THE USE OF PAPERBOARD AS MATERIAL FOR SOLAR THERMAL POWERED OVEN

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Abstract : The need for cheap and abundant energy to support daily activities, especially the food processing as well as the phenomenon of paperboard material availability of waste products from consumptive lifestyle today, pose a potential that is very likely to be developed into a product. With the geographic condition of Indonesia which is in latitude near the equator where the sun is available all year round then this potential can be used to solve the problems above. By using the design method, this study tried to resolve the problems above by utilizing the existing natural potential. The purpose of this study was to design a product in the form of solar powered oven by utilizing the paperboard material as the base material for the product. This study is expected to be one of the reference and trigger the development of alternative techniques to the problem of paper paperboard material utilization and utilization of solar heat radiation to support daily activities.

Keywords: *Oven, Solar, Paperboard*

1. INTRODUCTION

Cooking or food processing is an activity that can not be separated from human life, because to process the food is one of the things that distinguishes us (human) from animals. But how can we do the cooking if there are no tools ? or the ingredients are there but there is no fuel? or both are available, but the price of fuel is not affordable by most people?

Geographically, Indonesia is at the latitude of the equator which has the potential presence of the sun throughout the year with its position to the maximum occurs between mid-February until the end of August. With the presence of the sun cycles that occur throughout the year in Indonesia, solar heat radiation could potentially be put to maximum use for cooking in Indonesia, so as to answer the classic questions that occur from relying on fuels (petrol) as above.

Indonesia on the other hand with the majority being in the working class with medium economic capacity have other potential very likely to be exploited. Working people with medium economic capacity is a community group that tends consumption and purchasing power is quite good and one of the effects of consumptive lifestyles is generating the waste material in the form of packaging.

From the three issues above which are the need of cheap resources for cooking, geographical position of Indonesia which allows the presence of the sun throughout the year, and the availability of paperbord material in the form of packaging due to community lifestyle, generating a unique potential that allows it to be developed into an innovative product.

Questions to be answered in this study is "How to design a solar thermal powered oven by using paperboard material?"

2. THEORETICAL BACKGROUND

2.1 Solar Thermal Power

The thermal energy is energy that is widely used practically in everyday lives, either directly or first converted into energy, such as into electrical energy, and the energy of motion.

In the term of cooking thermal energy is clearly a major factor that determines the success of a cooking results. The thermal energy it self generated by many sources, but in the term of cooking the common sources used are including : kerosene, LPG, coal briquettes, firewood, charcoal, methane biogas, electricity.

The thermal energy has physical properties as follows:

- Displacement is influenced by the temperature, which means that the heat energy moves from a place or an object with a high temperature to a lower temperature or object.
- How heat transfer occurs in three ways, namely conduction (conduction) in which heat energy moves because of the direct contact between solid objects contain heat with other solid object at a lower temperature, radiation (radiation) where the thermal energy can be transfered without the need for direct contact or because there are other connective material between two objects or locations, the third one is convection (convection) in which heat energy moves with the aid of liquid or air that moves between objects.

2.2. Solar Thermal Powered Oven

The concept of using solar energy as a source of energy for cooking in the modern era actually appeared more than 220 years ago, and was first used by French special forces "Foreign Legion" since 1870.

Solar-powered oven is a good alternative as well as fun to replace the existing conventional oven. Solar-powered ovens that are already available today can function properly, and deserves more serious attention to be developed.

In principle, the solar-powered oven utilize the concentrated sunlight heat radiation at one point for raising the temperature of the food, or water up to the cooking temperature (temperature cooking starts from 250 to 400 degrees F).

2.3. Solar Thermal Powered Oven Working Principle

The working principle of the solar powered oven is divided into three parts:

- (Heat Gain) To obtain and collect heat by using the principle of the greenhouse effect, in which the heat reflected by the reflector is directed into the vacuum chamber that is opaque, so that the heat will be trapped and raise the vaacuum chamber temperature until reach its cooking temperature. (Figure.1)

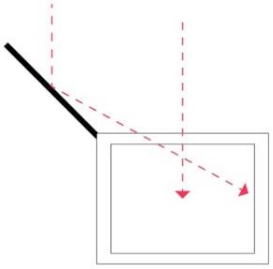

Figure.1 Heat Gain
Source: Personal Documentation

- (Heat Loss) To release and distribute the heat on the object of cuisine utilizing heat by radiation, and distribute this heat to the pot or pan. (Figure.2)

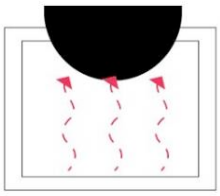

Figure.2 Heat loss
Source: Personal Documentation

- (Heat Storage) To store heat so that not easily lost by the time the sun began to sink, utilizing the isolation of a vacuum chamber with a thick material, and does not penetrate by the wind (Figure.3)

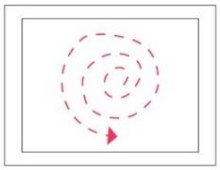

Figure.3 Heat storage
Source: Personal Documentation

2.4. Paperboard

There are six kinds of processed products are made of paper pulp in general, namely: Newsprint paper, printing and writing paper, Tissue paper, Corrugated material, paperboard, and includes other types of paper (say because of their use of a specific and limited). Paper and paperboard are made using the same technology base. Paper mainly provides printing surface, while paperboard has a surface for printing, good rigidity and good strength.

Here are some types of classification based on the physical properties of paper:

1. **FBB (*Folding Boxboard*)** : The paper consists of several layers, made of mechanical pulp which is placed between layers of chemical pulp. Mechanical pulp may be stone-ground wood (GW), pressurized-ground wood (PGW), thermo mechanical pulp (TMP) or chemi-thermomechanical pulp (CTMP). The top layer is a layer of bleached chemical pulp and vice versa is bleached chemical pulp or unbleached chemical pulp. the top and the reverse side can be coated with mineral pigments.
2. **LPB (*Liquid Packaging Board*)** : Most types of LPB paper used for food packaging and beverage, mainly to pack dairy products, juice and others, or non-food and non-beverage fluid. This paper structure has a polymer layer (polymer-coated) material that serves as a barrier between the product with paper-based material, or coated with aluminum foil for use as a long-term food packaging.
3. **SBS (*Solid Bleached Sulphate*)** : All the parts of these papers are of from bleached chemical pulp, but the outer (upper side and lower side) coated with mineral pigments.
4. **SUB (*Solid Unbleached Board*) SUS (*Solid Unbleached Sulphate*)** : Type of paper is largely chemical structure is built from unbleached pulp. To get a clean white surface of these papers make use of mineral pigments, and sometimes also use combining materials such as fiber layer that has been bleached (bleached fibers).
5. **WLC (*White Lined Chipboard*)** : Multilayer paper comprising at least one middle layer of recycled fibers. The top layer consists of bleached virgin chemical pulp or white recovered pulp. Among the top layer and the middle layer is usually a layer of chemical, mechanical or deinked recycled fiber. The opposite layer consists of recycled fibers or bleached/unbleached virgin fiber. The top side and the opposite is usually coated with mineral pigments.

3. THE RESEARCH METHOD

To find out how much the effectiveness of paperboard material as the material of solar oven, the study conducted by the quantitative method which is implemented through:

1. Survey : Conducted to determine the data on solar thermal oven.
2. Experiment for : Conducted to get the maximum configuration of the use of paperboard solar oven.
3. Analysis and : Performed for data processing obtained from surveys and experiments to produce a design decision in this study.

4. RESULT AND DISCUSSION

4.1. The Configuration: Forms Follow Basic Principles

There are three basic principles to be considered to get the maximum configuration in making this solar powered oven, those basic principles are as follows:

1. Heat gain : Considerations on the principle of heat gain produces the configuration of the shape and position of the reflector part and transparent coatings as a means of gaining solar heat radiation.

   The maximum configuration for the reflector part is the flat shape (flat shape can reflect heat radiation and spread it evenly so it is relatively safe because it does not establish hotspots as happens in parabolic reflector). Reflectors must also be positioned with a slope of 60 degrees in order to project the sun's heat radiation into the vacuum chamber optimally (Figure.4). Similarly, the configuration of transparent coating, to get the most out of this section must consist of two layers of transparent material and clean with a distance between them of about 5mm. it serves to hold the leaking of the heat radiation that has been trapped in a vacuum chamber creeping out (figure.4).

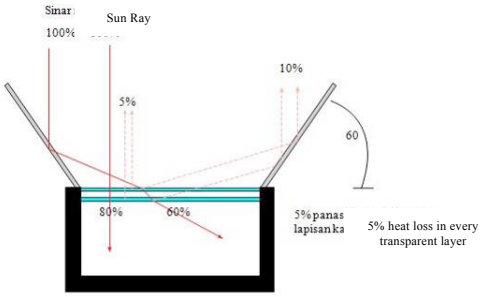

Figure.4. Reflector and transparent coating configuration as a mean of gaining solar heat radiation
Source: Personal Documentation

2. Heat loss : Considerations on the principle of heat loss produces the configuration of the color selection that can provide heat radiation with perfect distribution on the container in order to finalize the foodstuffs placed in the container.

   The inside of the vacuum cahmber must be "chromium" colored (Figure.5) in order to reflect the heat radiation to the maximum on food containers to be cooked (the food container it self recommended in dark color (black) in order to absorb the heat radiation perfectly).

Figure. 5 Chromium colored inside the vacuum chamber.
Source: Personal Documentation

3. Heat storage : Considerations on the principle of heat storage produces the configuration of vacuum chamber shapes and layer in order to be able to withstand a maximum heat radiation trapped in it as long as possible.

   In order to save heat radiation properly then vacuum chamber should be composed of two parts where there is a distance between them so that created second vacuum chamber that will serve as a buffer zone to withstand the heat radiation leaks. (Figure.6)

Figure. 6 The composition of the vacuum chamber configuration section.
Source: Personal Documentation

   In terms of material aspects, the basic principle of heat storage is also taken into consideration the choice of paperboard used to make solar powered oven. Corrugated board made of FBB (*Folding Boxboard*) kind of paperboard has choosen to be used in this oven. The physical properties of corrugated board it self gives an extra feature that can be used to reinforce the vacuum chamber. Corrugated board consists three layers in its structure, the midle layer consist FBB that shaped in curvaceous (curving) configuration which forms a small vacuum chamber arrangement. (Figure.7)

Figure.7 Corrugated board made of FBB
Source: Paperboard Guide, Stora Enso Renewable Packaging

4.2. The Experiments

Experiments in this stage was conducted to seek maximum configuration of the oven in order to function properly. Proportionaly to the time duration of each experimental session was conducted in cloudy weather conditions with the aim to find the performance of the oven under normal weather conditions in Indonesia. The assumption if the oven is working well in cloudy weather conditions, then the oven will work better during the hot sunny clear weather conditions.

The experiments carried out have resulted maximum configuration as follows : "Done during the day at 11 am, with a duration of 15 minutes can reach 93°C, the oven conditions covered by two

layers of clear HDPE (high density polyethylene) with a distance of 5mm between them, in cloudy weather conditions with air temperature of 27°C". (Table.1)

Table.1 Experiments Result

No	Date	Time	Ambient Air Temperature	(Minute)/Temperatur (°C)			Elucidation	Technical Conditions
1	20-08 - 2016	8.15	27° C (Cloudy)	(3)/30	(8)/32	(10)/33	6° C in 10 minutes (Not good enough)	Cover : 1 ply PolyEthylene (PE) transparent
2	20-08 - 2016	13.20	30° C (Cloudy)	(3)/40	(20)/60	(25)/75	45° C in 25 minutes (Better, but Not good enough)	Cover : 2 plies PolyEthylene (PE) transparent
3	20-08 - 2016	14.00	30° C (Rainy)				Carot on black plate (Did Not succeed due to raining)	
4	21-08 - 2016	10.50	28° C (Cloudy)	(5)/65	(10)/80		68° in 10 Minutes (Did made to pasteurize temperature (65 - 70° C (150° F))	Cover : 2 plies High Density PolyEthylene (HDPE) transparent
5	23-08 - 2016	11.00	27° C (Cloudy)	(5)/70	(10)/87	(15) /93	93° C in 15 minutes (Succeed)	Cover : 2 plies High Density PolyEthylene (HDPE) transparent + Sealant

Source: Personal Documentation

4.2. The Cooking Activity

After an experiment to find the maximum configuration is done and produce the best configuration, the next step is the process of proving that solar powered oven can do the job to cook food. The cooking process is done by trying to cook a different meal ingredients to get the average duration of each type of foodstuff.

In normal conditions the process of cooking using the solar powered oven made of papaerboard is indeed takes longer than using the traditional oven (Table.2), but if the parameters of its success is "able to cook food thoroughly", then the oven is said to be "worked pretty good". The results of the cooking process itself can be seen on table.2.

Table.2 Preparation of foods to be cooked in solar oven

No	Food Items	Preparation	Duration
1	Vegetables (Potatos, carot, pumpkins, asparagus, etc)	No need to add water if the vegetables were fresh. Sliced vegetables with the same size to ensure cooked evenly, and corn cooked better without cob.	± 1.5 Hours
2	Cereal and grains (Rice, wheat, etc)	Mix two parts water to each part of grains, or cereals. the result is highly dependent as desired. Leave it in the water bath a few hours before cooked so that cooking time later becomes faster. To ensure ripe with average then shake the pan after 50 minutes.	± 1.5 to 2 Hours
3	Pasta and dried vegetables	Heat water to boiling (about 50-70 minutes), then put the pasta and dried vegetables in, mix them all gently and cook for about 15 minutes.	± 65 - 85 minutes
4	Beans	Soak it in the water overnight, and boil it in the pan.	± 2 - 3 Hours
5	Nuts	Put in a pan and add a little oil if you like.	± 1.5 Hours
6	Egg	No need to add water, but be careful the egg white	± 1 - 1.5 Hours

		will change darken if cooked too long, but not burnt and the taste not changed.	
7	Beef, Chickes, Fish	No need to add water, and the longer the meat is cooked, the meat will be more tender.	Beef ± 2 - 3 Hours Chicken ± 1.5 - 2 Hr Fish ± 1 - 1.5 Hours
8	Bread, cakes and pastries	Depends on the type of dough to be cooked	± 1 - 1.5 Hours

Source: Personal Documentation

4.3. The Prototype

This solar powered oven is indeed not the prettiest ever build, but the solar powered oven in the present study was designed with approach on functionality aspects, and the use of discarded packaging materials of consumer grade products. Here below is a picture of the prototype with the best configuration that can be made from the waste paperboard packaging material of consumer grade products. (Figure.12)

Figure. 12 The prototype "Solar Powered Oven" made of FBB paperboard
Source : Personal Dokumentation

5. CONCLUSION

In this study, a few points the following conclusions :

1. FBB Paperboard in the form of corrugated board makes a good material to built a solar powered oven.
2. Solar powered oven made of FBB paperboard could meet the required cooking temperatures even in cloudy weather conditions.
3. Solar powered oven made of FBB paperboard cooks various ingredients well, but takes more time than traditional oven.

The point is solar powered oven made of paperboard can be means of good cooking and environmentally friendly. It is said to be "good" because it can be used to cook properly, and is said to be "environmentally friendly" because it uses a very cheap resource (solar energy available throughout the year and free), and utilize waste material (used cardboard packaging).

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