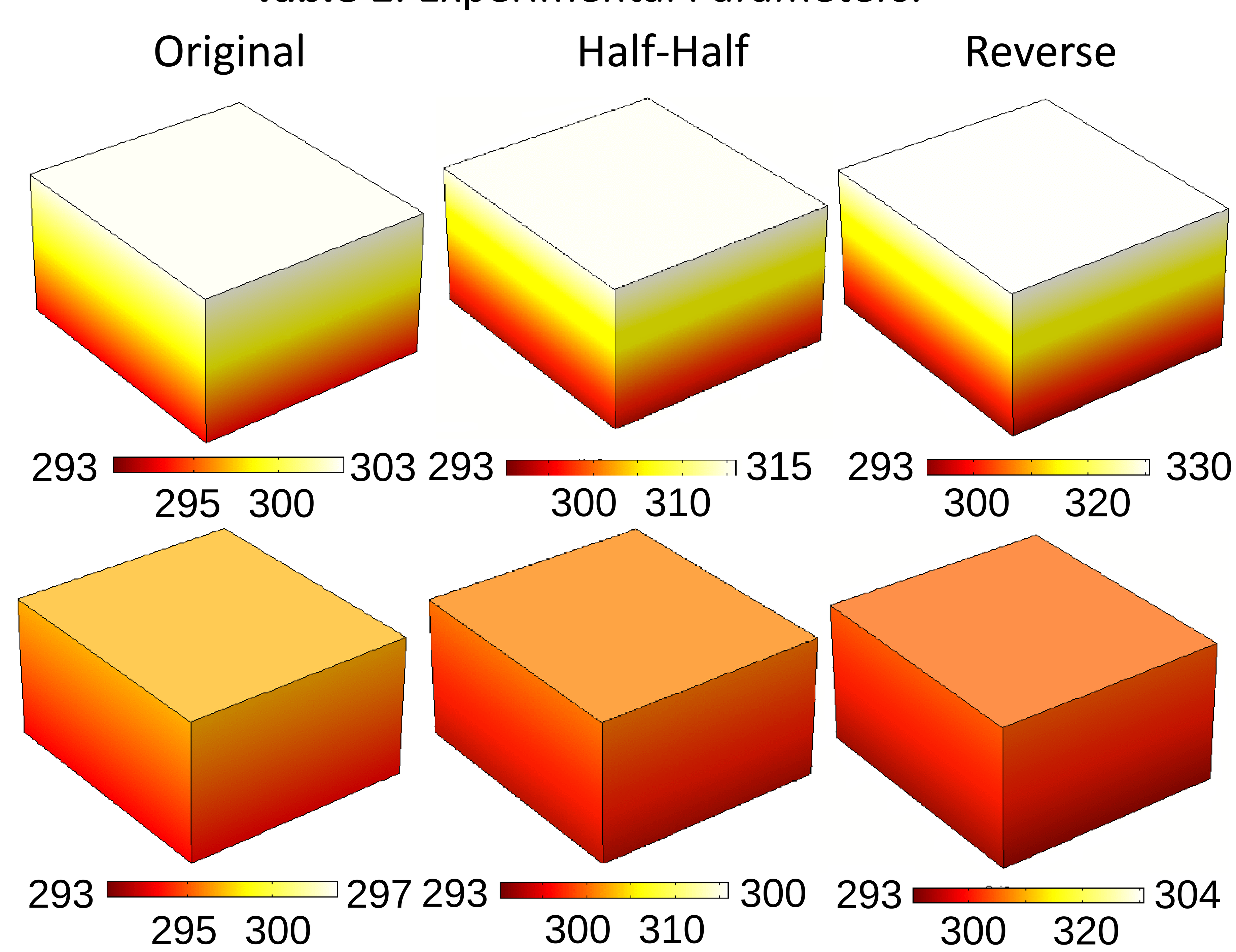

Figure 3. Temperature Profiles in Kelvin (K) at 12:00 (top) and 18:00 hours (bottom).

Conclusions: This data reveals that temperature profiles are highly dependent on optical properties. Temperatures of 330K can be achieved in a dryer designed with an acrylic material that has solar absorptivity and surface emissivity values of 0.8 and 0.2, respectively. Results of this work will be utilized to identify materials with these attributes to incorporate into the dryer design.

References:

1. V. Belessiotis, et. al., Solar drying, *Solar Energy*, **85**, 1665-1691 (2011).
2. I. Doymaz, Effect of dipping treatment on air drying of plums, *Journal of Food Engineering*, **64**, 465-470 (2004).