Thermo-optical performance of a solar funnel cooker

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The study

Funnel solar cookers are simple, effective and have multiple advantages

But there is limited data available in scientific literature about their thermo-optical performance

Study parts:
1-Analyze the optical performance (Antonio Carrillo’s presentation)
2-Thermal model (work in progress)
3-Experimental study
Experimental setup: Funnel solar cooker

3 identical solar cookers

Panels-Funnel

Receiver
Experimental setup: Panels-Funnel

Material:
- Aluminium composite panel
- Reflectance: 0.85

8cm thickness XPS insulator
Experimental setup: Receiver

Optical properties (Work in progress)
- Emissivity
- Absorptivity
- Reflectance
- ...

Pot
- Mass: 580g
- Height: 10cm
- Diameter: 20cm
- Capacity: 2.5l

Washing machine door glass
- Mass: 2239g

Metallic pot cover
- Mass: 252g

Glass pot cover
- Mass: 372g
Materials and methods: Instrumentation

Temperature measurement sensors
- 5 Thermocouples in water
- 1 TC air
- 3 TC pot
- 1 TC pot cover

Local weather station
- Horizontal global radiation pyrometer
- 40° global radiation pyrometer
- Ambient thermometer
- Anemometer

Weather station
Materials and methods: methods

Standard: ASAE S580 (Ref. Funk 2000)

Most Important variables

Uncontrolled (weather) variables
- Wind (avg. less than 1.0m/s & max less than 2.5m/s)
- Insolation (between 450W/m2 - 1100W/m2 & variation less than 100W/m2 during a 10-min)
- Solar altitude and azimuth (between 10:00 and 14:00 solar time)
Materials and methods: test data

E 57 CSR01 Temperature water–air–pot

[Graph showing temperature over time with different lines representing different conditions]
Materials and methods: test data

E 57 Solar Radiation 40deg

Solar Radiation (W/m²)

Local Time GMT+1 for date: 107
Materials and methods: test analysis

Analyze of the results according to the standard (ASAE S580, Ref. Funk 2000)

- Calculating cooking power

\[ P_i = \frac{T_2 - T_1}{600} \times m \times C_{pw} \]

- Standardizing cooking power (to be corrected to standard insolation of 700 W/m2)

\[ P_{si} = P_i \times \frac{700}{G_i} \]

\[ G_i \text{ : average insolation i } \left( \frac{W}{m^2} \right). \]
Materials and methods: test analysis


- Plotting: *(The standardized cooking power (W) is to be plotted against the temperature difference (ºC))*

- A linear regression

\[ R^2 = 0.98606 \]
\[ Ps = 93.14 - 0.65 \times Td \]
\[ n_{obs} = 8 \]
\[ Ps_{50} = 60.58 \text{ W} \]
Materials and methods: test analysis


- Single measure of performance (The value for standardized cooking power (W) is to be computed for a temperature difference of 50ºC)

![Graph showing standardized cooking power vs. average temperature difference](image-url)

\[ R^2 = 0.98606 \]

\[ Ps = 93.14 - 0.65 \times Td \]

\[ n_{obs} = 8 \]

\[ Ps_{50} = 60.58 \text{ W} \]
Experimental Results

Standarized cooking power Glass e=0cm

- Standardized cooking power (Ps) vs. Average temperature difference (Tw-Ta) C
- Equation: $R^2 = 0.907$,
  $Ps = 105.9 - 0.63 \cdot Td + 0 \cdot Td^2$
- $n_{obs} = 49$
- Ps50 = 74.4 W
- Ps50conf95% = 2.2 W [75.5–73.3]
- Ps50pred95% = 14.8 W [81.8–67]

Standarized cooking power Black metal e=0cm

- Standardized cooking power (Ps) vs. Average temperature difference (Tw-Ta) C
- Equation: $R^2 = 0.875$,
  $Ps = 100 - 0.95 \cdot Td + 0 \cdot Td^2$
- $n_{obs} = 43$
- Ps50 = 52.5 W
- Ps50conf95% = 3.5 W [54.3–50.8]
- Ps50pred95% = 23 W [64–41]
Experimental Results

Standardized cooking power Glass e=0cm

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R^2= 0.907 \\
Ps=105.9 - 0.63 \cdot Td + 0 \cdot Td^2 \\
n \text{obs}=49 \\
Ps50=74.4 W \\
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Experimental Results

**Standarized cooking power Glass e=0cm**

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- $Ps = 105.9 - 0.63 \cdot Td + 0 \cdot Td^2$
- $n_{obs} = 49$
- $Ps_{50} = 74.4 \text{W}$
- $Ps_{50,\text{conf95\%}} = 2.2 \text{W} [75.5 - 73.3]\%$
- $Ps_{50,\text{pred95\%}} = 14.8 \text{W} [81.8 - 67]\%$

**Standarized cooking power Black metal e=0cm**

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- $Ps = 100 - 0.95 \cdot Td + 0 \cdot Td^2$
- $n_{obs} = 43$
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- $Ps_{50,\text{conf95\%}} = 3.5 \text{W} [54.3 - 50.8]\%$
- $Ps_{50,\text{pred95\%}} = 23 \text{W} [64 - 41]\%$
Experimental Results

Receiver s have been raised

Different water loads
Conclusions and perspectives

- Thermal performance parameters for several configurations of a typical solar funnel cooker have been determined following standard ASAE S580.

- Results are robust and repeatable

- Configuration with glass cover and elevated receiver performs better

- Thermal performance is better with high water load

- Future work: characterize other configurations such as summer configuration, different fluids, receivers, reflector area, materials, etc.