CONSTRUCTION AND LABORATORY TESTING OF PARABOLIC TYPES SOLAR COOKER

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Construction and Laboratory Testing of Parabolic Types Solar Cooker

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Abstract—**Solar cooker is a delightful alternative to conventional cooking methods. As the rates of LPG Cylinders hit the roof and due to the fact that the conventional cooking fuels become scarce and cause considerable damage to the environment, there has been an increase in the demand for an alternative, environmental friendly cooking fuel. Meeting this demand is the unique solar cooker that utilizes solar power to cook up a meal. A research to develop, test and evaluate various types of solar cooker was carried out with the major objective to look into its suitability as an alternative means of cooking. There are ten models of parabolic solar cooker that have been built and tested to boil some amount of water in Peninsular Malaysia environment and the results shown that the fastest time in boiling the water is by using twelve angle sided cooker. In addition to the evaluation of the solar cooker based on the experimental results, the feasibility and possible modification in the design to improve the efficiency are also discussed.**

Keywords: parabolic, solar cooker, twelve angle sided cooker

I. Introduction

Cooking can be considered as part and parcel of important domestic activity thus making significant demands on energy supplies. Any successful attempt to substitute exhaustible fuels currently in use for domestic cooking with renewable energy sources is therefore welcomed because of its value in finding a permanent answer to domestic energy demand [1]. Applications that harness solar energy is practicable include the direct use or conversion of solar thermal energy.

A conventional design for a solar cooker basically consist of an insulated black box with a glass cover for letting in solar radiation and trapping it through the greenhouse effect, has long been known and its use is widespread. In order to get the high temperature to heat water or cook food, it is necessary to concentrate large amount of sunlight on a small light-absorbing area [2].

The basic idea is to focus the sun's rays using reflected area inside the cooker. Figure 1 (a) shows the concept used to build a solar cooker with a black pot located at the base of the cooker. Meanwhile, figure 1 (b) shows the sun's light ray reflects to a focus point hanging from the base of the cooker. When the heat from the sun hit the solar cooker inner surface constructed with aluminum foil, the heat will reflect to the black pot and heat the pot constantly.

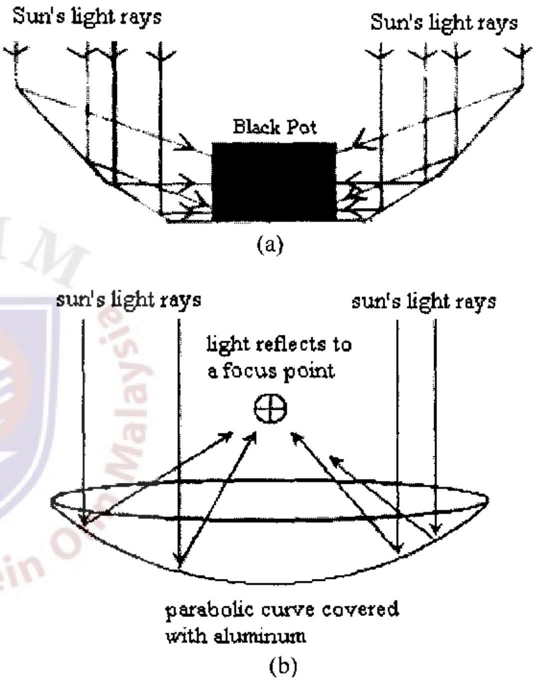

Figure 1. The concept of reflected heat for solar cooker

The most common approach is to use curved reflective panel. A reflector with a parabolic curve will concentrate sunlight on a very small spot to start a fire. Simple solar oven and cooker are used around the world in both commercial kitchens and people's home. Solar cooker can be easily made with everyday materials such as cardboard and tinfoil.

A solar cooker also is a good example of the "greenhouse effect" at work. Short wave radiation from the sun passes easily the glazing and absorbed by the dark surfaces inside the cooker and may become a delightful alternative to conventional cooking method. The solar cookers available today really functional and deserve serious evaluation by a much larger audience especially when the sunshine period is appreciably long and easily obtained.

Furthermore, cooking with solar cooker is smoke free and therefore increases life expectancy. Housewife's responds that

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they have more time for other works as by using solar cooker they has no worry on fire and also less dangerous to children. Nevertheless there are also some disadvantages of using solar cooker since it cannot be used to cook breakfast and meals in the evening when there is no sunlight.

II. Conversion of Energy

The energy available for cooking is the balance remaining after energy storage and heat losses are subtracted from energy entering the solar cooker. Application of the first law of thermodynamics (conservation of energy) and dimensional analysis provides the following equation:

$$P_u = X_o + X_1 A_i I_T - X_2 U_L A_u \Delta T_u + X_3 ktdT_a - X_4 L^3 C_v \Delta T_t \pm X_5 K A_i I_T \quad (1)$$

Only the constant, X_1, was assigned an expected value. This value, 0.15, is the efficiency of a solar cooker determined from earlier experiments (Funk, 1992).

The constant X_2 reflects the dependence of heat loss coefficient on temperature differences. The heat loss coefficient can usually be approximated with a linear relationship when the temperature difference is less than 100C because irradiative heat transfer is small relative to forced convection. If X_2 is other unity, it indicates a discrepancy between heat loss measured in the wind tunnel and experienced in the field.

The constant X_3 attempts to quantify the effect of internal heat transfer. It requires knowledge of thermal gradients within the absorber plate, information which is not available. This approach is also limited because it does not account for contact resistance. The largest problem is the interdependence of the internal heat transfer (absorber plate conductivity) and oven loading (pot quantity and mass of contents). Thermal conductivity has less influence on performance when the load is distributed (Funk and Larson, 1994).

Losses arising from internal thermal inertia are accounted for by the equation where the constant X_4 adjusts for variation in mass and heat capacity of construction materials. The time rate of change of absorber temperature may not be known, but is probably similar to that of the fluid in the pots if there is no warm-up period. Judging thermal inertia to be small for the cookers tested, this parameter was expected to be small. It was dropped from the equation as a means of simplification, to reduce the number of parameters to the most significant ones and to contain the present experimentation to a feasible scope. Yet, thermal inertia is important in predicting performance for solar cookers incorporating thermal storage, and may be worth examining future experimentation.

Finally, the relationship between clearness index (ratio of extraterrestrial to observed beam radiation) and concentration (ratio of intercept to aperture area) may be significant because reflectors primarily make use of beam radiation Diffuse radiation is a greater proportion of total radiation when the clearness index is low. Diffuse radiation is not effectively utilized by reflectors of imaging concentrators since it is impossible to focus a non-point source. The final constant, X_5 attempts to quantify clearness index effects.

III. Solar Cooker Design

There are three main principles incorporated into solar cooking which are fundamental to any cooker. These principles are reflection of the greatest possible amount of sunlight to the food, converting these light waves to heat and effectively retaining the heat by insulation.

For the reflection, the aim is to make the cooker that can be adjusted to the sun's varying positions to capture enough light to cook using the reflector that will direct the sun's rays onto the pot. The shape of the parabolic model is made such that it reflects only on a single point where the food is to be placed.

For the conversion, the aim is to make the cooker that can effectively absorb and convert the sun's rays into heat by using pots made of dark material. Dark-colored materials absorb more heat while light-colored reflect the sun's rays. If a shiny pot is used, the rays are reflected out of the cooker allowing no light energy to be converted to heat. On the contrary, the black pot absorbs the rays and converts them to heat.

In this experiment, ten different designs of solar cookers have been constructed using several tools and basic materials such as an umbrella, a cardboard, an aluminum foil and a black pot as shown in Figure 2. The focal length of each solar cooker has been calculated using parabolic equation to get the best location for collection of directed and reflected sun's light rays i.e.,

$$y = ax^2 + bx + c \quad (2)$$

Each prototype of the solar cooker has been tested to boil some amount of water ranging from 200 ml to 650 ml in Peninsular Malaysia environment with a minimum temperature of 24 °C to maximum of 33 °C.

The testing of each solar cooker has been made on the same day at about 11.00 am to 3.00 pm local time continuously from 12th to 16th April 2007. When the water start to boil i.e., the temperature of the water reach 100 °C, the boiling time is noted.

IV. Results

Table 1 and table 2 show the average results for all solar cookers that have been tested for five days. It shows that double angle twelve sided (DATS) solar cooker give the fastest time to boil i.e., 8 to 20 minutes for amount of water ranging from 200 ml to 650 ml. Meanwhile, figure 3 shows the plot of boiling time versus amount of water.

The results derived from Figure 3 shows that the fastest time to boil water is by using double angle twelve sided cooker with equivalent to Y = 1.25X + 6.73 where Y is the boiling time, and X is the amount of water. Meanwhile, the longest time to boil water is by using trapezium box cooker with equivalent to Y = 14.93 X + 41.2 respectively.

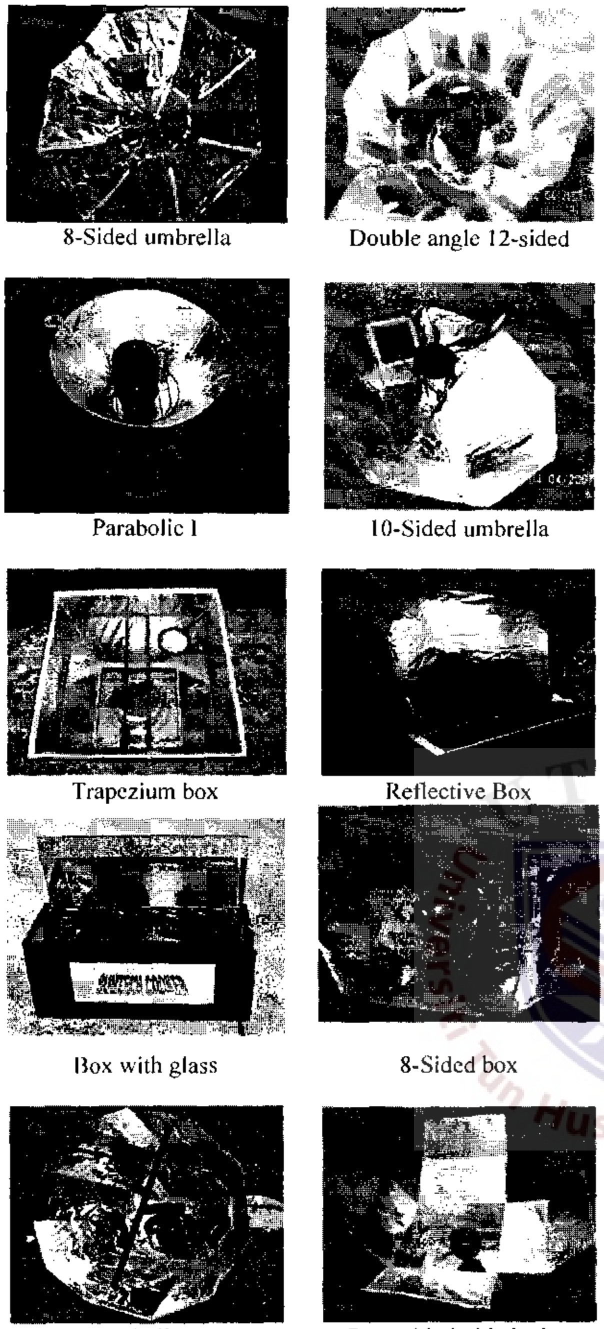

Figure 2. Ten different construction of solar cooker

Table 1. Data I

Water (ml)	Time (minute)				
	DATS	Parabolic 1	10 Sided Umbrella	Parabolic 2	8 Sided Umbrella
200	8	13	25	33	43
250	9	15	29	39	57
300	11	16	34	42	73
350	12	18	38	47	92
400	13	19	43	55	113
450	14	21	47	61	127
500	15	22	52	73	140
550	16	24	56	83	153
600	18	25	60	90	161
650	20	28	64	98	169

Table 2. Data II

Water (ml)	Time (minute)				
	Box 4 Wing	Box with glass	8 Sided Box	Cone Shape	Trapezium box
200	22	42	49	51	53
250	28	43	51	58	67
300	43	45	67	69	83
350	49	46	70	74	102
400	54	47	84	88	123
450	61	49	92	95	137
500	69	51	106	110	150
550	76	53	111	117	163
600	84	55	114	124	172
650	92	58	124	131	183

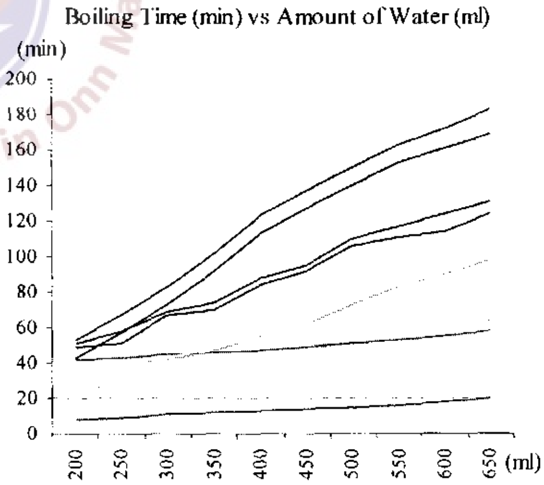

Figure 3. Boiling time (min) vs. amount of water (ml)

V. Conclusion

Solar cooker are the most common way that can offer a practical solution for solar energy. It must place out in the open area in order to get the maximum sunlight that depends on the equipment used to build it. In addition, it must be made to be efficient enough, robust, convenient to use and sufficiently cheap for rural people in developing countries.

The best concept of solar cooker is parabolic type base on the basic principle of reflection. The Doubled-Angle-Twelve-Sided solar cooker obtains the fastest time to boil water which is ranging from 8 minutes for 200 ml to 20 minutes at 650 ml. It is a renewable source that has never ending and environmentally friendly.

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REFERENCES

[1] Tamara Dwyer, 1999. 'Types of Solar Oven' Website: www.exoticblades.com
[2] H. P. Garg, J. Prakash. Solar Energy: Fundamental and Applications, Mc Graw Publishing, 2000.
[3] John Schaeffer, Doug Pratt. Solar Living Source Book: The Complete Guide to Renewable Energy Technologies and Sustainable Living, Gaiam Real Goods; 11th edition. August 2001.
[4] Kevin R. Porter, Solar Cooking Archive: The Next Generation. Solar Cookers and Food Processing International Conference proceedings, 2006.
[5] A Parabolic Solar Cooker for Unattended Cooking, Li-Yan Zhu., Yim K.Kim. http://solarcooking.org/umattendedparabolic.htm
[6] Innovative 'Balcony Model of Concentrating Solar Cooker', Ajay Chandak., Deepak Dubey., Rahul Kulkarni.
[7] Chances and Limitations of Solar Cookers, Agnes Klingshirn
[8] Varieties of Solar Cooker Devices and Uses, Shyam S. Nandwani
[9] Parabolic Solar Concentrators for Cooking, Food Processing and Other Applications, Deepak Gadhia., Shirin Gadhia.
[10] The Solar Cooker Development and Applications in China. Chen Xiofu, Han Tingcun.
[11] Shyam S. Nandwani, Book- La Cocina/Horno Solar. Hagala Usted Mismo, FUNDACION, Universidad Nacional, Costa Rica. 2004 (Revised Edition). 120 pages.
[12] SunSmile. Proposal for Development of a hybrid solar oven for rural Morocco, December 2004