HIGH TEMPERATURE SOLAR COOKING SYSTEM WITH A PCM ENERGY STORAGE UNIT

Olivia Alves – Departamento de Engenharia Mecânica, Universidade de Aveiro (Portugal)
Vítor A. F. Costa – Departamento de Engenharia Mecânica, Universidade de Aveiro (Portugal)
Usual indirect solar cooking systems require a specific cooking reservoir/pan, reducing their use and viability. Taking that in consideration, the proposed system allows the use of a conventional pan.
Primary circuit:

V1 and V2: open
V3: closed
Secondary circuit:

V2: open
V1 and V3: closed
17 modules = 8 HTF passages and 9 PCM modules
The chosen PCM is an eutectic mixture based on nitrite and nitrate salts (53 wt% KNO₃, 40 wt% NaNO₂, 7 wt% NaNO₃)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HITEC – Heat transfer Salt (PCM)</strong></td>
<td></td>
</tr>
<tr>
<td>( T_{\text{melt}} )</td>
<td>142 °C</td>
</tr>
<tr>
<td>( \Delta h_{mf} )</td>
<td>81.41 kJ/kg</td>
</tr>
<tr>
<td>( c_{p,s} )</td>
<td>1340 J/(kg.K)</td>
</tr>
<tr>
<td>( c_{p,l} )</td>
<td>1560 J/(kg.K)</td>
</tr>
<tr>
<td>( k )</td>
<td>0.57 W/(m.K)</td>
</tr>
</tbody>
</table>
The system is required to start boiling 1 L of water, and to cook 500 g rice during 20 min in the boiling water at 100 °C.

- Noon period: 12 pm
- Night period: 7 pm
Time evolution of the HTF temperature:

\[ T_{f,i+1}^{t+\Delta t} = T_{f,i}^{t} + \frac{\Delta t}{m_{f,i}c_{f}} [U_{i}A_{i}(T_{s,i}^{t} - T_{f,i}^{t}) + \frac{k_{f}A_{c}}{\Delta y}(T_{f,i-1}^{t} - 2T_{f,i}^{t} + T_{f,i+1}^{t}) + \dot{m}_{f}c_{f}(T_{f,i-1}^{t} - T_{f,i}^{t})] \]

Time evolution of the PCM temperature:

\[ T_{s,i+1}^{t+\Delta t} = T_{s,i}^{t} + \frac{\Delta t}{m_{s,i}c_{s}} [U_{i}A_{i}(T_{f,i}^{t} - T_{s,i}^{t}) + \frac{k_{f}A_{c}}{\Delta t}(T_{s,i-1}^{t} - 2T_{s,i}^{t} + T_{s,i+1}^{t})] \]
SOLAR DATA FOR AVEIRO

EnergyPlus™

- Winter typical day
- Summer typical day

Gb (W/m²)

Time of Day


CON SOL FOOD 2020
\[ \eta_{total} = 0.35 - 0.4632 \left( \frac{T_{in} - T_{amb}}{G_b} \right) \]

Area = 26.5 m²

\[ \dot{m}_f = 0.02 \text{ kg/s} \]
PCM TEMPERATURE TIME EVOLUTION IN THE WINTER TYPICAL DAY
WINTER TYPICAL DAY

Noon period:
Time required to reach the water boiling point = 26 min
+ Time required for the water + rice reach 100 °C = 7 min
+ 20 min of additional cooking time
= 53 min

Night period:
Time required to reach the water boiling point = 23 min
+ Time required for the water + rice reach 100 °C = 7 min
+ 20 min of additional cooking time
= 50 min
SUMMER TYPICAL DAY

Noon period:

Time required to reach the water boiling point = 8 min

+ 

Time required for the water + rice reach 100 °C = 1 min

+ 

20 min of additional cooking time

= 29 min

Night period:

Time required to reach the water boiling point = 8 min

+ 

Time required for the water + rice reach 100 °C = 1 min

+ 

20 min of additional cooking time

= 29 min
The proposed solar cooker proved to be feasible and viable for cooking at high temperatures, and could be an interesting solution to minimize current dependence on fossil fuels for cooking.

It has been proved to be feasible to cook using previously stored solar energy as thermal energy, using a high melting temperature PCM (considering the thermal levels required for quickly cooking food) in both Winter and Summer seasons.

Results show that the cooker’s performance at the noon period depends mainly on the amount of PCM used, leading to a longer cooking time than at the night cooking period (as more thermal energy is stored in the PCM at the end of the day).

More realistic simulations need to consider the thermal losses from energy storage system, and analysis of the temperature evolution of each single HTF and PCM modules.