Performance Analysis of Energy Storage and Transfer system for Solar Cooking using HDPE as a PCM

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Abstract: *Solar cooking is done by utilizing solar energy which is possible only in sunshine hours. This limitation makes solar cooking an outdoor activity. For universal acceptance of solar cooker, cooking should be carried out in indoor. To perform solar cooking in kitchen and after sunshine hours also an energy storage and transfer system is must. This paper deals with the performance analysis of the cooking when it is done with the help of stored energy. An energy storage system has been designed and developed for solar cooking applications. This system can store the energy during sunshine hours and releases it whenever necessary. This paper presents the comparative results between conventional cooking and solar cooking with the help of energy storage and transfer system.*

Key Words: Energy storage system, HDPE, PCM, Renewable energy, Solar cooking

Nomenclature

PCM	Phase change material
HTF	Heat transfer fluid
HDPE	High Density Polyethylene
Tc	Temperature of PCM
Qhdpe	Heat contain by HDPE

1. INTRODUCTION

There are lot of solar cookers developed since 17th century [1] [2] [3]. And still research is going on. But main hurdle in the popularity and acceptability of these solar cookers is that they cannot be used in kitchen i.e. it's an outdoor activity. To gain the popularity of the solar cooker, it should be easy to use and should be able to cook the food inside the house at any time. For cooking after the sunshine hours, an energy is required. This energy can be supplied from the energy storage system which stores the energy during sunshine hours when there is high availability of energy and it can retrieve this stored energy whenever it requires irrespective of time. This need an efficient energy storage as well as transfer system which can enables easy and effective energy storage. This storage needs medium. It may be sensible storing material or latent heat storage materials which are phase change materials (PCM). From the literature survey it is evident that, the PCM have more energy storing capacity [4] [5]. So, the proposed system uses a PCM for the storage of energy and HTF for the circulation (transfer purpose). The energy storage and transfer system which is used in the work, is specially designed for the cooking application. It is similar to the coiled type heat exchanger which is connected to the cooker.

2. Work Method

For studying performance of an energy storage and transfer system, the system is developed as per the design. A cooking food it fixed i.e. rice. Also, to study performance of an energy storage and transfer system with cooker, it is necessary to identify the variables and need to form a design of experiments. The cooking performance is compared with the conventional cooking. The flow chart for carrying this work is shown Fig.1.

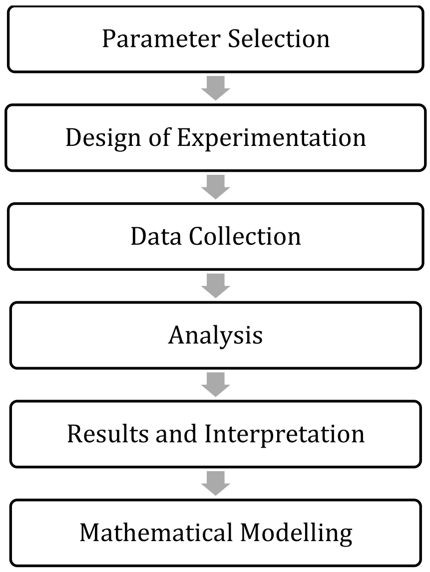

Fig.1 Flow chart of work method

2.1 Selection of Parameters

Selection of process parameters is most important step in the experimentation. The parameters which are selected should have significant impact on output of the experimentation. In the present work, cooking is a task for which experimentation has to be carried out. Performance of the energy storage system for solar cooking needs to be analyzed. For this, following parameters are selected as variables.

- Inlet HTF temperature
- Mass flow rate
- PCM used
- Atmospheric temperature

These parameters affect the output of the system i.e. cooking performance. But these performance needs to be measured so it is measured in terms of cooking time and heat balance after cooking. The high density polyethylene (HDPE) is used here as a PCM [6]. And performance is study for this HDPE.

3. Cooking Parameters

A rice is considered as a cooking food for evaluating the performance. For that same quality of rice is used throughout the experiment. A rice is presoaked [6] for the cooking in both conditions i.e. in conventional & in proposed system. A pressure cooker of capacity 2 liters is used for conventional as well for cooking by using stored energy. Standard method of cooking is used for cooking as cooking is supposed to be completed after the blowing off steam for thrice. 200 grams of rice is used for each trial.

Therefore, cooking depends on

1. Type of food – rice selected
2. Temperature of cooking – 123 ^{0}C (inside pressure cooker)
3. Quantity of water used – 0.5 liter
4. Type of rice used – Presoaked for 30 minutes.

4. Performance Analysis

For heat calculation, Prestige PIC 20, 1200W Induction cooktop is used. The conventional cooking is done at 1100W, Time taken to completely cook the rice is 9 minute 30 sec. (570 sec)

Therefore,

Heat consumed for cooking of rice by conventional method = watt x time

= 1100 * 570

= 627000 J

= 627 kJ

Cooking by Energy Storage system

The designed system cylindrical in shape is of the size 30cm diameter and 30cm height. Its volume is 11 Litre in which HDPE is stored. As after melting volume increases hence 3/4th of volume is only used for HDPE. That is 8kg HDPE is only used.

mass = volume x density of HDPE (1.1) [7]

= 8.25 x 970 = 8 kg

Hence, Heat stored in HDPE

$Q_{hdpe}= m_c \{C_{pc} (Tcm + T_{ci}) + \Delta h_f + C_{pc} (T_{co} – T_{cm})$ (1.2) [8]

= 4478.4 kJ

Also, heat stored in HTF which is passing through tubes of energy storage system is Q_f = 4119.49

Therefore, Total heat available = 8026.37 kJ

Considering Heat Stored up to 200 ºC at 5 pm and rice cooking has to be done at 9 pm (after 4 hour)

Heat available after cooking at 9 pm

= Heat available system – heat required for cooking

= 7399.37 kJ

Temperature Drop Analysis

HDPE and HTF are brought into equilibrium by circulating the HTF. At 4:30pm assuming that there is no further addition of energy possible, circulation of HTF is stopped and allowed to store the energy till the cooking time. When cooking needs to be done then circulation is started. The observations are shown in Table1 and its graphical representation is show in Fig.2.

Table 1 Temperature drop against time

Time	HTF Temp. ^{0} C	PCM Temp. ^{0} C	Remark/ Activity
4:30	200	198	Circulation of HTF Stops
8:30	180	181	Cooking starts
9:05	158	161	Cooking Done

From the experimentation, cooking time observed is 35 minutes.

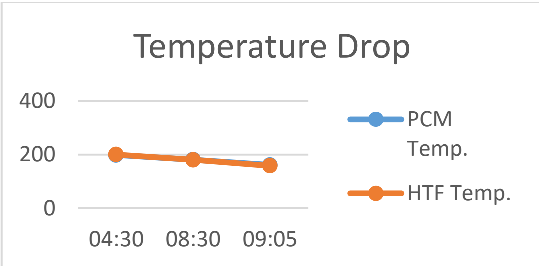

Fig. 2 Temperature drop of PCM and HTF against time

Table 2 Heat lost by PCM and HTF

Heat Lost by	HDPE	HTF
While Cooking	284.8	466.86
While Storage (in 4hr)	242.08	424.42
Total heat loss	**1418.17**	

4. RESULTS AND DISCUSSION

From the experimentation, heat balance is shown in Table 3 which indicates more heat loss while experimentation than theorotical.

Table 3 Heat Balance after cooking

	Initial Heat in system	Heat Balance After cooking
Theoretical	8026.27	7399.37
Experimental	8026.27	6608.1

It is obseverd that after cooking also 6608.1 kJ of heat is blanced which can be utilized for futher cooking. So it shows better efficiency of the system.

i.e. Efficiency = Theorotical x100/ Experimental = 6608.1x100/7399.37 = 89.30 %

Also it is obsevered that,

heat required for cooking of 200 gms of rice = 751.66 kJ

Therefore,

amount of rice which can be cooked on this available energy = 1.25 kg
As per servey,
2 person need 200gms of riced for 1 time meal,
Therefore, No. of persons = 1250/100
= 12.5
= 12 persons
For 12 person, rice can be cooked using this energy storage system cum cooker after sunshine hours also.

5. Conclusion

The above experimentation is carried on the cooker after four hours of energy storage. This four hour storing period shows that, the cooking can be carried after sunshine also. i.e. if sunset is at 5:30pm then cooking can be done at 9:30 pm also which is done in these experimentation. From the above experimentation it is evident that, the designed energy storage and transfer system can cook the rice easily and within an hour after 4 hours of energy discontinuation. The developed system can be efficiently used for cooking food for 12 peoples. The designed system is found 89.30% efficient.

CONFLICT OF INTEREST STATEMENT

On behalf of all authors, the corresponding author states that there is no conflict of interest.
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