HEFAT2008
6th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics
30 June to 2 July 2008
Pretoria, South Africa
Paper number: KP1

CONICAL SOLAR COOKER

Pongsakorn Kerdchang[1] and Withaya Puangsombut[2,*]
*Author for correspondence
[1]Department of Mechanical Engineering, Faculty of Engineering, South-East Asia University
19/1 Petkasem Rd., Nongkhaem, Bangkok 10160, Thailand
[2,*]Department of Mechanical Engineering, Faculty of Engineering, Kasem Bundit University
1761 Pattanakarn Rd., Suanluang, Bangkok 10250, Thailand
Tel: (662) 320-2777 Ext.1203, Fax: (662) 321-4444, *wpuangsombut@kbu.ac.th

ABSTRACT

A conical solar cooker is build based on concentrating solar radiation into heat. The radius of focus and opening of conical concentrator are 0.15 m and 0.362 m. It is made of polished, reflective stainless steel. The solar incidence angle can also be changed according to solar times and seasonal factors. Experiments were conducted by cooking rice, boiling the eggs and boiling the pickled mustard green pork. Cooking 300 grams of rice with 900 cm^3 of water, the rice was softened within 30 minutes and the rice was fully cooked within 2 hours at 91°C to boil the four eggs completely. Boiling 321 grams of pork with 1 liter of water, after 2 hours the temperature reach to 81°C. The experiments revealed that the solar cooker performed efficiently at a solar intensity of 350 W/m^2 and higher. The solar intensity affected the cooking performance. Therefore, for the best results, cooking should be conducted between 9:30 am to 3:30 p.m.

INTRODUCTION

Solar energy, which is an abundant, clean and safe source of energy is an attractive to substitute for the conventional fuels for cooking. Thailand is situated between 5°37' and 20°27' Lat. N and between 97°22' and 105°37' Long E to have high solar radiation values. The average daily intensity of solar radiation is 17.5 MJ/ (m^2 day) [1], which is sufficient to provide adequate energy for solar thermal applications.

Concerning the many applications, designing and the thermal performance of the solar cookers studies have been carried out by many researchers. The main types were as follows:

- Pipe cooker [2], which is oil filled pipe, connected to an insulated box where food and water are placed.

- Cylindrical Parabola solar cooker [3], which is just a reflecting basin with a cylindrical focus.

- Arafa cooker [4], which as a parabolic heater which needs direction adjustments every 20 minutes. It has a diameter of a 1.2 m and a solar area 1.13 m^2, the focus area is 0.8 m^2, the geometric concentration is 14.12. This cooker was tested and proved capable of heating oil to 200°C in 5 hours.

- Reyadh cooker [5], which is a spial concentrator. It has the following dimensions: diameter is 1.1 m, solar area is 0.95 m^2, diameter of focus is 0.1 m, focal area is 0.078 m^2 and the concentration is 126.6.

This paper proposes a solar cooker cone to cook the foods, viz., cooking rice, boiling the eggs and boiling the pickled mustard green pork.

NOMENCLATURE

A_1	[m^2]	Cooker pot area
A_2	[m^2]	Cooker pot cover area
A_r	[m^2]	Area of the opening end
A_T	[m^2]	Total cooker pot area
a	[m^2]	Area of the focus end
C	[-]	Area ratio
D	[m]	Outer diameter of cooker pot
d	[m]	Inner diameter of cooker pot
H, h	[m]	The height of reflective part
It	[W/m^2]	Solar intensity
L	[m]	The length of the cone side
ℓ	[m]	The length of the reflective
R_1	[m]	Radius of opening
R_2	[m]	Radius of the focus
V_1	[m^3]	Volume of cooker pot
V_t	[m^3]	Total volume of cooker pot
θ	[Degree]	Apex angle

THEORITICAL AND DESCRIPTION

Consideration the geometric concentration (Figure 1), the frustum any angle (θ) has a area ratio (C) as follow:

$$C = \frac{A_r}{a} = \frac{\pi R_1^2}{\pi R_2^2} = \frac{R_1^2}{R_2^2} \quad (1)$$

and $\Delta C'CB'$ where $\Delta C'B'C = \theta$ = apex angle

Then $CB' = B'A$

$$\frac{C'C}{B'A} = \tan\theta \quad (2)$$

$$\frac{2R_2}{B'A} = \tan\theta$$

For $\Delta BB'A$ $$\frac{BA}{B'A} = \sin\theta \quad (3)$$

$$\frac{R_1 - R_2}{B'A} = \sin\theta$$

From equation (2) and (3) obtained

$$R_1 = R_2(2\cdot\cos\theta + 1) \quad (4)$$

From equation (4) and (1) obtained

$$C = (2\cdot\cos\theta + 1)^2 \quad (5)$$

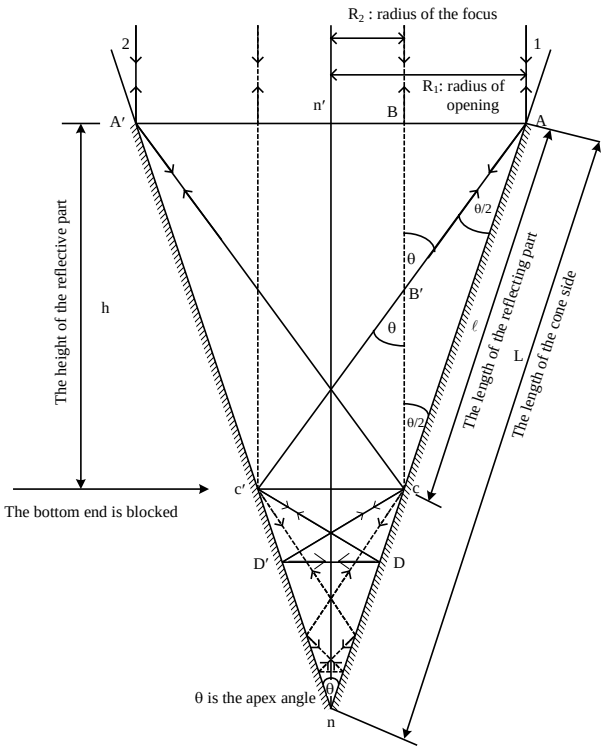

Figure 1 A section across a reflective frustum

-Conical design

The length of the cone side (L) $\Delta Ann'$

$$\frac{R_1}{L} = \sin\frac{\theta}{2}$$

$$L = \frac{R_1}{\sin\frac{\theta}{2}} \quad (6)$$

The length of the reflective side (ℓ) ΔACB

$$\frac{AB}{AC} = \sin\frac{\theta}{2} \quad (7)$$

$$\frac{R_1 - R_2}{\ell} = \sin\frac{\theta}{2}$$

$$\ell = (R_1 - R_2)\left[\frac{2}{1-\cos\theta}\right]^{0.5}$$

The height of the reflective part (H) $\Delta Ann'$ represents by nn'

$$\frac{R_1}{H} = \tan\frac{\theta}{2} \quad (8)$$

$$\tan\frac{\theta}{2} = \sqrt{\frac{1-\cos\theta}{1+\cos\theta}}$$

$$\therefore H = R_1\left[\frac{1+\cos\theta}{1-\cos\theta}\right]^{0.5} \quad (9)$$

The height of the reflective part (h) ΔABC represents by BC

$$\frac{BA}{BC} = \frac{R_1 - R_2}{h} = \tan\frac{\theta}{2}$$

$$\therefore h = (R_1 - R_2)\left[\frac{1+\cos\theta}{1-\cos\theta}\right]^{0.5} \quad (10)$$

- Cooker pot

The surface area of the cooker pot

$$A_1 = \pi dh \quad (11)$$

Volumetric of the cooker pot

$$V_1 = \frac{\pi}{4}(D^2 - d^2)h \quad (12)$$

The area of the cover

$$A_2 = \frac{\pi}{4} D^2 \quad (13)$$

The total area

$$A_T = A_1 + A_2 \quad (14)$$

The total volume of cooker pot

$$V_t = V_1 \quad (15)$$

- Thermal efficiency

Thermal efficiency of a solar cooker can be defined as the ratio of energy useful (energy increase in the water) to the energy input (Solar intensity on the receiver area). The thermal efficiency of the conical solar cooker was calculated as follow:

$$\eta = \frac{\frac{mc(T_f - T_i)}{\Delta T}}{I_t A_r} \quad (16)$$

-Description

The experimental set up and important size of the collector are presents (Figure 2).

Figure 2 The conical solar cooker

The collector has a conical concentrator without tracking. The conical apex angle is 45°. The radius of focus and opening sizes are 0.15 m and 0.362 m, respectively. The length of the cone side is 0.946 m and the length of the reflective part is 0.554 m. The height of the cone is 0.874 m. The cooker pot is 0.125 m of radius and 0.1 m of height. Seven thermocouples (type K) are installed on different positions (Figure 3). A pyranometer (Model: CM 11 Kipp & Zonen) is used to measure the solar intensity. The error of pyranometer is ± 10 W/m^2. This experiment is located on the open area of a football field.

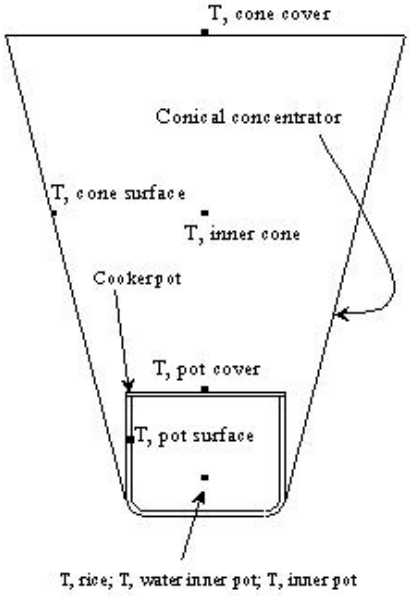

Figure 3 Schematic of temperature positions

EXPERIMENTAL RESULTS

As mentioned earlier, this paper proposes the foods cooking by using the conical solar cooker. The data analyses are present on during daytime (10.:45 a.m. to 01:15 p.m.)

- Cooking rice, 300 grams of rice's with 0.9 m^3 of water.
- Boiling the egg, 4 eggs with 1 liter of water.
- Boiling the pickled mustard green pork, 321 grams of pork; red onion and black pepper are 50 grams of total with 1 liter of water.

- Temperature distribution

This subsection demonstrated the temperature distribution any points of the experimental set-up.

Figs. 4 (a), (b) and (c) shown the temperature distribution and solar intensity versus time. During the experimental period the rice temperature (cooking rice), water temperature (boiling the eggs) and inner pot (boiling the pickled mustard green pork) are increased from 35°C to 91°C, 36°C to 77°C and 25°C to 81°C, respectively. These maximum temperatures are reached 91°C after 2.5 hr from the start. The ambient air temperature varied from 29°C to 37°C, whereas the solar intensity ranges from 230 to 512 W/m^2. In the meantime, the other temperature was also varied with solar intensity.

- Thermal efficiency

The variation of the thermal performance as a function of time for the conical solar cooker is presented in figure 5. The thermal efficiency of the conical solar cooker varied from 27%

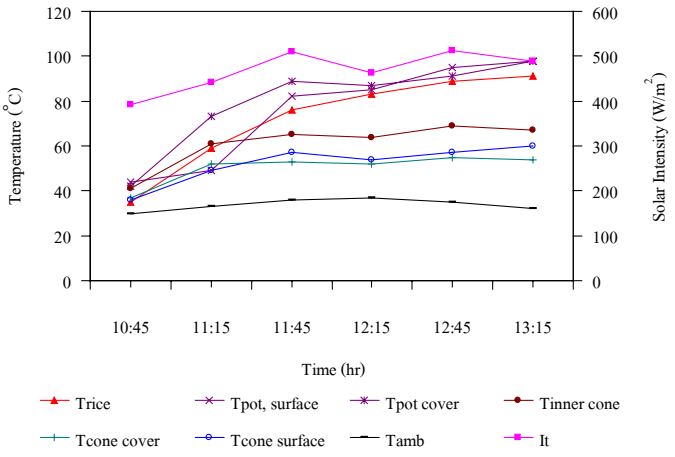

Figure 4 (a) Temperature distribution and solar intensity vs. time (cooking rice)

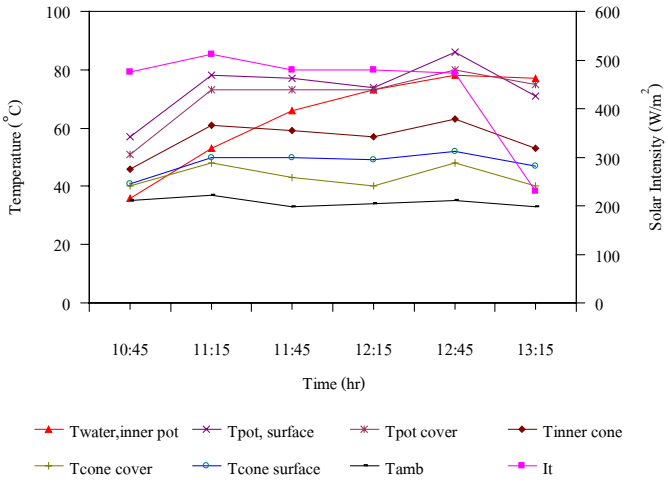

Figure 4 (b) Temperature distribution and solar intensity vs. time (Boiling the egg)

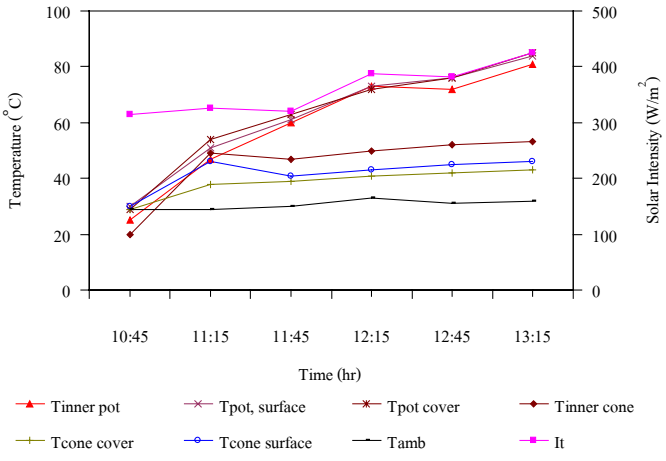

Figure 4 (c) Temperature distribution and solar intensity vs. time (Boiling the pickled mustard green pork)

to 37%. The daily average thermal efficiency of the conical solar cooker was 31.5%.

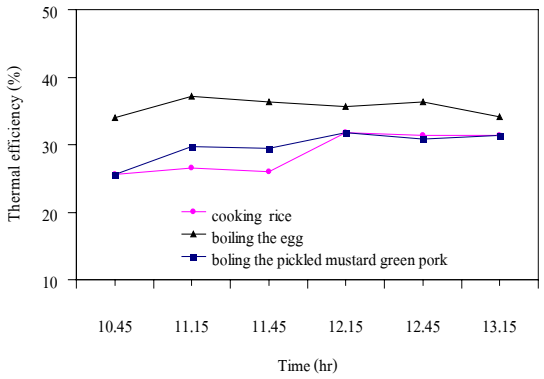

Figure 5 Thermal performance of conical solar cooker

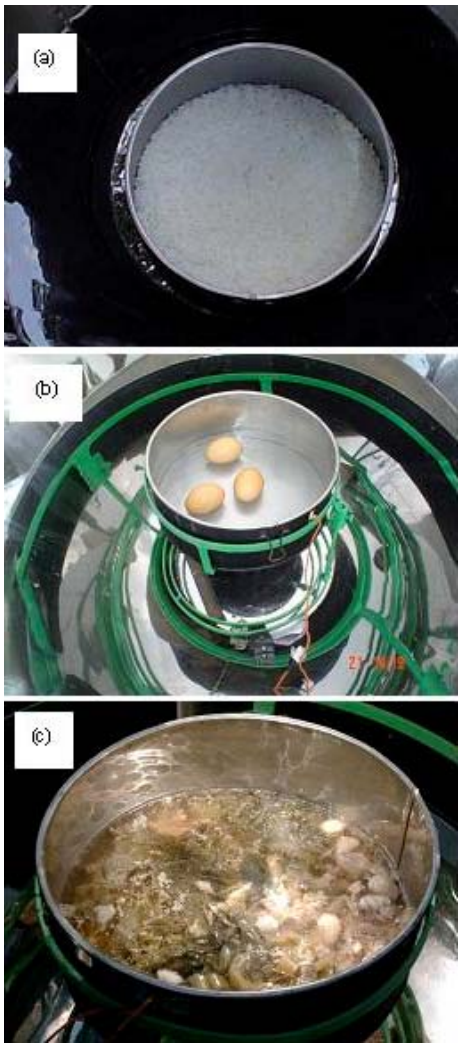

Figure 6 Three types of cooking food
(a) Cooking rice,
(b) Boiling the egg and
(c) Boiling the pickled mustard green pork

Fig. 6 shows the typical of food cooking by conical solar cooker, viz. (a) Cooking rice, (b) boiling the egg and (c) boiling the pickled mustard green pork. Three types of food could be eating after 2 hr from start experiment.

CONCLUSION

Experimental investigations of cooking in the conical solar cooker without tracking follow the sun. Three types of food are cooking, after 2 hours the foods were ripped. The average solar intensity is incidences by about 350 W/m^2. The conical solar cooker is a very interesting advantage where cooking in Thailand.

REFERENCES

[1] Khedari J., Sangprajak A. and Hirunlabh J., Thailand climatic zones, Renewable Energy, Vol.25, Issue 2, February 2002, pp. 267-280.

[2] Khalifa A.M.A., Taha M.M.A. and Akyurt M., Solar cookers for outdoors and indoors, Energy, Vol. 10, Issue 7, July 1985, pp. 819-829.

[3] Srivastave N.C., Solar cooking, Proceedings of 1st Nation Symposium on Energy, 25-27 March 1979, University of Mosul, Iraq.

[4] Khalifa A.M.A., Taha M.M. and Kgart M., On prediction of solar cooker performance and cooking in Pyrex pots, Solar and Wind Technology, Vol. 3, Issue 1, 1986, pp. 13-19.

[5] Sharaf E., A new design for an economical, highly efficient, conical solar cooker, Renewable Energy, Vol. 27, Issue 4, December 2002, pp. 599-619.