ISSN 1019-1011

Ç.Ü.MÜH.MİM.FAK.DERGİSİ		Haziran	2007	Ç.Ü.J.FAC.ENG.ARCH.	
CİLT.22	*SAYI.1*	*June*		*VOL.22*	*NO.1*

DESIGN, CONSTRUCTION AND EXPERIMENTAL TESTING OF A BOX-TYPE SOLAR COOKER

Funda KAHRAMAN ve Ercan KÖSE
M.Ü., Tarsus Teknik Eğitim Fakültesi, Makine Eğitimi Bölümü, Tarsus/Türkiye

Serap AKCAN
Ç.Ü., Endüstri Mühendisliği Bölümü, Adana/Türkiye

ABSTRACT : *Solar cookers are used to cook rice, vegetables, meat, bake cakes, etc. Most tropical developing countries, among the various types of solar cookers, box type solar cookers are becoming very popular. The two basic system components are the solar collectors with reflectors and a cooking unit. In this study, a box-type solar cooker was designed and constructed. It is consists of wooden, mirror, glass wools and glass covers. The inside of the solar cooker was covered with aluminium foils to transfer the sun rays to the absorber plate. The cooker was tested in summer conditions of Tarsus in southern Turkey. Experiments were performed without load for one week. The temperature of the solar cooker was measured with digital thermocouple. The experimental results show that the box-type solar cooker may be assumed suitable in some cooking process for the climatic conditions of the most regions of Turkey.*
Keywords: *Solar energy, T*he *solar cooker, Design, Temperature variations*

KUTU TİPİ BİR GÜNEŞ FIRININ TASARIMI, İMALATI VE DENEYSEL OLARAK TEST EDİLMESİ

ÖZET : *Güneş fırınları pirinç, sebze, et gibi yiyecekleri pişirmek için kullanılmaktadır. Çoğu gelişmekte olan ülkelerde güneş fırınlarının bir türü olan kutu tipi fırınların kullanılması çok yaygın hale gelmiştir. Sistemin temel bileşenleri yansıtıcılı toplayıcı ve pişirme ünitesidir. Bu çalışmada, kutu tipi bir güneş fırını tasarlanmış ve üretilmiştir. Fırın; ahşap, ayna, cam yünü ve cam kapaktan yapılmıştır. Fırının iç kısmı, güneş ışınlarını, ısı tutucu plakaya transfer etmek için alüminyum folyo ile kaplanmıştır. Fırın, Türkiye'nin güneyinde Tarsus'un yaz iklim koşullarında test edilmiştir. Deneyler bir hafta boyunca yüksüz olarak yapılmıştır. Güneş fırınının sıcaklığı dijital thermocouple yardımı ile ölçülmüştür. Deneysel sonuçlar, kutu tipi güneş fırınlarının, Türkiye'nin çoğu bölgesinin iklim koşulları için bazı yemeklerin pişirilmesinin uygun olabileceğini göstermiştir.*
Anahtar kelimeler: *Güneş enerjisi, Güneş fırını, Tasarım, Sıcaklık değişimi*

1. INTRODUCTION

Over one-third of all humanity and two-thirds of the developing world cook over biomass fuel wood, charcoal, dung and crop residues etc. For these persons a hot meal depends on a day journey that will take them several miles from home and travel on foot in search of firewood, also an unsustainable source of energy. In addition, according to different studies, women typically spend three to seven hours per day near the fire, exposed to smoke, often with children nearby. In homes, exposures to smoke, particulate matter along with carbon monoxide, formaldehyde, benzene, nitrogen dioxide, etc., pose serious health threats millions of people become sick each year from drinking contaminated water. Children are especially susceptible. According to the study made by World Health Organization polluted water and sanitation deficiency are the cause of 80% of all the diseases. Solar cookers are the only smoke-free solutions mainly for cooking and for pasteurizing water. The necessity of the use of solar cookers in order to reduce the consumption of firewood or conventional fuel is well recognized by various national and international organizations. In spite of various efforts made, the widespread use of solar cookers has not become possible due to different reasons including the impossibility of using during the period lacking sufficient sunshine for cooking [1].Solar cookers are used primarily to cook food and pasteurize water. Additional uses are continually being developed. However, there are many factors that affect peoples approach to solar cooking. Among these factors are access to materials, availability of traditional cooking fuels, climate, food preferences, cultural factors and technical capabilities.

Solar cookers (or commonly solar ovens) are one of two types, box type cookers and concentrating cookers. In concentrating cookers, the radiation is concentrated by a parabolic reflecting surface. The cooking vessel is placed at the focus of the parabolic reflector and is, thus, directly heated. This results in a remarkable reduction of cooking time, and temperatures above 200 ^{0}C can be achieved in such a cooker. A common problem in concentrating cookers is food spillage, unless a vapor tight vessel is used. Further, some form of tracking is needed which adds to the cost of the device. The box type cooker is the simplest device to collect the incoming solar radiation and convert it into heat energy. Part of this heat is delivered as useful energy to the cooked food. Box type cookers have the advantage of being simple in design and do not cost much. It requires no tracking, which allows unattended cooking. Also, diffuse radiation contributes to the heat input [2]. Box type solar cookers are suitable mainly for the boiling type of cooking. The cooking temperatureis, in this case, close to 100 ^{0}C. This range of temperature is suitable for cooking, boiling, which is prevalent in most of parts of Turkey, India, Pakistan, Africa etc.

2. LITERATURE REVIEW

Solar cookers have attracted the attention of many researchers.

Khalifa et al. [3] have studied the heat transfer in the cooking process as an approach to develop outdoor and indoor cookers.

Channiwala and Doshi [4] have presented a correlation for the determination of the top loss coefficient in terms of cooker configuration, optical properties and wind velocity.

Grupp et al. [5] have presented a novel design of the box type solar cooker in which the cooker has a fixed cooking vessel in good thermal contact with the conductive absorber plate. The cooking vessel is also set into the glazing to enable easier access to the vessel. The cooker has been used for boiling water, and it has been reported that 5 liters of water per square meter of opening surface can be brought to full boiling in less than one hour.

Bushnell and Sohi [6] have reported the performance measurements of a solar cooking oven design that collects solar energy and stores it in a phase change Material located in a heat exchanger.

Mohamad et al. [7] have investigated theoretically the performance of a box solar cooker during the year. The effect of cooker configuration and solar insolation on the performance has been investigated. Results of experimental verification on two different cookers have been reported. It has been concluded that the cooker aspect ratio, reflector angle and cooker orientation are the main factors affecting the cooker performance. It has been reported that an improved performance has been achieved by considering a transparent south facing side of the cooker.

Suharta et al. [8] have described several generations of solar ovens and their field testing in Indonesia. It has been reported that an oven temperature up to 175 ^{0}C has been reached and that solar ovens proved their ability to cook effectively.

Gogna et al. [9] reported a relatively simple test procedure based on zero thermal loss from the solar collector at the steady-state condition. It involves the measurement of stagnation temperature that the absorber approaches when no heat is extracted from the collector.

Mullick et al. [10] developed the thermal test procedure to determine the optical efficiency for a paraboloid concentrator solar cooker.

Kumar [11] compared the three experimental test procedures for determination of optical efficiency of concentrator solar cooker.

Namdwani [1] has designed and studied different solar devices like solar cookers, solar cooker cum drier, solar cooker cum water heater and solar stil for the last 25 years.He made multipurpose device at home for different practical uses and to study advantages, conveniences and limitations. His device named as food processor, which could cook meal or heat water for pasteurizing, dry agriculture products, distill some liquid (mainly water).

Esen [12] designed a solar cooker integrated vacuum-tube collector with high pipes containing different refrigerants and he analysed its thermal performance experimentally. His study demonstrated that cooking times between 27 and 70 min as well as short heat up times can be obtained with a solar cooking system consisting of vacuum tube collector with integrated long heat pipes using refrigerant as working fluid.

El-Sebaii et al. [13] constructed and tested with or without load. The best performance of box type solar cookers was achived with the largest cooker load.

Oturanc et al. [14] designed and a box type solar cooker and its thermal performance analysed experimentally. The thermal performance and efficiency values obtained may be assumed sufficient for the climatic conditions of TurkeY. Although boiling temperatures are not reached, some foods like patatoes, rice, egg, macoroni, etc. can be easily cooked by the designed cooker. Some cooking processes are performed

with the cooker and realized in 90-180 min periods which is the proposed cooking period for box type solar cookers.

3. MATERIAL AND METHODS

The constructed box type solar cooker is shown in Figure 1. It is consists of wooden, mirror, glass wools and glass covers. The inside surfaces of the box were covered with aluminum foils. Shape of the solar cooker is rectangular prism. The inner dimensions of the box are 0.78 mX0.42 mX0,63 mX0,53 m. The top of the solar cooker was covered with double glass separated by 0.02m. The double glass covers minimizing the rate of heat lost through the top of the cooker. Mirror reflector was used to reflect the solar radiation onto the cooker cover for increasing of efficiency. Dimension of the mirror 0.70 m and 0.78 m. A steel platform was used for the absorbing surface for the incoming solar radiation in bottom of the solar cooker. Thickness and dimension of the platform are 0.001m and 0.55X0.75m^2, respectively. The temperatures were measured for two angles of cooker which are 16º and 26º. Radiation of sun is vertical for 26º according to the surface of the cooker.

The experiments were conducted on 21-25 June 2006. Temperatures were measured between 10 AM and 16 PM with an interval of 1 hour.

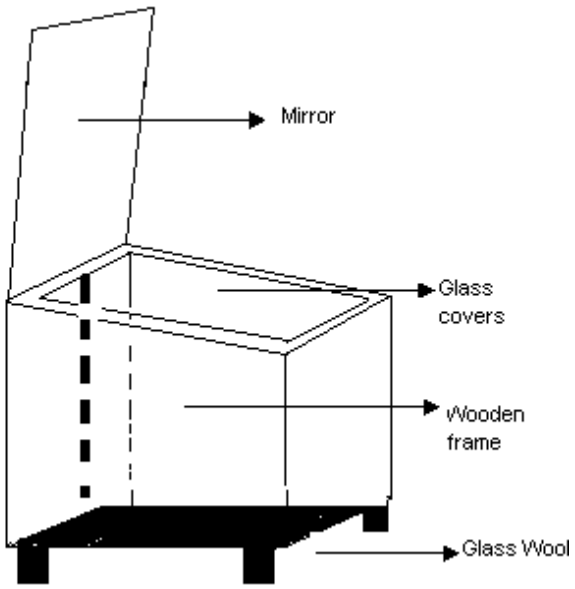

Figure 1. Schematic diagram of the constructed box type solar cooker

4. RESULTS AND DISCUSSION

Experiment was started at 10.00 AM on 21 June 2006. The sun angle of the cooker was adjusted to 16º. The cooker was kept under the sun until the temperatures of the cooker to obtain their maximum values. The results were found to be 36, 45, 58, 69,80, 82, and 79 ºC, respectively (D1). When the sun angle of the cooker was altered to 26º, the temperatures were measured to be 37, 65, 82, 102, 119, 126 and 123 ºC (D2) on 22 June 2006; 45, 81, 119, 127, 131, 128 and 130 ºC (D3) on 23 June 2006; 45, 85, 121, 130, 135, 128, and 126ºC (D4) on 24 June 2006; 36, 51, 62, 70, 84, 91 and 92 ºC (D5)

on 25 June 2006, respectively. The weather was clear and sunny on the 21-24 June 2006 but it was cloudy on the 25 June 2006. As seen from figure 2 the lower temperatures were obtained on the 25 June 2006 (D5). Temperature distribution for the box type cooker without load is shown in Fig. 2. The graph was attained by using matlab program. From the results of Fig. 2, it is clear that the temperatures of the cooker increase with the time of the day until they achieved their maximum values at 2.00 PM.

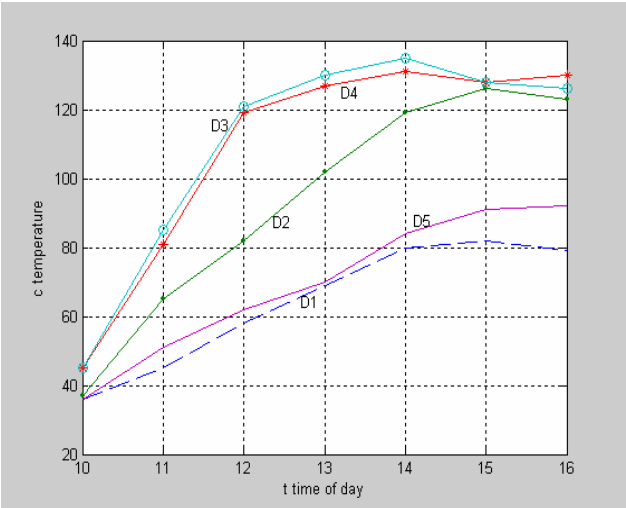

Figure 2. The relationship between time of day and temperature for the cooker without load

5. CONCLUSIONS

- The designed cooker is inexpensive and easy to manufacture and use.
- Boling temperature of water was reached. Thus, some cooking process may be performed with the box type cooker and may be realized in the short time at Tarsus's climatic conditions.
- Thermal performances and cooking abilities may be improved by adapting some modifications in non-tropical regions.
- The use of these solar cookers is limited because they do not have any storage, i.e. these cookers cannot be used on cloudy days or in late evening.

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