A Comprehensive Review of Solar Cooker Development

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Abstract- *A detailed analysis of the available solar cooker literature is discussed in this article. The analysis shall be carried out in a thematic manner with a view to facilitating the comparison, discussion and evaluation of the results obtained by the researchers, in particular with regard to parameters affecting the performance of solar cookers. The research includes a historical overview of solar cooking technology experiments, a detailed summary of different experimental studies on solar cookers, different types of solar cookers such as direct type and indirect type, as well as the analysis and research of the heat storage system with and without.*

Keywords- Solar cooker, parabolic trough collector, cooking, pan

I. INTRODUCTION

Global energy consumption has depended to a great degree on fossil fuels over the past few decades. Energy use in developed countries rises annually by an average of 1% and in developing countries by 5% [1,2]. Several expectations show that fossil fuels will not satisfy this rising demand due to the constant rise in electricity demand, and their prices will certainly increase dramatically. Thus, in addition to certain environmental concerns such as deforestation, greenhouse impacts, global warming, etc., the rising prices of fossil fuels have provided renewable energy[3-8] a remarkable international interest over the past few years. Renewable energy sources are environmentally sustainable and supply about 14% of the world's energy demand, which is expected to grow in the future[9]. Solar energy, though, holds the throne of green energy. Solar energy is expected to land at an average of 120 per watts on the Earth's surface. This indicates that the solar energy delivered to the Planet in one day is equal to the demand for energy needed in 20 years. The International Energy Agency has shown that solar energy is capable of meeting about 45% of the world's energy demand in 2050[10]. Solar energy is used in a wide variety of applications that can be categorised into two categories of systems[11]: systems that transform solar energy into thermal energy for various purposes[12], and systems that transform solar energy directly into electricity by means of photovoltaic technology[13]. Solar energy can also be classified by solar collector type [14,15]. The primary function of the solar collector is to absorb and turn solar radiation into heat and move it to a working fluid.
The solar cooker[1,16-19] is used for food heating, pasteurisation and sterilisation. One of the most popular renewable energy uses is the renewable cooker. Approximately 36 percent of the global primary energy used is energy required for cooking. Therefore, in the domestic market, solar cookers have tremendous potential. The number of studies on solar cookers has been striking over the years , and especially over the last four years. This illustrates the magnitude of solar cookers as a system for solar energy and their potential in the coming years to be a critical application. The present job concerns, in this sense, a study of solar cooker technology.In particular, it introduces the theory, classification, and criteria of experimental analysis concerning the efficiency of a solar cooker.

A. Principle of Solar Cooking

The cooking principles were defined by Lof [5]. As per his theory, during the appropriate heating time, the energy requirement is at its limit. There is less heat required for physical and chemical modifications used in cooking. The energy required for a particular cooking procedure is not always well specified, and the cooking methods used can vary greatly. 20% of heat is expended on getting food to boiling temperature during heating, 35% of heat is expended on water vaporisation and 45% of heat is spent on convection losses from cooking utensils. The heat loss can be greatly minimised by insulating the walls of the vessel and having the vessel sealed with a lid.

Therefore, once the contents of the vessel have been sensitively heated to the cooking temperature, the cooking speed is virtually independent of the heat rate, as long as thermal losses are produced. Therefore, variations in the time taken to cook equivalent amounts of food are primarily due to multiple appropriate intervals of heating.

II. CLASSIFICATION OF SOLAR COOKERS

The accessible solar cookers are narrowly classified under two categories in this current analysis. i) non-stored solar cooker and (ii) non-stored solar cooker.

A. Solar cookers without storage

Based on the method of heat transfer to the cooking pot, solar cookers without storage are categorized into direct and indirect solar cookers. Direct solar cookers use solar radiation directly during the cooking process, while indirect cookers use a heat transfer fluid to transfer the heat to the cooking unit from the collector.

B. Direct type cookers

The thermal efficiency of a nontracking box cooker with two planars was planned, developed and experimentally evaluated by Negi and Purohit [1]. The concentrator is mounted on a slanting frame in an east-west configuration that is positioned on the cooker box in order to reflect solar irradiation on the cooker absorber. The experimental findings revealed that the focus cooker temperature was 15-22 ° C higher than the traditional box solar cooker at no load. The focus cooker even hit the boiling point earlier than the traditional box cooker by 50-55 minutes. The result was that, in contrast to the traditional cooker, the cooker with non-tracking reflectors improved heat collection and cooked quicker.

Ekechukwu and Ugwuoke[2] designed a plane reflector plywood body cooker and created a stream relief hose in the cooking pot, which went through the sidewall to drain steam into the atmosphere from the cooking chamber. The temperature and boiling time without a reflector cooker were 1190C and 70 min and 1380C and 60 min with a reflector cooker.

After various solar cooker designs were technically studied according to the north-south facing booster mirror, Mirdha and Dhariwal[3] built and studied an improved box solar cooker with tilted collection surface. It features one fixed vertical mirror and two tractable mirrors. The cooker offers enough high temperatures with three adjustments in the locations of the tractable mirrors to allow cooking for two meals a day. They were given a 163^0C stagnation temperature. Conventional cookers of the same size and material were designed and better cookers were found to achieve higher temperatures.

Claude et al.[4] then developed and installed a box cooker with a parabolic solar concentrator inside, which gradually improved the retention ratio and quantum efficiency of the captured infra-red radiation. The readings on a sunny day, gloomy day and slightly cloudy day were taken without and with the parabolic concentrator. The high temperature for sunny days was 78-80 ° C, 70 ° C for partly cloudy days and 59-64 ° C for cloudy days. The findings revealed that the parabolic concentrator played an important role in raising the collection ratio within the solar cooker.

Harmim et al.[6] performed a study of research work to concentrate on diverse solar cookers of the box type. First, a basic box cooker with a tilted absorber-plate was designed, then a double exposure solar cooker was designed and a non-tracking box cooker was made, prepared as a booster-reflector and its absorber-plate in the form of a phase with a fixed asymmetric CPC. With its rear opening in the kitchen, the double exposure cooker can be placed on a building wall facing south. Work has been done to check performance of box cooker with or without reflector.

Kahsay et al.[7] indicated that the efficiency of solar cooker style boxes could be improved using internal reflectors. The findings of the theoretical study estimated that the efficiency of the cooker without the reflector with the internal reflector would be higher relative to the same cooker. The steady state study shows that the cooking power, the temperature of the base absorber plate and the normal stagnation temperature (SST) of the reflector cooker are more comparable to cookers without a reflector.

Adewole et al .[8] worked in Ile-Ife, Nigeria on the thermal efficiency of low cost solar cooker based reflectors. The cooker was made from material available locally. In terms of F1 , F2 and cooker efficiency, there were four reflectors and one cooking pot to perform thermal evaluation. Testing was done on the basis of Part 2: Components (First Revision) Indian Standard IS 13429:2000 Solar Cooker-Box Type-Specification. The findings revealed that at 11.00 a.m. the minimum solar radiation was 246 W / m2 and at 2:00 p.m. the limit was 520 W / m2. During the test times, a mean solar isolation of 403 W / m2 and an atmospheric temperature of 40 ° C are measured. The observed water temperature was between 60 ° C and 67 ° C with solar radiation between 398 and 520 W / m2. This happens between 1:20 pm and 4:00 pm, with the peak water temperature at 3:00 pm being 67 ° C. In terms of F1 , F2 and thermal power, the cooker output showed that the cooker had greater heat retaining capability and the cooker compared favourably to well with Indian Standards.

A box style solar cooker with dual booster mirrors was designed by Farooqui[10] with three different length to width ratios. The experiment's output parameters were calculated by numerical simulations. In order to track the process for free desirable tilt angles for both mirrors, it was decided for 365 days. In order to measure the optimal power collection potential of the cooker, a cooking time of 6 hours from 9 a.m to 3 p.m was considered for numerical investigation at latitude 25 ° N. For the inquiry, three cookers with a length to breadth ratio of 1.33, 2.66 and 3.99 were picked. In order to compare the concurrent efficiency of all three cookers at full load, free experimentation was monitored for three days. Experimental effects have been analysed and F1 , F2, cooking strength, consistency factor and energy consumption have been calculated. The most suitable dual mirror cooker with a ratio of 2.66 was found and up to four food products can be cooked together.

C. Indirect Type Solar Cooker

The indirect solar cooker consists of a collector that absorbs heat and cooks to take advantage of the yield. The cooking vessel is transferred from the collector to be isolated and shielded from radiation. Heat is transferred by a heat transfer fluid from the collector to the cooking container, where a small circulating pump may be used to circulate the working fluid, especially when the collector is held above the height of the cooking machine. On the other side, the heat transfer fluid flow rate is oriented to the pot or to the storage tank by a manual control valve. It is possible to cook in a different position in an indirect solar cooker, or to store energy as responsive or latent energy during the sunlight, and to exploit it later. One of the benefits of indirect cookers is that it is possible to put the cooking machine indoors [11]. This benefit will also assist with the cookers' social acceptance[105]. In the previous pages, all of the cookers examined were of the direct form. Therefore, in this section, only indirect types are discussed.

The efficiency of thermal energy storage oils for solar cookers during charging was experimentally compared by Mawire et al.[12]. Experiments were performed using an enclosed 20 L storage tank and three thermal oils to be tested and evaluated: Sunflower Oil, Shell Thermia C and Shell Thermia B. From the experimental findings , it was concluded that Sunflower Oil has the best performance among the other thermal oils studied under high power charges.

Two indirect concentrate cookers were designed and built by Kaushik and Gupta[13]: a domestic size cooker (DSC) and a group size cooker (CSC). The DSC model consisted of just a parabolic dish and a pot positioned at the point of concentration. Vessel capacity for the DSC and CSC prototypes was 5 and 50 L, respectively. The authors measured the thermal efficiency and energy efficiency of the cookers and the output power. The maximum output was 288,17W and 1026,66W; for DSC and CSC versions, the maximum energy efficiency was 43,56% and 21,97%; and the maximum exergy efficiency was 2.72% and 1.14%.

A novel, improved indirect cooker consisting of a vacuum tube and linear Fresnel collectors was modelled by Farooqui [14]. With an efficiency of 30 percent and temperatures up to 250 ° C, the system produced 208 W / m2 (collector area). In addition, the architecture was such that it was possible to position the collector component outside the house and cook it inside. The author suggested that a traditional solar cooker's heat absorption can be improved more than fivefold by vacuum tubes.

In another work, using a vacuum tube, Farooqui[15] created an indirect concentrated solar cooker. He studied the effects on various device parameters of ambient temperature and water load quantity, and stated that water load has a major influence on the efficiency of this type of cooker. He has shown that 6 L of water load has the best efficiency among the other loads for a 7-L size cooking vessel.

A cooker that included a parabolic trough collector and a double walled hemispherical cooking machine was developed by Kumaresan et al.[16]. Olive oil was selected as the heat transfer fluid in their work, which was warmed within the collector and then flowed between the cooker 's walls. The authors stated that the temperature of the oil rose from 30 to 152 ° C in their system, and that of the cooker rose from 30 to 150 ° C in 15 minutes.

D. Solar cookers with storage

G.Kumaresanet. Al.[17] presents the performance assessment of a newly designed double-walled cooking unit (type tava) suitable for use in indirect solar cooking applications combined with a thermal energy storage device. A cooking machine, a holding tank and a positive displacement pump make up the experimental set-up. Therminol 55 and D-Mannitol were used, respectively, as the heat transfer fluid and storage medium. The highest temperature achieved by the olive oil in the cooking unit during the cooking experiment was 152 ° C over a period of 15 minutes, which is comparatively lower than the time taken by a traditional LPG stove in simmering mode. To account for the heat input and the distribution pattern, a heat balance for the built cooking unit was prepared. An experiment was also performed to determine the average heat loss under no load condition contained in the device and it was contained that during the discharge process there was a substantial heat loss in the flow circuit.

For the thermal storage device, Kalbande V. et.al [18] used metal and phase change material (PCM). As a safer choice for thermal preservation, aluminium was suggested as a metal and erythritol as the PCM. A solar collector was used to charge this thermal storage with the help of solar energy. To capture solar energy, the Parabolic Trough Solar Collector was used. The evacuated tube was used to absorb solar radiation and the nanofluid centred on soybean oil containing Al2O3 nanoparticles is filled in the tube at a volume concentration of 0.1 percent to transfer heat from the absorber tube to thermal storage. With the help of the ultrasonic process, nanofluid was prepared. The transfer of heat through the self-circulation unit from the absorber to thermal storage. Experiments is performed with and without nanofluids. Soybean oil and Al2O3 nanofluid have improved the solar collector 's performance. When using nanofluid, the thermal storage and absorber temperature was achieved up to 153 ° C and 178 ° C. In addition, KalbandeVP[19] used the oil and aluminium-based energy storage device for experiments with the same storage capacity and for storage of energy containing material for phase shift that has a melting temperature of 210-220 ° C. Energy obtained by the solar collector heats the fluid stored in the receiver tube (i.e. soybean oil) and takes the energy to the storage room. Between storage and solar collectors, which include soybean oil as a heat transfer fluid, the self-circulation unit was introduced. The key goal of the idea was to conserve energy during the day and to use it for cooking purposes during the night.

With Moussaoui et. The configuration, working, and testing of the solar thermal cooker (PSTC) parabolic trough has been identified by al[20]. The oven, which allows steady cooking temperatures above 200 ° C, was designed to satisfy the needs of rural residents , particularly urban residents. The cooking of this cooker was based on the concentrating of the rays of the sun on a vacuum tube of glass and the heating of the circulating oil in a wide tube within the glass tube. The hot oil rises and heats the pot of the cooking pot containing the food to be cooked for a volume of 5 kg through two narrow tubes, combined with a wide hose. This cooker has been developed in Germany and thoroughly tested in Morocco for the use of wood from forests by the inhabitants. The highest temperatures reported for the small tube, the wide tube and the middle of the pot on a sunny day with a highest solar radiation of around 720 W / m2 and ambient temperature of around 26 ° C are: 370 ° C, 270 ° C and 260 ° C , respectively. The cooking method of food at high temperatures reveals that the temperature of the cooking oil increases to 200 ° C; after 1 h of heating, the cooking time was 20 minutes at a temperature of 120 ° C. Following fluctuations and decreases in the level of radiance during the day, these temperatures were practically constant. The comparison of these observations with those of the literature indicates a 30-50 percent increase in the overall temperature value with a heat storage that could achieve 60 minutes of autonomy. The successful working of the PSTC and the viability of cooking food at a high temperature (> 200 ° C) was shown by all the results obtained.

Babu Kumar Sasiet. Al. [21] performed tests using solar energy on solar cookers. Via the Storage Tank (ST), heat captured by a fluid from the Parabolic Trough Collector (PTC) with the manual Monitoring Mechanism(TM) was passed via. In the ST materials, a Phase Change Substance (PCM) absorbed the heat in intermittent sunlight and was continuously released for cooking purposes. A heat transfer study of the Solar Cooker (SC) was carried out on the basis of PTC and ST observations, taking into account the 0.035, 0.045 and 0.065 kg / sec Mass Flow Rate (MFR) of the heat transfer fluid. At 1 pm, the overall heat gain (HG) of the 82 ° Rim Angle (RA) PTC receiver was found to be 2095 W, 13 KW in ST with the Wastage Engine Oils (WEO) medium. The WEO 's heat production was determined to be 16% greater than that of water. The performance of the newly developed solar cooker along with the storage medium was measured at MFR 0.035, 0.045 and 0.065 kg / sec. The MFR findings of 0.035 kg / sec were shown to be higher than 0.045 for the water and WEO medium, and 0.065 kg / sec. The energy produced was thus higher. The WEO, with lower energy losses than water, was seen as more robust. For PCM products, stearic acid (SA) was added.

YannaGao et. Uh, et. Al.[22] performed a comparison experiment to analyse the thermal efficiency of the LHTES-Tank and SHTES-Tank, respectively, with paraffin RT55 and water as thermal storage media. By adjusting Heat Transfer Fluid (HTF) temperatures between 20 ° C and 80 ° C, the experiment involved 5 thermal charging and discharging periods. Results demonstrate that the thermal discharge in the LHTES-Tank was more complicated than thermal load. Much paraffin was able to melt entirely but not totally solidify, although about 19.36 percent of the paraffin in the LHTES-Tank was always solid or liquid, serving as a dead mass. Paraffin has a higher thermal storage capacity than water in the phase-change temperature spectrum only, but under the broad HTF temperature differential, water will play the thermal storage potential more effectively than paraffin. Based on this reason, as opposed to SHTES-Tank under the HTF temperature of 20 ° C-80 ° C, LHTES-Tank had only a slight advantage in thermal and exergy performance compared to SHTES-Tank,but its ability for optimization has been seen to be rather broad. Finally, according to the thermal behaviour of the LHTES-Tank, the key current problems have been summarised.

Hitesh Panchal et. Al.[23] took scheffler reflector to provide heat with fair and latent heat storage materials to specially built cookers. Here, as latent heat storage materials, three different types of appropriate heat storage materials, such as sand, pebbles and iron balls, and acetamide. Between the months of March and April 2018, tests were performed with sensible and latent heat storage materials. Rice and water are used for cooking purposes. It was found that solar cooking with the sand-acetamide and pebbles-acetamide pair of sensitive and latent heat storage was efficient compared to iron balls-acetamide pair for evening cooking and rice found adequately in it after a series of experiments. In comparison, the pair of sand-acetamide and pebbles-acetamide found 3 to 3.5 times more heat compared to the pair of iron balls-acetamide.

Bave A. Et., et. Al. [24] Development of a solar cooker thermal storage type for high temperature cooking using solar salt. In parabolic dish concentrators, high temperature cooking operations such as frying, roasting and baking using solar energy are typically conducted at the concentrate. This results in heat pain, the possibility of burns or injury to the user's eyes. A system was developed and tested to store latent heat in a phase-changing eutectic mixture called "solar salt," which would allow it to be stored in an insulated container and cooked when needed in the shade of a kitchen. With a charging time of 110 minutes, it was able to successfully store heat at its melting point of 220 ° C. During indoor cooking, frying temperatures of 170-180 ° C for the oil were readily obtained and 0.25 kg of potato chips were fried in 17 minutes from one heat charge, while a total of around 0.6 kg of rice was cooked in two successive batches from one heat charge, each taking 20 minutes.

From Dejeneet. Al.[25] uses a 1D finite difference numerical model to analyse the performance of solar cookers with parabolic concentrating collectors combined with thermal storage. Under Addis Ababa temperature conditions for days, a cooker stove on packed pebble bed thermal storage with 0.3 m diameter and 0.9 m height and a storage capacity of 40.1 MJ of energy during a clear day and 12.85 MJ of energy was simulated for charging and discharging (cooking), with highest and lowest solar irradiance and thermal storage efficiency of 66.7 percent, cooker thermal efficiency of 45 perce For discharge by forced convection and conduction, the average performance of the cooker with thermal storage was 30% and 22%, respectively.The storage, thermal and total efficiencies for the day with the lowest beam solar irradiance were 70.9 percent, 31.1 percent and 22.0 percent , respectively. Thus, it can be inferred that on a clear sky day when the Sun is overhead in tropical regions, solar focusing cookers with thermal storage can have an average cooking efficiency between 22 percent and 30 percent.

BW Mulukunet. Al.[26] developed a 45-minute method for cooking 1 kg of rice requiring 421 W of power obtained from the sun's stored energy. As the experimental outcome shows, owing to too many losses, the flow of energy to the water decreased to some degree and its temperature reached 355K. And if it has low capacity, it is possible to minimise TES capacity to the surrounding environment by positioning it during discharge in the enclosed tank. There is, however, a difference between experiment and analytical measurement since the fundamental losses and difference in solar radiation were not taken into account in the model. After it is withdrawn from the solar collector, the discharge of TES is begun, but it is automatically placed on the insulated tank and filled with water by the pot. Therefore, the mean water temperature reached after 40 minutes is 355.

III. CONCLUSION

In Indian households as well as worldwide, cooking energy plays an significant role in sustainable energy management. There are different ways to fulfil the needs of the end consumer using both commercial and non-commercial energy. With built solar cookers, conventional fuel-wood usage must be reduced. This would translate to a decline in human drudgery. Such an initiative would not only be beneficial for enhancing the quality of living, but also for protecting the environment. This review paper concentrates on the latest solar cookers available. This offers a general idea of the form of box and the concentration of solar cookers in a direct solar cooking technique. For the indirect cooking technique, high temperature solar cooking may be feasible and easy to prepare. The Furthur thermal energy storage technology for solar cookers is available. With the storage unit, food can be cooked late at night, while it was not possible to cook late at night with a regular solar cooker. In this way, the solar cooker with storage unit is very useful for humans and for the recycling of energy. This paper presents the historical and current studies in this unique area of solar cooker energy storage.

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