Design Solar Box Cooker with Low Cost Materials

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Abstract:

In this research we designed solar box cooker and studied the factors which affects on cooking process and the interaction of the sun energy with materials which help us to introduce new materials can be chosen to build an effective solar cooking device with low cost such as cardboard, aluminum foil, and glass. This research shows that we can use this material to heat the water up to 72°C.

تصميم طباخ شمسي باستخدام مواد جديدة أقل كلفة

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الخلاصة:

تم في هذا البحث تصميم طباخ شمسي ودراسة العوامل المؤثرة على عمل الطباخ في هذا النوع من الطباخات ودراسة التأثر بين طاقة الشمس مع المواد التي يمكن أن تساعدنا في إيجاد مواد جديدة يمكننا اختيارها في صناعة طباخ شمسي فعال بأقل كلفة مثل الورق المقوى، رقاقات الألمنيوم والزجاج. ويبين هذا البحث أنه بإمكاننا تسخين الماء إلى درجة تصل إلى ٧٢ درجة سيليزية .

1. Introduction:

The box-type of solar cooker is an old invention; the first documented use was in the late 18th century when a Swiss, Nicholas de Saussure, prepared food using a device of this kind. However, a more widespread use of solar cookers did not take place until the 1970's. At the present time the number of solar cookers in use varies from one-half million to two million, depending on the available sources using in cooking. They are mostly used in China and India. About two-thirds of these cooker kinds used in these two countries which are of the box type [1].

People use solar cookers primarily to cook food and pasteurize water and there are Numerous factors including access to materials, availability of traditional cooking fuels, climate, food preferences, cultural factors, and technical capabilities, affect people's approach to solar cooking [2] .

In the late 1700's, experiments with glass and trapped solar heat by French-Swiss naturalist Horace deSaussure laid the foundation for not only solar cooking but also for passive solar heating of buildings and active heating of

water by use of solar collector boxes. Le Journal de Paris received from deSaussure descriptions of experiments and observations [٣]. At the same time there was little empirical research regarding temperatures and glass covered heat traps, so in 1767 deSaussure executed a series of experiments to determine the nature of this phenomena by constructing a miniature greenhouse (a series of bottomless glass boxes) nesting within the other with air between, and all sitting on a black base [4]. He then aimed it to the sun, and measured the temperature concentric box. He discovered that the outermost box registered the lowest of the temperatures (which was still higher than the outside air temperature) while the innermost box registered the highest at 185 degrees F [5].

In 1870's W.A. Adams developed a solar cooking unit very similar to today's popular contemporary ovens. A glass fronted box mounted on a small tilt able platform, and using an eight sided mirror to focus the sun's energy to the center of the cooker, this design reached to high temperatures enough to cook a four pound turkey within 4 hours [6].

The early 1900's scientists saw, and backyard tinkerers alike, developing designs that improved upon deSaussure's original "hot box", and that development continues to present day and Arizona has a very significant role in that envelopment. The First National Solar Cook-off in Phoenix, Arizona on September 19, 1981, [7].

2. The importance of research:

Solar cookers are safe, healthy and convenient because there is no fire to cause burns or blow out of control, no smoke to injure eyes and cause lung problems. People allergic to smoke can now enjoy "solar cues" barbecues without the smoke. Also, most solar cookers cook at 82-121ºC (180-250ºF), ideal for retaining nutrients, moisture and flavor and not burning foods. Wood and gas fire temperatures, by contrast, exceed 260ºC (500ºF). You can bake, boil and lightly fry foods in their own juices. Meats get very tender. As well, solar water pasteurization is a skill everyone should know for emergencies. When solar cooking, your kitchen stays cool on hot in the sunny days. The Cooker folds for easy storage or carrying for meals away from home [8].

3. Theoretical Part:

The basic rule is the more available direct sunshine and the stronger, it is the better a solar box cooker works. At noon and luminous seasons solar radiation is over 1000 W/m^2 per hour. If we have a solar box cooker with 0.4 m^2 surface, its gross power is approximately 400 watts. The most advantageous areas for solar cooking are often the same with the biggest shortage of firewood [9].

A solar box cooker needs direct sunshine in order to work properly. Even in totally cloudless conditions cooking usually takes longer time than the fire. In cloudy or rainy weather a solar box cooker works even slower or does not work at all, depending on the conditions. Wind slows solar cooking down to some extent. A strong wind might even turn a cooker upside down; therefore it is advisable to have a stable lid [1].

The box cooker, which is the simplest and the cheapest solar cooker type, is still able to heat food to 150°C (300°F). It consists of an insulated box with a glass or a plastic window. The window acts as a solar energy trap by exploiting the greenhouse effect. Solar radiation passes through the window, and is absorbed by the walls, the bottom of the cooker and the cooking utensils (pots, pans,… etc.). The darker pots inside the cooker are heated better. The window is not transparent to heat radiation, which means that the heat radiation coming from the walls and the pots will be trapped inside the cooker, thus heating the air. To maximize the heating effect, the cooker's walls, and the outer side (not the inner side) of the cooking pots should be painted black. The bottom should be covered with a black metal plate to carry heat to the pots. A double window is better than a single window because it reduces heat conduction. To increase the incoming solar radiation, reflective plates can be used; and in less-than-optional solar condition, their use is essential. They should be positioned so as to reflect radiation from a wider area into the box. In addition, the box should be mad as airtight as possible, so as to minimize the flow of hot air to the outside as show in Fig. (1) [2].

The second law of thermodynamics states that heat always travels from hot to cold. Heat within a solar box cooker is lost in three fundamental ways: conduction, radiation, and convection.

The solar heated absorber plate conducts heat to the bottom of the pot, to prevent loss of this heat via conduction through the bottom of the cooker, the absorber plate is raised from the bottom using small insulating spacers .consider a slab of thermal cross-sectional area A and length L, whose ends are maintained at temperatures T_H and T_c. Let Q be the heat that flows thought the slab from its hot face to its cold face, in time t. Experiment shows that the rate of heat flow (H) is given by:

$$H = \frac{Q}{t} = kA\frac{T_H - T_C}{L} \qquad (1)$$

where k is the thermal conductivity, which is constant depending to every material and proportional directly with value that define good heat conductors, and conversely

As the density and weight of the materials within the insulated shell of a solar box cooker increase, the capacity of the box to hold heat increases. The box interior including heavy materials such as rocks, bricks, heavy pans, water, or heavy foods will take longer to heat up because of this additional heat storage capacity. The incoming energy is stored as heat in these heavy materials, slowing down the heating of the air in the box. These dense materials, charged with heat, will radiate that heat within the box, keeping it warm for a longer period at the day's end [8].

4. Experimental Part:

In the present design, an attempt is made to reduce the cost of conventional box type cooker by using materials different from the common type. Performance of this new design will be more or less or same as conventional cooker. This newly designed cooker will be very appropriate for personal applications. Fabrication of the cooker is very easy and so cost to people in Iraq.

The detailed constructional feature of the cooker is shown in Fig. (2). The top open cooker box is made of 5cm thick wood tiles. Cooker box is kept in a wood box and at least 5cm thick cotton layer is put in all sides and bottom in between wood box and cooker box. The arrangement not only will save the cooker box from the chance of breakage but it will also reduce the heat loss from cooker box to the surroundings. Outside of the wood layer if covered by a polythene sheet it will be more effective for heat retention. Inside surface of the cooker box is covered by aluminum foil in all sides and bottom to direct solar radiation towards the cooking pots. For reflecting surface, wood material of the box will not be able to absorb radiant heat. Heat will be transferred to the tile box only through the conduction process from aluminum foil but foil will not be able to transfer heat much as thin foil itself will absorb heat only from entrapped hot air and tile material is not at all a good conductor. So, most of the absorbed heat will be retained in cooking pots only. Cooking pots should not be directly in touch with foil to avoid damage of the foil; rather these are to be kept on pot stands (common ring shaped stands made of steel wire available in utensil shops). A rectangular frame made of wooden battens tightly fitted with outside of the cooker box walls at top.

A 2mm thick asbestos based paper gasket is used in between wooden frame and walls of the cooker box for sealing purpose. This type of asbestos gasket is generally used in high pressure joints of automobile water lines and there is no chance of contamination of loose asbestos fiber with food item for high quality bonding of the gasket materials. Slotted wooden frame provides seating for cover glazing. South facing booster reflector is also hinged with the wooden frame. A 3 mm thick single glass pan is used as cover glazing. Frame of the glass cover is made from low cost tin sheet available by cutting any broken glass. Cooking pots are to be placed side by side inside of the cooker by opening hinged glass cover as usual. Booster reflector is fabricated by fixing aluminum foil on tin sheet of glass. Reflector can be adjusted in desired inclination through the adjustment of wing nut in slotted links.

To make leak proof joint in between wooden seating and closed cover glazing, nylon rubber pieces cut from old tube of motorcar tire is used as gasket material. For proper setting of gasket, small grooves may be cut at the topside of wooden battens. Rubber gasket is also used inside of metallic channels of cover frame for sealing of glass pan.

Epoxy adhesive is used in addition for fixing gasket in all the joints. Adhesive is also used to attach aluminum foil inside of cooker box and on reflector sheet. Inside dimensions of the cooker box are 50x30x10cm. Length of the cooker, greater than its width is designed to increase the time gap in between reorientations. Diameter and height of the two aluminum cooking pots are 16cm and 6cm respectively. Cooking pots are painted dull black by automobile muffler paint (blackboard paint is not suitable because it is not so permanent color and clean out during washing of pots). We made our measurements at 12.00 pm when sunshine become direct and strong.

5. Results and Discussion:

In general, we can use the cooker when the length of your shadow on the ground is shorter than your height. This is an indicator that the sun is high enough in the sky to cook. In many countries there are a few months each year when simple solar cookers cannot be used. People living in the darker areas on the following map tend to have longer cooking seasons as Fig. (3) [8].

We have some processes serve us in solar cooker work like transmission, reflection and absorption and we must arrange the components of the cooker which has a better reflection or transmission until reaches the pot which should be made from good absorbent materials.

We made some statements about rank of transmission, reflection and absorption to the materials which are used in our solar cooker design to help us choose the appropriate and the better and low cost material in cooker design as shown in table (1). We studied three cases; first case is white case, second is dark case and third is dark with cover case. We studied the temperature variation with time to these three cases, we note that third case is the best to cook food because the high and trapped heat inside it.

Dark surfaces get very hot in sunlight, whereas light surfaces don't. Food cooks best in dark, shallow, thin metal pots with dark, tight-fitting lids to hold in heat and moisture.

A transparent heat trap around the dark pot lets in sunlight, but keeps in the heat. This is a clear, heat-resistant plastic bag or large inverted glass bowl (panel cookers) or an insulated box with a glass or plastic window (box cookers).The two best performing cooker both used large reflecting panels, a dark container at the base for water, and cover to retain heat as shown in Fig. (4), both were lightweight and thus relatively portable.

6. Conclusions:

There are many factors that affect to speed the cook food or heat water in a solar cooker, including time of year, amount of sun, type and amount of food. We cannot cook early in the morning or after sunset .the sun is most intense between 10:00 a.m. and 2:00p.m. so we can make the solar cooker more spread wide by industrialization the solar cooker from low cost materials which give as good results. In this research we introduced new and good materials that cook food with acceptable results.

Reference:

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[7] J. Radabaugh, Heaven's Flame. USA: Home Power Publishing (1998).
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[9] S.S. Nandwani (ed.), Developments in solar cooking: Proceedings of the second world conference on solar cookers - use and technology (1994).

Table (1) transmitter, reflector and absorber light for some materials

Material	As a Transmitter Description-Rank	As an Absorber Description-Rank	As an Reflector Description-Rank
Mirror	Bad	Bad	Excellent
Window Glass	Excellent	Bad	Bad
Aluminum Foil	Bad	Bad	Good
Waxed Paper	Bad	Bad	Medium
Wood	Bad	Excellent	Bad
Aluminum	Bad	Medium	Medium

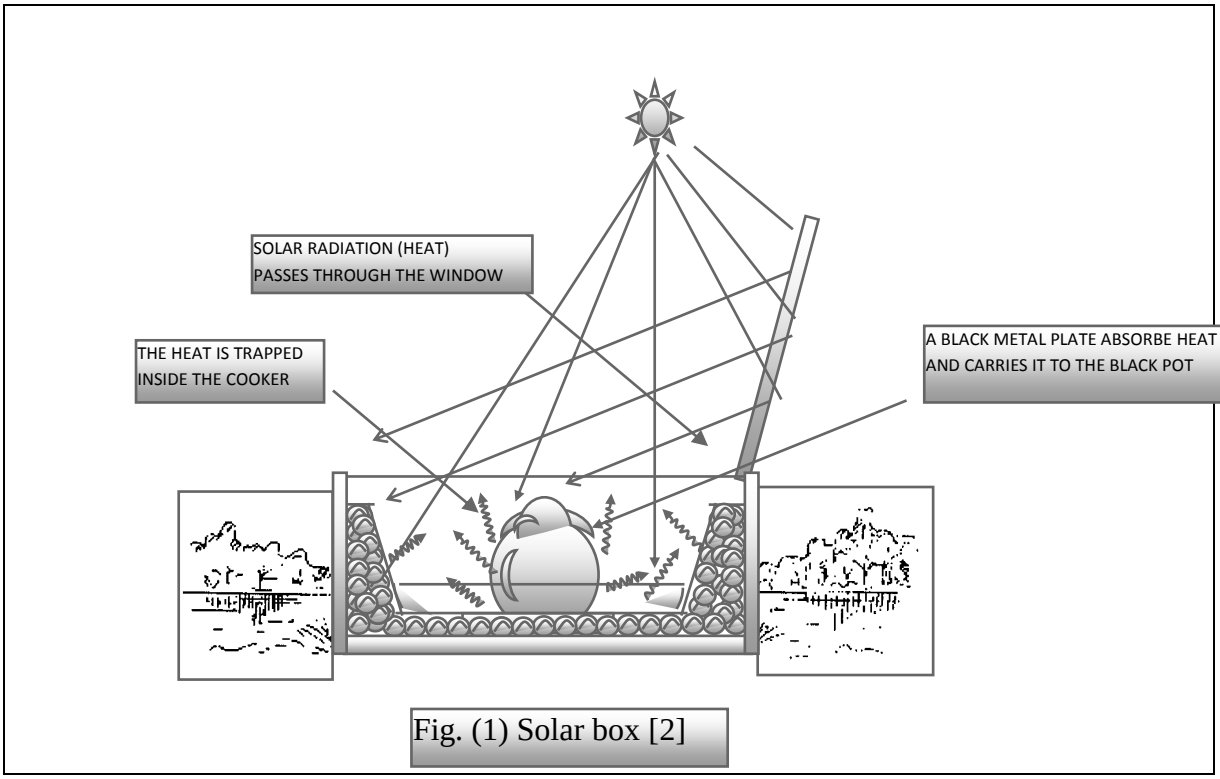

Fig. (1) Solar box [2]

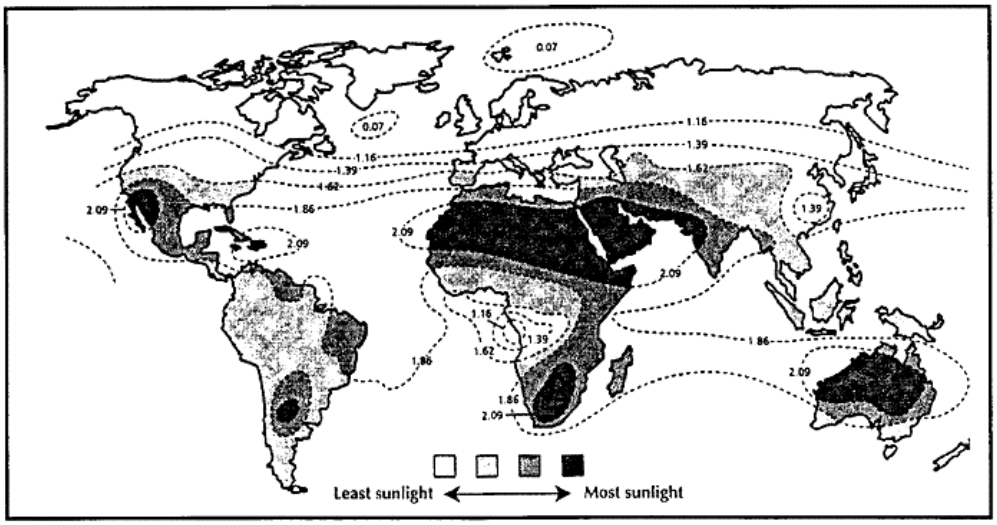

Fig. (3) Average annual solar radiation [8]

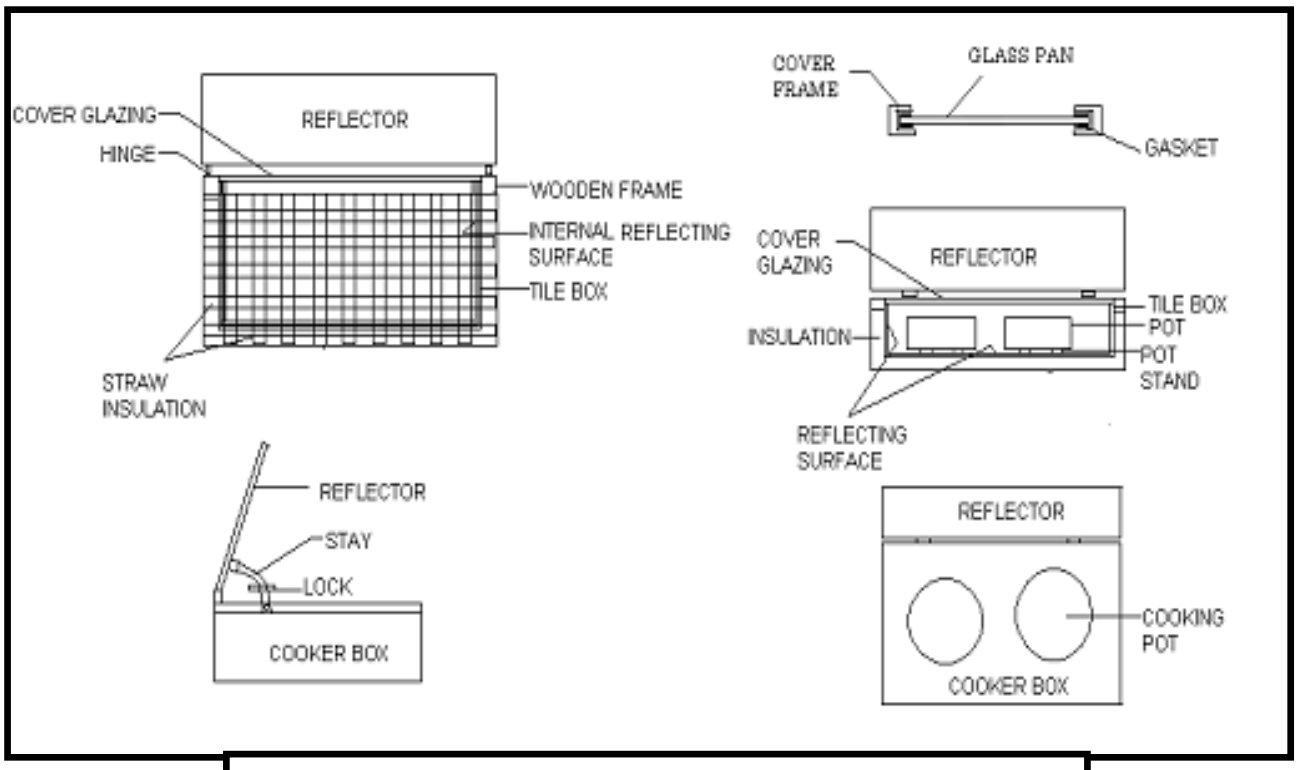

Fig. (2) Constructional Features for box cooker

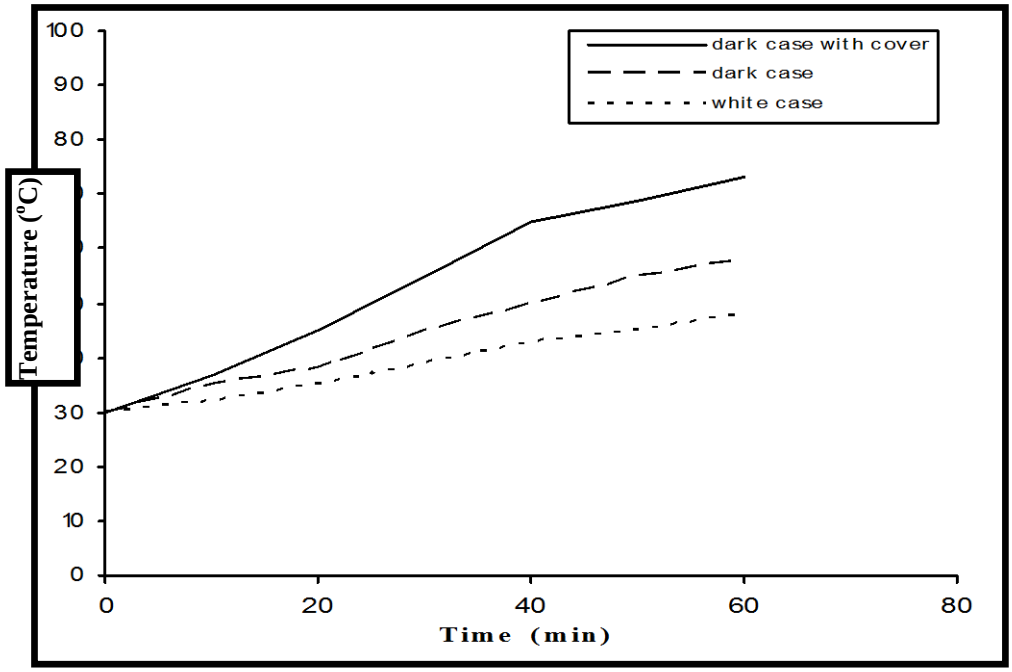

Fig. (4) Compare between dark, white case and dark cover case full 200 milliliters water