Solar Dryer Exergetic and Energetic Efficiency Analysis

H. Lucatero-Villaseñor[1], L. Romero-Salazar[1], E. Ruiz-Baltazar[1], M. Mayorga[1], J. Arteaga-Arcos[1]

[1]Universidad Autónoma del Estado de México, Facultad de Ciencias, Toluca, DF México

Introduction: The design of a drying chamber for dehydration purposes requires the knowledge of exergetic and energetic efficiencies, i.e. a thermodynamic comprehension [1]. We model the case of a so-called indirect solar dryer [2] that includes a thermal isolated chamber attached to a solar collector as the source of thermal energy. We compare the effect of conductivity against inlet velocity.

Computational Methods: The exergy is defined as the maximum amount of work that can be produced by a given flux until the equilibrium conditions are obtained[3]. We use both, the heat transfer and CFD modules for an initial non isothermic laminar flux.

The outlet velocity obeys:

$$\mathbf{u} = -U_o \mathbf{n}$$

The inlet heat flux transfered from the solar collector satisfies:

$$-\mathbf{n}\cdot\left(-d_z k \nabla T\right) = d_z q_o$$

The exergy values are calculated to obtain the efficiency of the chamber [3], given by:

$$Ex_{dci} = C_{pda}\left[\left(T_{dci} - T_a\right) - T_a \ln \frac{T_{dci}}{T_a}\right]$$

$$Ex_{dco} = C_{pda}\left[\left(T_{dco} - T_a\right) - T_a \ln \frac{T_{dco}}{T_a}\right]$$

$$Ex_{loss} = Ex_{dci} - Ex_{dco}$$

$$\eta_{Ex} = \frac{Ex_{dco}}{Ex_{dci}} = 1 - \frac{Ex_{loss}}{Ex_{dci}}$$

The geometry includes a 2D model of the chamber with a single tray and an upper chamber, we compare results for two different materials and two different inlet velocities.

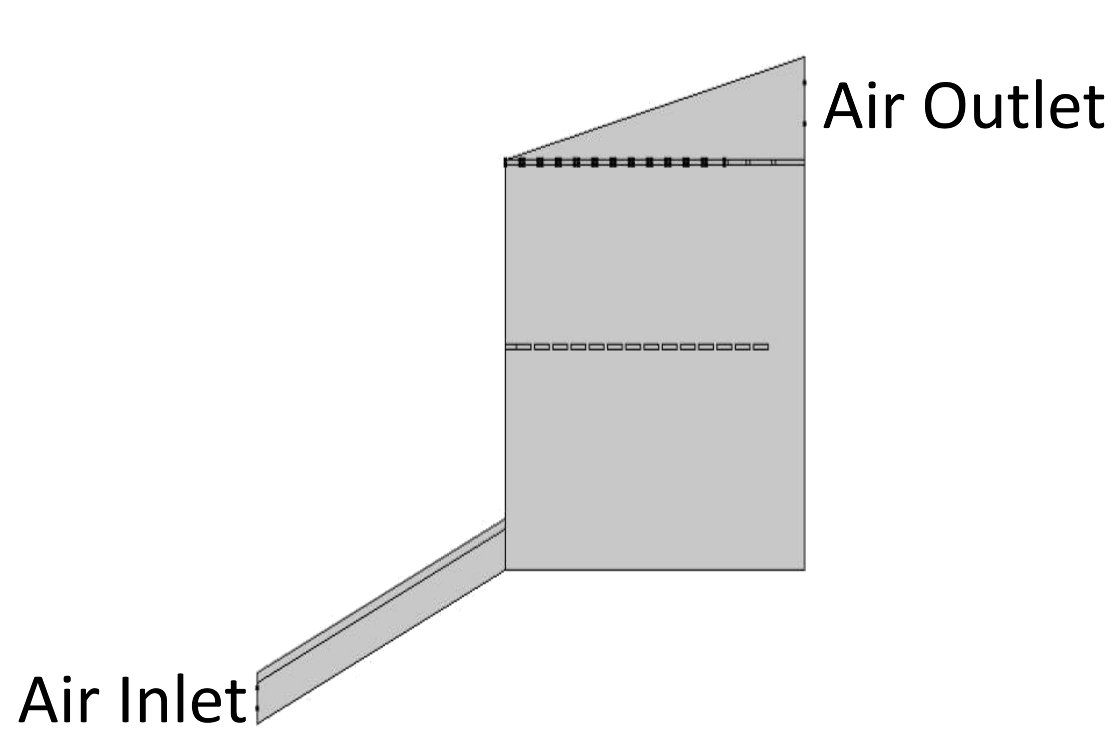

Figure 2. Simulation's Geometry

Results:

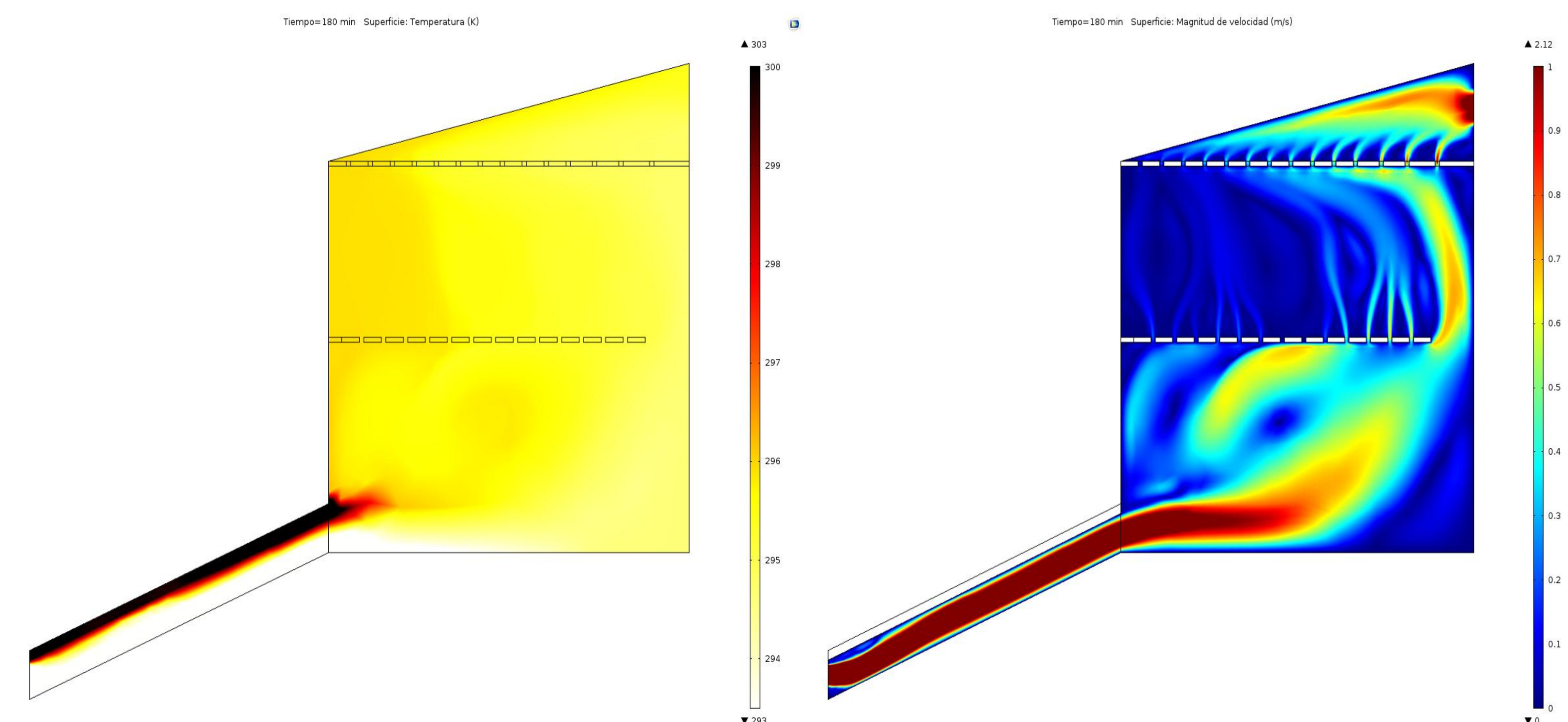

Fig 1. Case A. Left: Temperature field. Right: Velocity field. At t=180 min

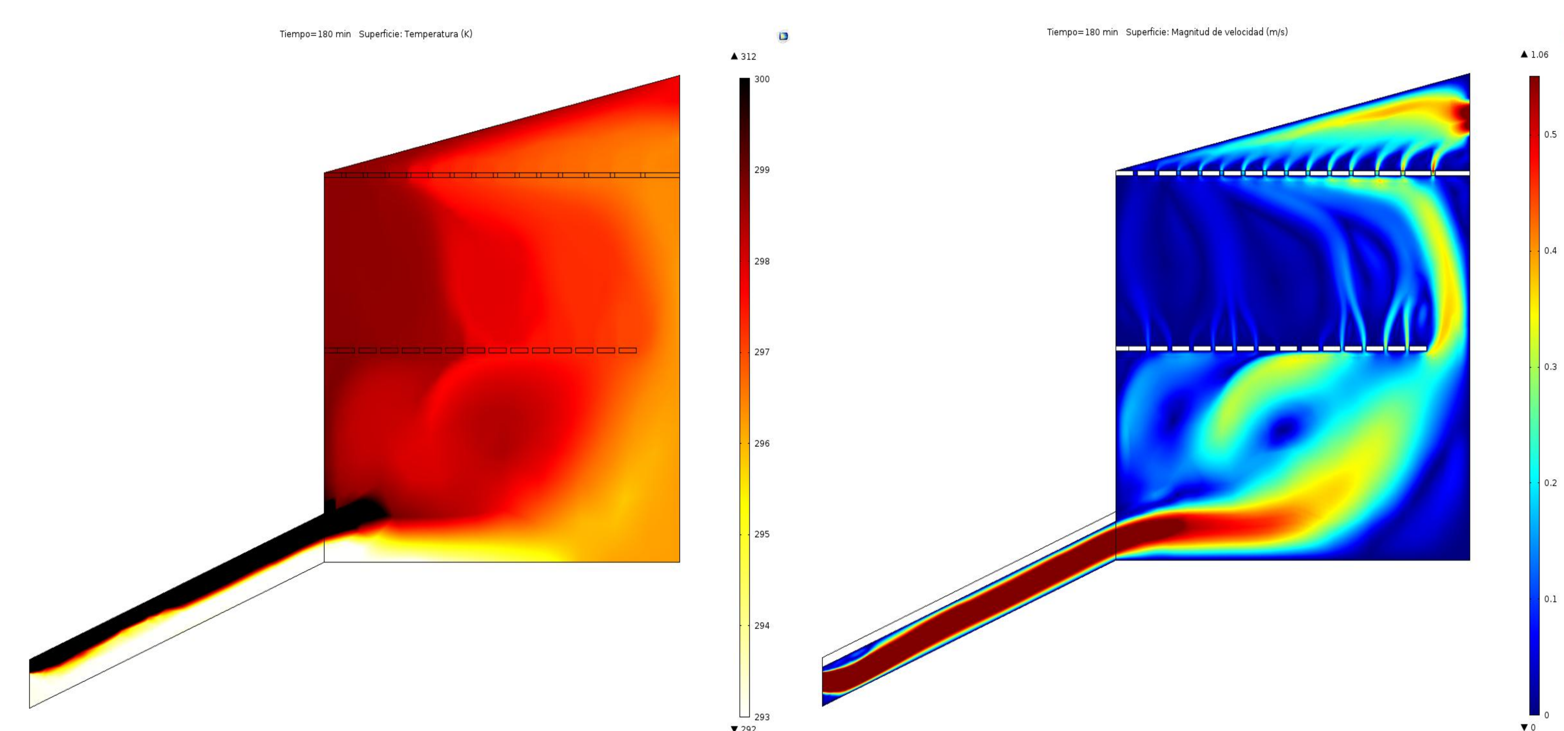

Fig 2. Case A1. Left: Temperature field. Right: Velocity field. At t=180 min

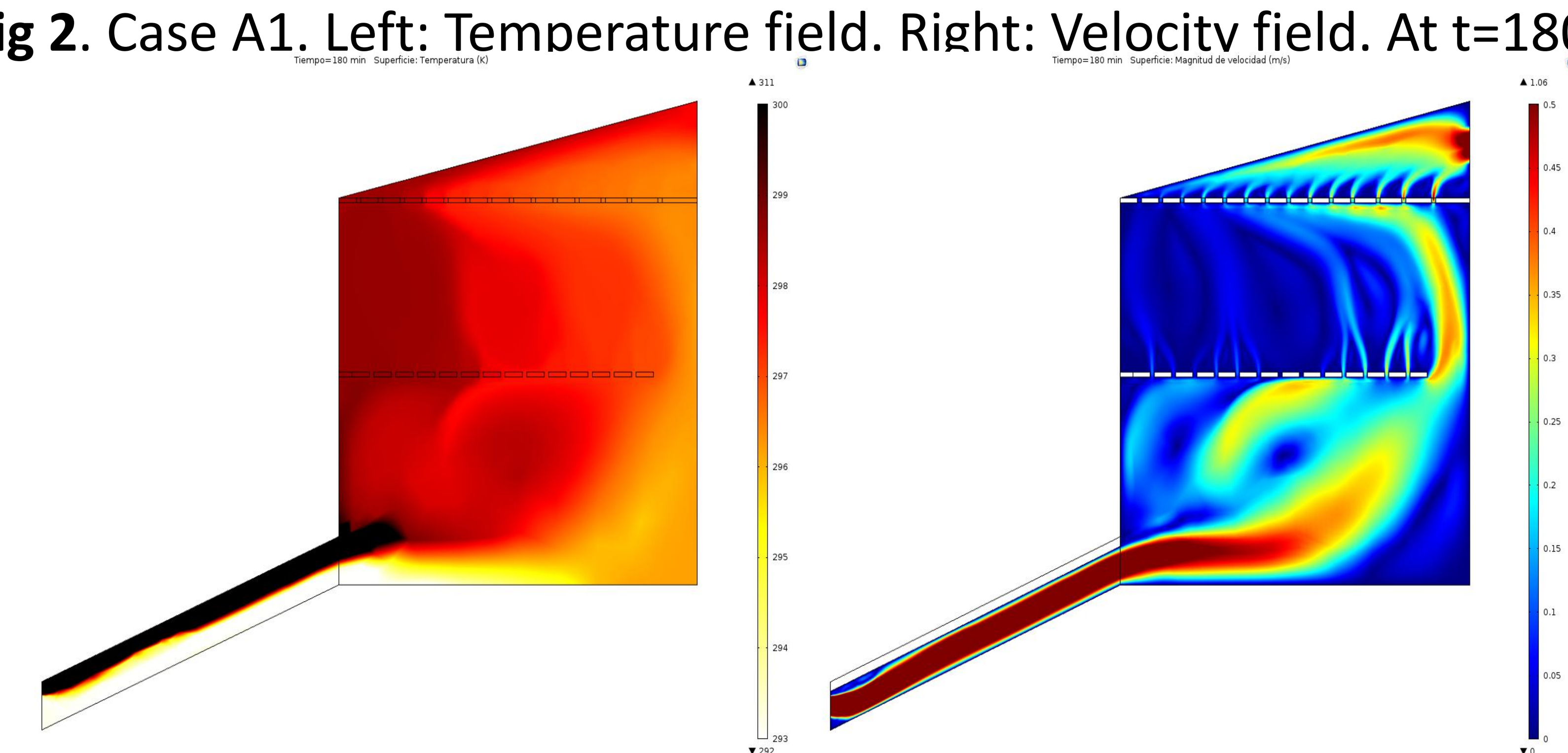

Fig 3. Case B. Left: Temperature field. Right: Velocity field. At t=180 min

Variable	Units	Case A	Case A1	Case B
Inlet Velocity	m/s	1	2	1
Thermal conductivity	W/(K·m)	155	155	400
Efficiency	%	19.79	15.06	14.85
General heat inlet flux= 500W/m^2[4] Air temperature=293.15 K				

Table 1. Initial Conditions and Efficiency Results

Conclusion:
The highest efficiency was obtained for a low conductivity and low inlet velocity because the drying process is governed by an adiabatic behavior inside the chamber.

References:
1. Ahmad F., Kamaruzzaman S., Mohd O., Energy and exergy analyses of solar drying system of red seaweed, Energy and Buildings, 64, 121-129, (2014).
2. Sharma A., Chen C. R., Vu L. N., Solar energy drying systems: A review. Elsevier, (2009)
3. Midilli A., Kucuk H., Energy and exergy analyses of solar drying process of pistachio, Energy, 28, 539-556, (2001).
4. Rodríguez P. J. M, Transferencia de calor, flujo de aire y similitud en un secador solar pasivo de tipo indirecto, Bogotá, Universidad de los Andes, (2008).