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Analysis of Solar Cooker Using Sensible Energy Storing Material

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Abstract – *In present setup of India, energy is very essential for human being and nature. For achieving this energy solar energy is one of them most important alternative for cooking purpose. Soyabean oil is used heat storing the solar thermal energy in the form of heat which is used as square parabolic dish as a concentrator was used. In this research article the effect of soyabean oil is analysed. It is found that soyabean oil is beneficial for solar cooking system. It is observed that the storing capacity of soyabean oil is upto 4 hours. The temperature of soyabean oil is upto 195 degrees. Analysis of soyabean oil is done by directly solar radiations by cooking rice is 15 min and dal 19 min. Analysis of stored solar thermal energy with the help of insulation for cooking time to soyabean oil rice is 17 min and dal 21 min.*

***Key Words*: Solar Energy, Solar Cooker, Dish Concentrator, Soyabean oil, Thermal Storage Tank**

1. INTRODUCTION

In today's era, energy is the primary and most universal measure of all kinds of work by human beings and nature. Everything what happens in the world is the expression of flow of energy in one of its form. Energy is required as an input to all machines and that energy is extracted from conventional fuels and electric power. Cooking is an integral part of each and every human being as food is one of the basic necessities for living. An enormous amount of energy is thus expended regularly on cooking. Commonly used sources of energy for cooking are firewood, crop residue, cow dung, kerosene, electricity, liquefied petroleum gas (LPG), biogas etc. Half of the world's population is exposed to indoor air pollution, mainly the result of burning solid fuels for cooking and heating. Wood cut for cooking purpose contributes to the 16 million hectares (above 4% of total area of India) of forest destroyed annually. The world health organization (WHO) reports that in 23 countries 10% of deaths are due to just two environmental risk factors: unsafe water, including poor sanitation and hygiene; and indoor air pollution due to solid fuel usage for cooking. In under-developed countries, women have to walk 2kms on average and spend significant amount of time for collecting the firewood for cooking. The cooking energy demand in rural areas of developing countries is largely met with bio-fuels such as fuel wood, charcoal, agricultural residues and dung cakes, whereas LPG or electricity is predominantly used in urban areas. Solar energy is considered as a suitable alternative for variety of applications. It is an abundant renewable resource, freely available everywhere in adequate amount, making it one of the most promising, clean, non-polluting resources. Solar energy devices hold a large potential for use in a variety of applications in developing countries. India's geographical location is in such a way that theoretically it receives 5×10^{15}kWh/year of solar energy. Solar cooking is the simplest, safest, environmental friendly and most convenient way to cook. Modern technologies comprise solar kitchens and cooking plants for community applications using high temperature solar concentrators. Nowadays a new geometry of solar parabolic concentrators with square or rectangular shape has gain more attention than traditional parabolic concentrators. This new design permits framed bowl structure with excellent transportability with higher efficiency. This new designed concentrator can be used very effectively with solar thermal heat storage concept.

2. EXPERIMENTAL SETUP

Solar collector is used to concentrate solar energy at the focal point on the thermal storage tank. Thermal storage tank has arrangement as shown in above figure. Heat storing fluid is heated to its highest temperature based on several variables including area of the collector, emissivity, absorptivity, reflectivity and boiling/smoking temperatures, among others. As the oil near focal point is heated its density decreases so this heated oil moves up in thermal storage tank and this space is occupied by cold oil. In this way total quantity of oil available in tank is heated by using natural circulation phenomenon. This solar cooker is very useful concept as per as evening and early morning cooking is concerned. This solar cooker is able to cook the food anytime throughout day irrespective of the atmospheric conditions. In this system solar thermal energy is stored in sensible heat storing material like oil. So cooking is done during day time and also during evening period by using the heat energy stored in the oil.

Fig -1: Experimental Setup

2.1 Square parabolic dish collector

As all the rays are coming on the collector are to be concentrated at focal point to achieve high temperature, so parabolic solar dish collector is more useful for this application. For getting maximum efficiency of reflection for dish, aluminium anodised sheets are used for the manufacturing of square parabolic dish collector. It is a parabolic concentrator with square or rectangular dish shape. This shape permits use of same sized strips to make bowl. This makes the bowl sturdy. As the members of the dish have same geometric shape interchange ability of support members is possible.

2.2 Thermal storage tank

As all the rays are going to focused at focal point so the storage tank should not act as an obstacle for heat transfer, so copper is selected as tank material because of its high thermal conductivity (401 W/m K). Tank is used to store the oil which will act as sensible heat storing material. Tank has 0.22m diameter and 0.23m height. Copper is low in reactivity Series. That means it doesn't tend to corrode. Again, this is important for its use for pipes, electrical cables, saucepans and radiators. Copper is a ductile metal. This means that it can easily be shaped into pipes and drawn into wires.

PARAMETERS	VALUE
Melting point	1084.62 °C
Boiling point	2562 °C
Density	8960 Kg/m^3
Thermal conductivity	401 W/m k
Thermal expansion	16.5 µm/m k @ 25 °C

Above table gives the information about the different properties of copper

2.3 Soyabean oil

Soybean oil is a vegetable oil extracted from the seeds of the soybean. It is one of the most widely consumed cooking oils. As a drying oil, processed soybean oil is also used as a base for printing inks (soy ink) and oil paints. To produce soybean oil, the soybeans are cracked, adjusted for moisture content, heated to between 60°C and 88°C (140–190 °F), rolled into flakes, and solvent-extracted with hexanes. The oil is then refined, blended for different applications, and sometimes hydrogenated. Soybean oils, both liquid and partially hydrogenated are sold as "vegetable oil," or are ingredients in a wide variety of processed foods. Most of the remaining residue (soybean meal) is used as animal feed. The physical properties of fatty acids vary with their chain length, un saturation, and other substituent and change with temperature. Soybean oil's properties should reflect its constituents and, especially, its fatty acid composition, and physical properties have frequently been measured for typical soybean oils, but there have been fewer measurements of soybean oils with modified fatty acid compositions. Soybean oil of typical composition performs well as a salad oil, but it is usually hydrogenated for use as a margarine stock or frying oil. Soybean oil's stability to oxidation also is limited by its content of linolenic acid. Recent decades have witnessed numerous attempts to manipulate the fatty acid composition of soybean oil to help it compete better in various uses, but the cost of growing, segregating, and testing special varieties and resistance to genetically modified oils have limited the appeal of these altered varieties.

PARAMETERS	VALUES
Melting point	0.6°C (33.08°F)
Boiling point	300°C (572°F)
Smoke point	245°C (473°F)
Viscosity	0.0585 – 0.0622 N s/m^2 @ 20°C
Density	916.5 – 926.1 kg/m^3 @ 20°C
Thermal Conductivity	0.0692 W/m k
Specific heat capacity	1.97 KJ/Kg k @20°C

Above table shows the thermo physical properties of soybean oil of typical composition.

3. METHODOLOGY

Following steps are carried out during experimentation with the experimental set-up.

3. 1Experimentation

- Clean the square parabolic reflector, thermal storage tank and cooking vessel.
- Attach thermocouples at specified points on thermal storage tank.
- Fill the sensible heat storing material (oil) in thermal storage tank.
- Attach the cooking vessel to thermal storage tank.
- Place square parabolic reflector in the solar radiations.
- Track the reflector properly.
- Place thermal storage tank at the focal point of square parabolic reflector.
- Attach thermocouples to temperature indicator and give AC supply to indicator.
- Check the tracking of reflector continuously.
- Record the temperature after every 15 minutes also record the intensity of solar radiations by using lux meter.
- Wait till the oil will attain the maximum possible temperature, and then provide complete insulation to thermal storage tank to store the energy inside the tank.
- Record temperature continuously to check the energy storing time for the particular oil.
- Repeat this procedure by changing different oils inside the thermal storage tank.
- For cooking, put cooking material inside the cooking vessel and cover the cooking vessel with lid. Record time required and temperature required for cooking by varying the cooking products.

4. RESULTS

Setup is tested in different environmental conditions and compared observations. All the readings are taken during clear sunny day for getting good performance analysis. It is necessary for the purpose of evaluation of system parameters that the time mentioned is in hours and minutes. In this section only maximum temperature achieved by the oils and the time for which that temperature can be stored by using insulating material is checked. Temperature of oil is raised by using solar radiations.

TIME	OIL TEMPERATURE
WITHOUT	**INSULATION**
9:30	32
10:00	43
10:30	51
11:00	64
11:30	77
12:00	89
12:30	105
1:00	139
1:30	151
2:00	163
2:30	174
3:00	182
3:30	195
4:00	187
WITH	**INSULATION**
4:15	179
5:15	168
5:45	157
6:15	148
7:15	139
7:45	124
8:15	113

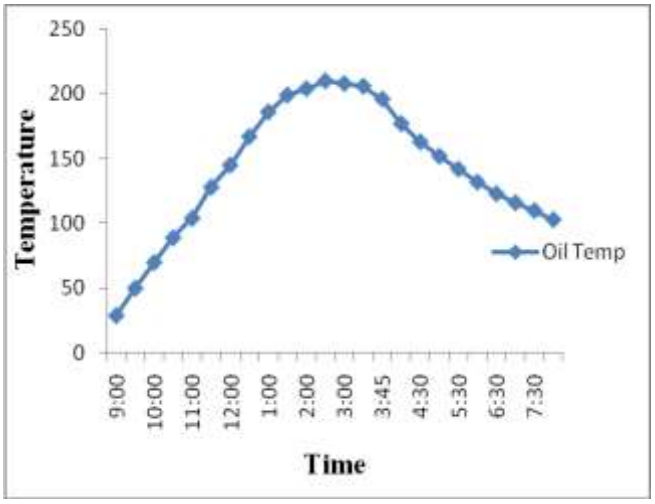

Chart -1: Time vs Temperature

The system was installed in solar radiations at 9:30 am and at that time, the temperature of oil was 32^{0}C (Room temperature). It increased gradually because of high intensity of solar radiations and it reached up to 195^{0}C at 3:30pm. The rate of temperature increment was stopped at 3:30pm and after that it starts decreasing because solar intensity starts decreasing after 4:00pm. Insulation is provided to the system at 4:15 pm and readings are taken upto 8:15 pm, at that time temperature was 113^{0}C. The storing capacity of oil is upto 4 hours.

4.1 Cooking results with direct solar radiations

In this section cooking results of different food products are recorded. For this purpose three food products are selected i.e. rice & dal (500 gm each). Temperature of oil is raised by using direct solar radiations.

TYPES OF FOOD	RICE	DAL
INITIAL TIME (Min.)	3:00	3:18
FINAL TIME (Min.)	3:16	3:37
INITIAL OIL TEMP(°c)	190	187
FINAL OIL TEMP (°c)	158	152
TOTAL TIME (Min.)	15	19

Above table shows the cooking results obtained by using soyabean oil as heat storing material. As per the observations recorded rice and dal requires 15 and 19 minutes respectively for cooking. Also rice and dal require 32 and 37 degrees respectively for complete cooking.

4.2 Cooking results with stored thermal energy

In this section cooking results of different food products are recorded. For this purpose three food products are selected i.e. rice & dal (500 gm each). Temperature of oil is raised by using solar radiations and after reaching maximum temperature insulation is provided to thermal storage tank. Afterwards cooking is performed by using thermal energy stored in thermal energy storage tank.

TYPES OF FOOD	RICE	DAL
INITIAL TIME (Min.)	4:18	5:10
FINAL TIME (Min.)	4:34	5:28
INITIAL OIL TEMP(°c)	170	168
FINAL OIL TEMP (°c)	145	127
TOTAL TIME (Min.)	17	21

Above table shows the cooking results obtained by using soyabean oil as heat storing material. As per the observations recorded rice and dal requires 17 and 21 minutes respectively for cooking. Also rice and dal require 35 and 41 degrees respectively for complete cooking.

5. CONCLUSIONS

In this research article the effect of soyabean oil is analysed. It is found that soyabean oil is beneficial for solar cooking system. It is observed that the storing capacity of soyabean oil is upto 4 hours. The temperature of soyabean oil is upto 195 degrees. Analysis of soyabean oil is done by directly solar raditions by cooking rice is 15 min and dal 19 min. Analysis of stored solar thermal energy with the help of insulation for cooking time to soyabean oil rice is 17 min and dal 21 min.

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