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Design of Solar Dryer Cum Cooker

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ABSTRACT

Solar energy represents non-polluting, inexhaustible renewable source of energy that can be utilized economically to supply man's needs for all the time. A Modified Solar cooker cum dryer was designed to facilitate solar drying and solar cooking in the same structure. Different components (Trays, Aluminium pipe, Blower, Fins, lens and Glass plate) of the solar dryer cum cooker were theoretically justified to find out the feasibility and advantage of the new dryer cum cooker. As with time the sun hour increase, so does the solar intensity increases. Fin type flat plate collector is provided for dissipation of heat to the drying chamber, which is just below the solar cooking chamber. Glass cover of solar collector normally should be at least 0.33 cm thick. Black body is provided for absorbing the radiation, which is coated to the cooking chamber. Lens is provided to reflect the heat to the drying and cooking chamber. Trays is provided for drying the food materials fruits and vegetable slices), which is attached to the aluminium pipe. Blower is equipment which increase the velocity of air, which is just below the fin type flat plate collector. The solar cooker was used as the solar collector for the solar dryer. The solar dryer was designed with 0.49m^2 area. A solar cooker having size 900 mm x 750 mm x 300 mm the drying chamber for the dryer having size is 900 mm x 750 mm x 600mm. The plenum chamber of size 750 mm x 600 mm x 300mm has to be constructed. A tray having size 700 mmx 500mm is to be provided for supporting the material to be dried.

Keywords: solar dryer, solar cooker, thermal performance, solar energy.

CHAPTER -1 INTRODUCTION

Solar energy has been continued to utilize by various countries since 1900"s. In the present era a variety of the techniques are there, to utilize solar energy in various aspects of households and commercial sectors. Cooking, water heating, desalination, power generation, heating and cooling of buildings, even lightening now can be operated on solar energy in different households and commercial sectors worldwide. This energy is radiated from the sun in all directions and a very small fraction of it reaches the earth. **Ezzati et al. (2002)** reported that by using solar energy we can save a huge amount of various fuels and capital. In Africa, for example, 90% of the population uses firewood for cooking. In India 150 million tons of firewood, 52 million tons of cow dung, and 36 million tons of other waste biomass are used only for cooking. These huge amounts of non-commercial sources are equivalent to about 45% of the total energy available in the country. On the other hand, in the United States only 20% of the total energy produced is consumed in the domestic sector, of which only 5% (or 1% of the total) is used for cooking.

Sources Beside this, solar energy is a clean fuel and due to combustion free, it is Non - polluting fuel too. We not only save the money and fuels but also can maintain a good health by using it and keep away from various harmful diseases which are generated by the burning of biomass.

The sun gives 3.7 x 10^{26} watts energy of which earth intercepts only 1.8 x 10^{17} watts. This means that the energy emitted by the sun within three minutes is equivalent to the world energy consumption during year. The 99 % of the energy of the solar radiation is contained in the wavelength bond from 0.15 to 4 micro meters comprising the near ultraviolet, visible and near infrared region of solar spectrum. The solar constant has a value of 1.36 Kw/ m^2 or 1.95 Cal/cm^2/min

The power from the sun intercepted by the earth is approximately 1.8 x10^{11} MW, whichis many thousands of time larger than the present consumption rate on the of all commercial

energy sources. In a tropical counties like India where the sun shine with brilliance for more than 300 days in the year and where solar radiation is as much as 650 calories per sq. cm per day, the utilization of solar energy can be very effective.

A box type solar cooker in the agricultural tool Research center, Suruchi Campus, Bardoli. It consisted of a double box with double glass cover. The temperature inside the cooker rose to 90°C in winter and 105°C in summer.

Bahai International Community Institute used solar box cooker for its own cooking and later two Scheffler type reflectors with thermal heat storage capability. The basic design consists of a rectangular container, preferably insulated and covered with a roof or clear plastics. There are holes in the base and upper parts of the cabinet and rear panels. The interior of the cabinet was blackened to act as a solar absorber. Perforated drying trays are positioned within the cabinet

This study aims to report the design, fabrication, testing, of the concept of truncated pyramid geometry for developing solar dryer cum cooker suitable for house hold applications

Use of solar cookers may reduce consumption of dirty (cow dung, wood etc.) as well as expensive clean cooking fuels (LPG, kerosene etc.) in rural and urban areas. Several solar cookers have been developed so far; these are classified mainly into three types: box type, focusing type and advanced or indirect type. Simple structure, easy operation mode and low cost have attracted the attention of researchers towards box-type solar cookers. Various types of improvements have been done in SBCs in order to increase the thermal performance, energy saving and durability; decrease the weight, cost and payback period. Despite of all these improvements and implementation, the solar cooking has not gain substantial popularity among the users. It reflects the fact that there are some major hindrances in the popularization of solar cookers. Among those, inability of cooking during scattered (partial) cloudy/cloudy day, rainy day and in night is most crucial availability of sun light and in night then these can be substantially popularized in rural as well as in urban areas . Energy is fairly essential, meanwhile life is directly influenced by energy and its consumption. Present cooking fuels are originated from fossil fuels like LPG, kerosene and biomass such as firewood, crop residue and cow dung. These biomass based energy resources still play a vital role in global energy consumption, but due to continuous burning of these fuels adverse affects on environment, human and soil heath

are attaining alarming levels particularly in developing countries **(Sahin et al., 2007).** Solar energy is most commonly employed for solar cooking, water heating and solar drying applications. As cooking is an integral part of every human being, it expends a prime portion of the domestic energy requirement. Under the current scenario, solar cooking is green, clean and environment friendly replacement which precludes global warming due to non-emission of greenhouse gases and also diminishes indoor air pollution besides preventing health problems.

Moreover, adequate cooking temperatures in solar cooking devices also help to preserve food nutrients **(Muthusivagami et al., 2010).** Numerous designs of solar cookers have been presented by eminent researchers over the last more than half a century. Simple structure, easy operation mode and low cost have attracted the attention of researchers towards box-type solar cookers. Various improvements have been incorporated in solar box cookers.

A solar cooker cum drier was designed by **Pande and Thanvi (1988)** in which optimum booster-collector geometry was considered to eliminate sun tracking. Tilting arrangements were also provided to capture more solar energy. The device worked well for cooking as well as dehydrating fruits and vegetables.

Hence, in this study an effiicient inclined solar cooker-cum-dryer having simple geometry, low cost and easy side loading and unloading along with innovative parallel piped vessel design for cooking applications has been designed.

The present study was undertaken to develop a solar dryer cum cooker with locally available material and simple to operate.

Department of Rural Engineering, Gujarat, conducted research on the performance of commercially available box type Jyoti solar cooker and it was evaluated with respect to inside cooker temperature and cooker temperature for three insulating materials namely, fibre glass, saw dust and Aak floss mixed with paddy husk ash were measured. Modifications were made to increase the effectiveness of absorbing surface and to make cooker airtight. The maximum temperature in cooker was recorded for the insulation of Aak floss mixed with paddy husk ash10

Designed and develops a solar oven providing theoretical concentration of solar energy in the Mechanical Engineering Department, Punjab Agricultural University Ludhiana, Baking and

cooking various foods tested the solar oven. It took about 2 hours about cooking red beans and35 minutes for rice.

Bahai International Community Institute used solar box cooker for its own cooking and later two Scheffler type reflectors with thermal heat storage capability. Many women were attracted, and therefore the next phase did the institute serve placing household size parabolic in village3.The basic design consists of a rectangular container, preferably insulated and covered with a roof or clear plastics. There are holes in the base and upper parts of the cabinet and rear panels. The interior of the cabinet was blackened to act as a solar absorber. Perforated drying trays are positioned within the cabinet.

The solar dryers have been classified on the following criteria. 1.Whether or not the drying product is exposed to isolation 2.The mode of airflow through dryer 3.The temperature of drying airflow circulated

The cooker was single glazed with a pane of 2 mm thickness flat glass as well as the whole system was i.e. MSES. The inner absorber tray was designed particularly for good sensible heat storage and a rubber gasket of 1.5 mm thickness was placed in opening lid to make leak proof. Apart this, a high intensity planar reflector, 184 × 75 cm^2 of corrugated lacquered aluminium was used to enhance the efficiency of the combined components of the system.

At the time of harvesting, almost all agricultural products are harvested at high moisture content of 30-35%. Drying is required for improving shelf life of agricultural products mainly vegetables, spices and fruits. Sun drying is the traditional method for drying but it has several drawbacks, solar drying is the very important method for improves the sun drying method. Several research and performance studies on solar dryer with flat plate collectors and heat storage material have been reported aiming at the improvement of the drying system **(Ahmad Fudholi at el, 2013).**

There are many designs of solar, electrical and mechanical dryers and cookers are available for drying and cooking applications and they are commercially available in the market. Nevertheless, the drying air characteristics in solar dryers and cookers depend on ambient conditions, due to the non-reliable nature of the solar energy. What can reduce the final product'squality and devices becomes less efficient most of the time. Major problems with the electrical

dryers are non-availability of electricity and high capital investment which makes it unsuitable for use of rural producers. Developed hybrid dryer cum cooker will become a good alternative for the drying and cooking applications. It can operate around the full day and during any season and it has required less area for operate.

Solar Drying

The solar drying involves the drying of the product inside a closed cabinet structure. The top surface of the drying cabinet is made transparent, so that the radiations can be absorbed. The inclined surface is used to trap the solar radiation.The advantages of the solar drying are

- Increased drying temperature.
- Increased drying rate of the product.
- Short drying time.
- Preservation of product quality.

- Product colour is also preserved.
- Less contamination by dust, rain and insects.

The disadvantages of solar dryer are

- The working of a solar dryer is limited to the daytime only. It fails to work withoutsunlight.
- During cloudy days, the working of dryer is limited due to its inability to attain therequisite drying temperature at the day time.
- The temperature attained by the dryer during the daytime is too high which also destroysthe drying product quality. Drying temperature cannot be controlled.

Classification of the Solar Dryer

Different types of the solar dryer have been designed and developed by researchers to dryvarious agricultural and food products in different parts of the world. The driers can be classified either on the basis of mode of air flow or the mode of incident solar radiation.

Based on the mode of air flow

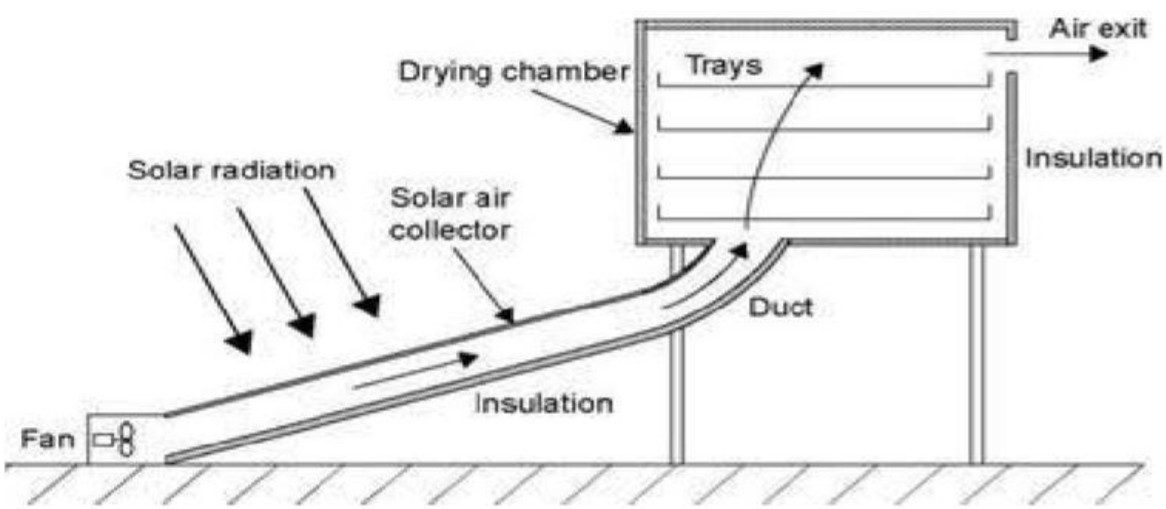
The dryers are classified into two types based on the mode of air flow

- Active solar drying system
- Passive solar drying system

Active solar drying system

In this type of drying system, the air is forced blown into the drying systems. This system essentially consists of a blower to force the air through the product, a chamber, and covered with a transparent sheet. In Fig 1 (**Steinfield et al. 1986**) an active solar dryer is shown in which a fan is used to force the air through the product to be dried.

Fig 1.0 Active solar dryer



Passive solar drying system

In a passive solar dryer, air is heated and circulated naturally by buoyancy force or as a result of wind pressure or in a combination of both. Normal and reverse absorber cabinet dryer and greenhouse dryer operates in passive mode. This method is still common in many Mediterranean, tropical and subtropical regions especially in Africa and Asia or in small agricultural communities. The dryers made using this mode are primitive, inexpensive in construction, easy to install and to operate especially at sites far off from the electrical grid. The passive dryers are best suited for drying small batches of fruits and vegetables such as banana, pineapple, mango, potato, carrots, etc. A schematic diagram of passive solar drying system is (**Pangavhane et al. 2002**) in which solar radiation is allowed to fall on the collector and the air is thus heated and circulated through the dryer as a result of wind pressure.

SOLAR COOKING

A solar cooker is a device which uses the energy of direct sunlight to heat, cook and other food materials. Many solar cookers currently in use are relatively inexpensive, low-tech devices, although some are as powerful or as expensive as traditional stoves,[1] and advanced, large-scale solar cookers can cook for hundreds of people. Because they use no fuel and cost nothing to

operate, many Non-profit organizations are promoting their use worldwide in order to help reduce fuel costs and air pollution, and to help slow down.

Types of Solar Cookers

Basically, there are 3 types of solar cookers available on the market:

1. Box cookers
2. Panel cookers
3. Parabolic cooker

Box Cookers

Solar box cookers (sometimes called solar ovens) are the most common and inexpensive type of solar cookers. These box cookers have a very simple construction and they are made of low cost materials. The outer box is often made of wood. The inner box is made of insulating material, which is covered with clear glass or with plastic, and often has a reflector of aluminium. According to Solar Cooker International, solar box cookers cook at moderate temperatures and often can accommodate multiple pots. It can reach a temperature of 140˚C. The solar box cooker, like other solar cookers, needs direct sunshine to operate and produces zero emission. However, the temperature is low and it cannot store and save solar heat for later use. Many non-profit organizations promote these cookers worldwide in order to help reduce fuel costs and to slow down deforestation caused by firewood collection and charcoal production.

Panel Cookers

Panel cookers have a flat panel which reflects and focuses sunlight for cooking and heating. According to Solar Cooker International, panel cookers incorporate elements of box and curved concentrator cookers. They are simple and relatively inexpensive to buy or to produce. The "Cook it" of Solar Cookers International is the most widely used solar cooker so far. The Cook it is a cheap solar cooker in which rice, pasta, lentils, vegetables, chicken, goat, baby food and pasteurized water can be prepared. In bright sunlight the food is ready within 2-3 hours. The Cook it is made of cardboard, lined with aluminium foil. A lightweight 4-litre, flat black painted pan is placed in the Cook it, in a heat resistant plastic bag. The panel cooker is quite similar in operation to the solar box cooker. The same principles are employed but instead of an insulated box, panel cookers typically rely on a large (often multifaceted) reflective panel. Panel cookers
are unable to collect and store sunlight for later use and they are unstable in high winds. Also it cannot retain much heat when the sun is hidden behind the clouds.

Parabolic Solar Cookers

In comparison to solar box and panel cookers, parabolic cookers (sometimes called curved concentrator cookers) can reach much higher temperatures and can cook more quickly, but require frequent adjustment and supervision for safe operation, according to Solar Cooker International. It needs more precision to focus the sunlight on the food in the pan. If the sunlight is not correctly focused on the food in the pan, the food will not be cooked well. There are many designs for parabolic solar cooking appliances. Because of the parabolic shapes and with the aid of reflecting material quite a lot of solar energy is concentrated in the focal point. A very high temperature of between 200 and 300ºC can be reached because of a combination of the circular design, the size and the polished aluminium. It is suitable for baking, roasting and grilling. Parabolic solar cookers function well if they are used correctly. However, they are not easy to make and need much care to use. Like other solar cookers, parabolic cookers also need direct sunshine and they cannot store and keep sunlight for later use. If the parabolic collector is too small in size, it will not produce sufficient heat for the most effective cooking results. The opposite is true if it is too large; the heat would be too intense

OBJECTIVES

1. To design modified solar dryer cum cooker
2. To theoretically study the feasibility and advantageous of the designed solar dryer cum cooker

1.6 JUSTIFICATION

The modified design of the solar dryer cum cooker is to facilitate the solar drying and cooking simultaneously. This combined technique of solar drying and cooking in one may drastically reduce the cost of fabrication. The design might accelerate the solar cooking and also might accelerate the drying due to the use of lens reflectors.

CHAPTER -2 REVIEW OF LITERATURE

Nandwani (1996): This study discusses the quality and quantity of energy used for cooking in Costa Rica and in the world as a whole, and then compares the advantages and limitations of solar ovens with conventional firewood and electric stoves. The payback period of a common hotbox type solar oven, even if used 6-8 months a year, is around 12-14 months. Even if only 5 %of persons facing fuel shortages in the year 2005 use solar ovens, roughly 16.8 million tons of firewood will be saved and the emission of 38.4 million tons of carbon dioxide per year will be prevented.

Sengar and Kurchania (2005): Solar Dryer cum Cooker (SOC) device for cooking and drying was designed and fabricated at Department of Renewable Energy Sources, C.T.A.E., Udaipur and tested for no load condition and full load condition. In winter and summer to find out Its performances. F_l , F_2 values of solar cooker were 0.119, 0.120 and 0.32, 0.30 for winter and Summer. Time required for rice, tur dal, moong dal was 90, 130 and 100 minutes in winter 60,90and 75 minutes in summer. The efficiency for drying maize, wheat and potato was found to be

15.55 %, 10.89 % and 10.42 %, for solar dryer in winter, 12.97%, 8.90 % and 10.16 % for solar dryer in summer respectively. The total cost of SOC was Rs. 2715.

Patel et .al (2013): In this paper a review of the solar dryer is presented. The world population is more than 6 billion and about 20-25 percent people does not have enough food to eat. It has been estimated that world as a whole more than 25-30 **%** food grains and 30-50 **%** vegetables , fruits etc. are lost before it reaches to the consumers. To overcoming spoiling problems of vegetables, food grains and fruit; various preserving methods are used and renewable sources are best for this purpose by which we can save energy for preservation and keeping the product in their natural flavour. A solar dryer is an enclosed unit, which is used to dry agricultural products. It is also required to keep the food safe from damage, birds, insects and unexpected rainfall. Solar dryers, also known as dehydrators , have been used throughout the ages to preserve grains, vegetables and fruits by removing moisture. Solar dryers can be made locally of any size and capacity and solar dryers are economical if cash crops are dried. The various design of the solar dryer is reported in the literature thus far is presented.

Aidan (2014): A suitable solar parabolic dish collector cooker has been constructed and evaluated under Yola climatic conditions using the international standard procedures for the evaluation of solar parabolic cookers. The optical efficiency of the collector has been found to be about 17.86%, the overall heat loss coefficient of 8.896 $WK^{-1}m^{-2}$ and the adjusted cooking power that measures its performance has been found to be 96.53 W. The parabolic solar dish collector cooker can be used by families for cooking in Yola to minimize the purchase of other cooking fuels for at least cooking the afternoon meals.

Yusuf, et. al (2014) : This paper presents the evaluation of the thermal performance of a constructed box type solar oven with reflector. The solar box oven was used to perform an experiment with reflector and without reflector in which the ambient temperature, the air temperature inside the oven, the plate temperature at the side and the bottom, of the oven were obtained. The wind speed and the solar radiation were also recorded for different days. The temperature profiles without load and with load assure its good thermal performance and the ability to boil water. The stagnation test and the water boiling test were performed during the year 2012. The efficiency of the solar oven without and with reflector was found to be about 96% and 99% respectively. Efficiency increase with decreasing temperature difference between plate temperature and ambient temperature, while it decreases with decrease in solar radiation. The result shows that the oven has a good reliability for baking and boiling water.

Ashish Agarwal. et.al (2014): Drying of agricultural food products is one of the most attractive and cost-effective applications of solar energy. The solar dryer is less reliable due to the intermittent nature of solar energy. This shortcoming can be overcome to some extent by storing solar energy. Information on sensible and latent heat storage materials and systems is spread widely in the literature. In this paper, we try to gather information about the previous and current research works in the field of thermal energy storage technology for solar air heater and dryer. The relative studies are classified on the basis of the type of storage material used in solar dryers, i.e. phase change material (PCM), rock, water, etc. Several designs of solar dryers with different heat storage materials were proposed by researchers. Recent studies focused on PCMs such as Paraffin and salt hydrate, due to their high heat storage capacity per unit volume.

Sayyad, et al. (2015): Solar energy represents non-polluting, inexhaustible renewable source of energy that can be utilized economically to supply man's needs for all the time. A solar cooker cum dryer was designed, developed and fabricated. The performance evaluation of the system was carried out. The solar cooker was used as the solar collector for the solar dryer. A solar cooker having size 750mm x 600mm x 150mm has been developed. The solar dryer was designed with 0.49 m^2 collector area. The collector angle was calculated for Jalgaon and it is 24.16° facing south. Drying chamber of size 750mm x 600mm x 450mm was designed and fabricated. This equipment was tested for cooking of food materials. The various atmospheric and drying parameters were also observed during the testing.

Elamin Akoy (2015): In this study, three different types of solar cookers namely; box-type, panel-type and parabolic solar cooker were designed and constructed using locally available materials. The main objective of the study was to investigate the thermal performance of the constructed solar cookers. The standard procedure for testing solar cookers was adopted to test the thermal performance of the constructed solar cookers. Several tests were conducted on the constructed cookers under Zalingei (Sudan) prevailing weather conditions during March 2011. In addition, a questionnaire was designed to evaluate the dissemination possibility of the constructed solar cookers in the study area which consisted of 50 respondents (males and females). Results of thermal performance showed that, the parabolic solar cooker attained a maximum temperatureof86.5oC on average basis and was the best followed by the box-type solar cooker 52.36ºC and finally the panel-type 43.5ºC. Also the results of the solar cookers, efficiency for the parabolic cooker, box-type and panel-type were found to be 31.53%, 77.4% and 67.4%, respectively. Finally the results of questionnaire indicated that 74% believe that solar cookers were economically feasible and could protect the environment.

Singh, et al.(2017): A novel design of multi-shelf side loading inclined solar cooker-cum-dryer (ISCCD) is designed using single reflector North Facing Booster Mirror (NFBM) to improve the performance of both cooking and drying operations particularly in winter months. Innovative parallelepiped shape vessel (PSV) is designed (having longest inclined south facing wall) to further enhance the performance of ISCCD in cooking mode. Solar radiation capture model by

ISCCD is used in developed thermal model for various interactive components such as; glass covers, chamber air, absorber plate, cooking vessel and vessel water while considering the effect of NFBM and experimentally validated at Ludhiana climate (30°N latitude), India. Volume to aperture area ratio along with size of PSV is optimized in such a way that ISCCD with three- shelves is capable of cooking three times more food as compared to the conventional horizontally placed solar cooker (HPSC). Due to optimized vessel design and NFBM effect, ISCCD can be effectively used in extreme winter conditions when maximum temperature during the day hours around 15–20°C (on sunny days) at latitudes>30°N for both cooking as well as drying operation when conventional HPSC and dryer (generally not fitted with booster mirror) do not perform well due to lower solar radiation availability. Stagnation test (first figure of merit F1) and sensible heat test (second figure of merit F2) were also computed and compared with HPSC to ascertain the performance of ISCCD. In drying mode, ISCCD was tested for drying gooseberry (Emblica officinalis) (local name Amla) under natural as well as forced convention modes with and without the effect of NFBM. The Logarithmic drying model was found to be the best fit for drying gooseberry. Techno-economic analysis showed that in cooking mode ISCCD can be used to cook at least one meal per day for a joint family of 10 persons during 280days in a year and can recover its cost within 65months if compared with wood burning costs besides having the advantage of being used as an efficient dryer thereby saving the cost of second gadget. In terms of savings in biomass fuel burning, ISCCD can mitigate much higher CO_2 emissions as compared to conventional HPSC.

Mahavar et al. (2017): The major hindrance in popularization of box type solar cookers (SBCs) is cooking incapability of these appliances in low availability of sun light and in night. This paper introduces a new parameter "required electric back-up power (Prb)" for SBCs to remove this limitation. An analytical model is presented here to derive Prb for SBCs under different weather and cooking time conditions. To validate proposed model, a Solar cum Electric Cooker (SEC) has been fabricated as per Prb value estimated via analytical model. SEC has been tested under different conditions. Experimental results are in support to the analytical approach. SEC is capable for cooking of 1.2 kg food load under indoor and outdoor. For outdoor, cooking time on sunny day without back-up is recorded between 1.5 and 2.5 h. The cooking time on scattered cloudy day with back-up is found to be 100 min (back-up is 0.12 kWh that is 82% less than the 1conventional electric heater). For indoor, cooking time is found to be 85 min (with 0.23 kWh lectric back-up). Paper also reveals that electric back-up in SBC also reduces its payback periodand increases its net present value (NPV) in respect to different cooking fuels.

Vigneswaran and Kumaresan , et.al. (2017) : Solar cooking is one of the most promising techniques to meet the cooking needs in remote areas where electricity and fuel supplies are merger. Solar box cooker is an efficient device used in solar cooking as it is simple to fabricate, easy to operate and hazard-free. In this context, the performance evaluation of a solar box cooker with varied number of reflectors has been undertaken. It was found that the time consumed for cooking in a box type solar cooker with four reflectors is lesser compared to that of a single reflector and its overall utilization efficiency increases with increase in the cooking mass. Further, a latent heat energy storage system was designed and fabricated to cook the food at off- peak hours of solar radiation. This latent heat energy storage system was combined with the solar box cooker. Oxalic acid dehydrate was used as the phase change material due to its high specific enthalpy and its melting point lying close to the cooking temperature. It was found that the solar box cooker with phase change material could be effectively utilized to cook food during off-peakhours of solar radiation.

Saxena (2017): A solar box cooker (SBC) has been developed for the thermal performance evaluation by operating it on a low cost thermal storage. For this, a mixture of sand and granular carbon has been prepared and tested for an optimum ratio under a solar collector. After testing, the ratio of 4:6 (sand: carbon) has been observed to maintain a high temperature range with long term heat storage. This mixture has been used as thermal heat storage inside the SBC. The experimentation procedure has been conducted under climatic conditions of Moradabad, India. Results indicated that the first Figure of merit (F1) was 0.13 m^2 °C /W, second Figure of merit (F_2) was 0.44 m^2 °C /W, thermal efficiency was estimated to be 37.1%, cooking power was estimated as 44.81% and overall heat loss coefficient was 3.01 W/m^2°C. The system was found feasible for cooking during the off sunshine conditions.

Ademe (2017): This research work describes the performance evaluation of a double-glazed box-type solar oven with three reflectors and with a vapor wiper mechanism fabricated using locally available materials. The box cooker has external box dimensions of 600 mm × 600 mm × 250 mm and pyramidal internal box dimensions of 460 mm ×460 mm top face and 300 mm ×300 mm bottom face with depth of 150 mm. The thermal performance was tested as per the ASAE

International Test procedure and Bureau of Indian Standards (BIS) for testing the thermal performance of a box-type solar cooker. The obtained test results after employing required calculations were figures of merit F_1 = 0.123 Km^2 /W, F_2 = 0.540, the standard cooking power P50 = 36 W and the cumulative efficiency to be 22%, whereas with the application of the wiper mechanism, it was found that F_1 = 0.123, F_2 = 0.827, the standard cooking power (P50) = 51 W, and the cumulative efficiency to be 31.4%. The standard boiling time of 1.43 kg of water was calculated to be 53.54 and 88.84 minutes for the cooker with and without the application of wiper mechanism respectively. The thermal distribution of the cooker was modelled using interior box geometry as a boundary condition with ANSYS 15.0. The temperature distribution inside the box was simulated and the maximum wall temperature was found to be 139°C. This was lower than the experimental results by 22°C. The method of modelling and simulation of the cooker with and without a wiper mechanism is similar except for the variation of the transmittance of the glass due to shading of vapor which can be deducted from the cumulative efficiency for the latter case. The results show that using the vapor wiper mechanism increases the cumulative efficiency by 9.4% and reduces the boiling time by 35.3 minutes. Finally, the techno-economic analysis shows that the cooker with a vapor wiper mechanism has a good reliability for outdoor cooking of food and is economically feasible.

Kumara et.al (2018): Solar cooker is used for cooking foods mainly in rural areas by using solarenergy. Parabolic solar cooker having 1.39 meter aperture diameter, 0.45 meter depth and 0.26 meter focal length is designed, constructed and fabricated. The parabolic solar cooker is tested onone litre of water in cylindrical cooking vessel of two different materials namely, aluminium and GI sheet. Thermal performance is done for both types of cylindrical cooking vessel and evaluated the values of heat loss factor, optical effectiveness factor, cooking power, sensible cooking power, Average sensible efficiency, energy efficiency. On the basis of these performance factors, aluminium vessel is better than galvanized iron sheet vessel.

Kullu et. Al. (2018): Reduction of fossil fuel and increase in fuel price has led to utilization of solar energy for different applications. One of the important applications of solar energy is solar cooking. Commercially different variety of solar cookers is available: box type solar cooker and concentrating solar cooker. Box type solar cooker generally use flat reflectors. But there is diverse type ofreflectors in design can be employed in the solar cookers like flat reflector, compound concentrating

collectors, cylindrical parabolic collectors. Work has been done to increase the temperature inside the solar cooker and increase the efficiency of box cooker using different variety of reflectors. This paper gives a short review on box type of solar cooker using different types and number of reflectors. Paper wise review has been done which makes it easier to compare and evaluate the work of researchers. This review covers various box cookers designed and fabricated by altering geometrical parameters whicht5effect thermal performance of the cooker, by using different type of reflector and varying number of booster mirror. Moreover, result of each paper has been discussed in the study

Azad (2018): The solar dryer described in this paper can be used for drying various products in rural area under hygienic conditions. This solar drying system was constructed, consisting of two parts (solar collector and solar drying cabinet). Solar collector with area of $1.2m^2$ (1.2mx1.0mx0.2m) has black painted rocks to absorb solar radiation and a cabinet that is divided into five divisions separated by four removable shelves. Each shelf is 0.3m width and 0.5m length and made of nylon wire net framed in wooden border. Three sides of the drying chamber walls are covered by fibre glass sheet and a door in the back. Grapes were dried during the present work. The moisture content of grapes was reduced from 81.7% to 36.7% within five days of drying. The drying air flows through the product by natural circulation. In this work two modes of operation are discussed. The results were applied to the design of modified large scale solar agricultural dryer. This paper deals with a suitable design of a solar agricultural dryer that can be built in rural area with locally available construction materials and skills.

CHAPTER -3 MATERIALS & METHOD

The materials required in the designed prototype solar dryer cum cooker is wood , Glass plate , Reflectors , Fins , Blower , Pipes, Trays , caser wheels as shown in figure .

Glass plate

Solar cookers is a device that uses the energy of direct sunlight to heat or cook food materials. The sun rays pass through the glass plate and get absorbed inside the cooker. The glass plate traps larger amounts of heat to use in heating the food item than a steel plate. Glass is the principal material used to glaze solar collectors. Glass material has highly desirable property of transmitting as much as 90% of the incoming short-wave radiation. To be specific, glass cover for solar collector normally should be at least 0.33 cm thick. As the heat from the sun goes inside the solar cookers, this heat needs to be trapped inside the cooker so that the temperature may remain enough to heat the food, so to trap this heat so that it does not escape back out from the cooker, a glass is kept which keeps the heat inside the cooker

Reflectors

The reflector on the top of the solar cooker is used to focus the solar energy over the glass surface. The mirror reflects the heat energy in a confined area and increases the net input energy to the solar cooker. Concave mirrors are used in solar cookers. This is because they are the only type of mirrors that reflect sunlight to a single focal point.

Black body

Black body in physics, a surface that absorbs all radiant energy falling on it. The term arises because incident visible light will be absorbed rather than reflected. A black body or blackbody is an idealized physical body that absorbs all incident electromagnetic radiation, regardless of frequency or angle of incidence. The name "black body" is given because it absorbs radiation in all frequencies, not because it only absorbs: a black body can *emit* black- body radiation.

Fins

The purpose of using the fin is to enlarge the surface area exposed to the sun's heat so that radiation heat transfer increases. Increasing the temperature gradient between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Thus, adding a fin to an object, increases the surface area and can sometimes be an economical solution to heat transfer problems.

Blower

Blower is equipment or a device which increases the velocity of air or gas when it is passed through equipped impellers. Blowers are very efficient. Operating cost of a blower is a fraction of the cost of using compressed air for a given volume of air. Blowers also provide clean air there is no danger of oil droplets or residue in the blower air stream since blowers do not use oil as a lubricant.

Trays

Tray is a batch process used to dry materials that are liquid or wet cake. It's simple to use. The basic working principle of this incredible machine is the continuous circulation of hot air. In the tray dryer, moisture is removed from the solids that are placed in the tray by a forced convectional heating. The moist air is removal is conducted partially but in a simultaneous fashion.

Aluminium pipe

Aluminium Pipe is a extruded product that is widely used for all types of fabrication projects where lightweight and corrosion resistance is a primary concern. Aluminium pipe corrosion- resistant properties mean optimal air flow, reduced energy costs, and better air quality. The fittings used with aluminium pipe systems fit securely and leak far less than the fittings used withthreaded systems. This translates directly into energy savings and improved plant productivity.

Caster Wheels:

Solar cooker may be provided with 4 caster wheels each having ball bearing (see IS 5932) or twocylindrical plastic or non-corrosive supports (buffers) for front and two plastic or non-corrosive wheels for rear.

Workmanship and Finish

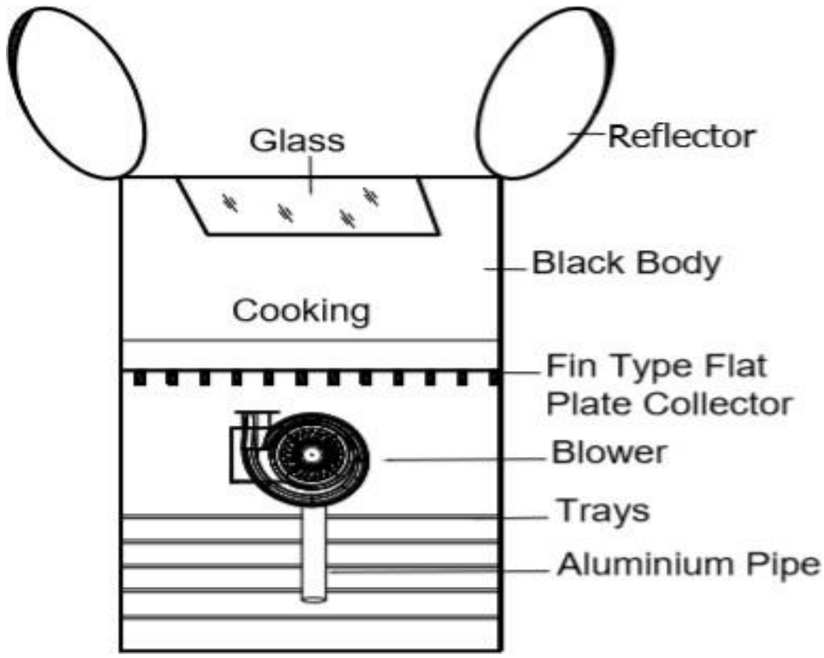
All the surfaces shall be smooth and free from roughness, raised spots, scale or any other surface defects. Sharp edges and corners shall be rounded off.

The screws, hinges, lever rods, locks, handle, caster wheels etc, used in the cooker shall be properly fitted. The weight of various components of cooker shall also be set in such a way that itdoes not topple back while lifting the cover plate for loading and unloading of cooking pots.

Method

In this Modified prototype solar dryer cum cooker there are two reflectors & Glass provided.The box is coated with black colour, so that the model can absorb more heat from the sunlight and will be good for cooking. Firstly in this equipment we can fabricated for the cooking. under the cooking box, plate was provided & fins also attached to the plate, bottom of the fins we provided the blower, for the air circulation purpose, pipe is directly connected to the blower for the passing of heat, trays are attached side of the pipe & holes will be inserted to the trays for theproper drying purpose. In this whole equipment cooking & drying can take place

Fig 1.2 Solar dryer cum cooker



3. 2 DESIGN CONSIDERATIONS :

1. Slope of the collector (b) was calculated by following formula,$\beta = (\phi - \delta)$
2. Heat Balance = Sensible heat + Latent heat
3. Area of collector = Heat required / Heat available x nc

For safe design effective collector area of 0.49 m^2 was considered

Drying Efficiency (nd)

Drying efficiency decreases with increase in the drying temperature. In the day lower temperatures were recorded during the morning and evening hours with the morning hours recording the lowest temperature. It was observed that the efficiency of the dryer was high at the beginning that is 11.4 % and minimum at the time of completion of drying that is 0.7%. Drying efficiency of dryer for Fruits and Vegetables was high in winter and low in summer respectively. Drying efficiency was high in winter than summer due to higher solar insolation in the month of April.

Heat Utilization Factor (HUF)

The heating utilization factor is defined as the ratio of the reduction in heating needs resulting from the heat gains, over say a month, divided by the total heat gains for the same period. The net heat gain at any time is the difference between simultaneous heat gains and losses.

This is defined as the ratio of temperature decrease due to cooling air during drying and thetemperature increase due to heating of air **(Brenidorfer et. al 1985).**

HUF is calculated by formula as HUF = $(t_1 - t_2)/(t_1 - t_0)$

Where;

t_0= Dry bulb temperature of a ambient air

t_1 = Dry temperature of drying air

t_2= Dry bulb temperature of exhaust air.

Coefficient of Performance

It is calculated by as follows, COP = $(t_2-t_0)/(t_1-t_0)$

Where,

t_0, t_1, and t_2 have the same meaning as mentioned above. HUF + COP = 1

Upper glass cover: The energy balance equation for upper glass cover of ISCCD isgiven as

$$mg1Cg1 \frac{dTg1}{dT} = Q1 - Q2 - Q3 + Q4$$ --------------------- Eq (3.2)

where

Q1 is heat gain by upper glass by solar radiation incident on itQ2 is heat flow by convection from upper glass to ambient airQ3 is heat flow by radiation from upper glass towards the skyQ4 is heat flow by radiation from lower glass to upper glass

Lower glass cover

After transmitting the solar radiation by upper glass it falls on lower glass cover. Various energybalances of heat in flux and out flux for lower glass cover is given below

$$mg2Cg2 \frac{dTg2}{dT} = rg1\, Q1 + Q5 + 3Q6 - Q4 + Q7$$ ------------------------ Eq (3.3)

where

Q5 is heat flow by convection from chamber air to lower glassQ6 is heat flow by radiation from vessel to lower glass

Q7 is heat flow by radiation from absorber plate to lower glass

Absorber plate

Heat gain by absorber plate depends on solar radiation falling on it after transmitting through two glass covers. Various heat losses by absorber plate are given below

$$mpCp \frac{dTp}{dT} = Q10 - Q11 - Q8 - Q12 - Q7$$ ---------------------------Eq (3.4)

where

Q10 is the solar radiation capture by absorber plate

Q11 is heat flow by conduction from absorber plate to ambient airQ12 is heat flow by radiation from absorber plate to vessel.

Cooking vessel

As the parallelepiped shaped cooking vessel was placed horizontally inside the ISCCD and the solar radiation directly incident on long south wall of three vessels after transmitted by two glass covers. The energy balance equation of cooking vessel including heat influx and out flux is described

$$mvCv \frac{dTv}{dT} = Q15 + Q12 - Q14 - Q9 - Q6$$ ---------------------- Eq (3.5)

Where

Q15 is solar radiation capture by vessel.

Drying performance of ISCCD

Drying performance parameters used are given below Moisture content (%) on wet basis

$$Mwb = \frac{Wi-Wf}{Wf} \times 100 \quad \text{--Eq (3.6)}$$

Moisture content (%) on dry basis:

$$Mdb = \frac{Mwb}{100-Mwb} \times 100 \quad \text{------------------------- Eq (3.7)}$$

Drying rate

$$K= \frac{mp}{t} \quad \text{---Eq (3.8)-------------------}$$

The drying data obtained from experiments was fitted in four well known drying models as shown in Table 1 to predict the drying behaviour of amla (gooseberry) in distinctive drying modes. Moisture content data was transformed to moisture ratio (MR) using following expression.

$$MR = \frac{Mt-Me}{Mi-Me} \quad \text{--------------------------- Eq (3.9)}$$

ASSEMBLY OF COMPONENTS

The solar cooker shall be assembled so that replaceable components are easily accessible for repair or replacement. There shall be no direct contact between cooking tray & cooking box. The top cover of the cooker box shall not cause any pressure either on the cover plate or on the mirror.

TESTS FOR SOLAR COOKER PERFORMANCE

Routine tests

Leakage test

The cooker tray, rubber gaskets and cover plate shall be subjected to the leakage test in accordance with 4.1 of IS 13429 (Part 3). There shall be no sign of leakage.

Slam Test

The cooker shall be subjected to slam test in accordance with 4.2 of IS 13429 (Part 3). Thereshall be no damage to cover plate, mirror or any part of cooker.

Mirror Reflectivity Test

The mirror shall be subjected to reflectivity test in accordance of IS 13429 (Part 3). It shall haveminimum 65 percent reflectivity.

Type tests

Exposure Test

The cooker shall be subjected to exposure test in accordance with 4.4 of IS 13429 (Part 3). Thereshall be no

a) Appearance of any sign of degradation of rubber or plastic material;

b) Out gassing from the insulation material;

c) Discoloration or peeling of black paint on the cooking pots and cooking tray;

d) Deposition of water vapour, dust or any other material inside the cover plate when inspectedvisually; and

e) Cracking of glazings and/or mirror and/or body of the cover.

Load Test

The cooker box made of fiber reinforced plastic shall be subjected to load test with 50 kg load kept on the box at the centre covering 50 percent of top surface area, for one hour. No cracks shall appear on the box when inspected visually with naked eye.

CHAPTER 4

RESULTS AND DISCUSSION

A solar dryer cum cooker is designed for drying and cooking of selected food materials. The design describe the basic purpose of project is to facilitate the drying and cooking in one with accelerated or enhanced pattern of cooking and drying of the food materials.

4.1 Design of modified solar dryer cum cooker

In this design the dryer cum cooker is in one chamber. Based upon previous designs this modification of design was performed by using some different parts in the design, which deliberately be the main highlight feature to address simultaneous drying and cooking in one chamber. The important components of the design is about perforated tray for uniform drying. fins to transfer heat for drying, blower is included for proper circulation of heat.

4.1.1 Outer Black Body

Which absorbs the heat of the incident sunlight and makes the temperature of chamber more than the surrounding temperature. Drying chamber absorbs the sunlight and generates the heat and after some time inner temperature becomes much larger than the outer temperature. Covering glass restrict the flow of heat outside.

4.1.2 Glass Plate

Glass, as the solar collector cover and the cover for the drying chamber. It permits the solar radiation into the system but resists the flow of heat energy out of the systems. The performance of solar collector depends on climatic conditions and several operating condition such as collector orientation, thickness of cover materials, wind speed, collector length, collector depth, and the type of absorber material used. Currently, these factors are not well considered during solar system design. Therefore, development of a well-performed solar collector is of significant economic importance in solar drying system. This study has dealt with the effect of glass thickness on solar collector performance. The solar collector models with different glazing thicknesses had been successfully designed, constructed, and tested in this study. From the results obtained, it could be concluded that the use of 4 mm glass thick improves the performance of air solar collector by 7.6% compared to 3,5,and 6 mm glass thicknesses. However, the risk for glass breakage during construction is high when using thinner glass, 4 mm compared to 5 mm and 6 mm, especially when constructing larger collector with longer/wider span **(Ramadhani Bakari et al 2013).**

4.1.3 Lens Reflector

In each case, 500 g of peeled and sliced bananas, with 76% (w/w) initial moisture content, were kept on a wire mesh in a single layer inside the drying chamber. The experiment with reflectors on collector is labeled A and the one without is labeled B. This example teaches us that whereas with use of reflectors on the collector the moisture level in the banana could be brought down to ca. 15% w/w with respect to the dried product within 2 hours, the moisture content was as high as 62% w/w with respect to the dried product under otherwise similar conditions. The direct dryer fitted with reflectors on dryer side, in addition to the collector side, shows even higher rate of drying than the one which has reflectors on the collector side alone **(Ghosh et al 2006).**

4.1.4 Fins

The use of fins is one way to improve the performance of solar dryers. Fin serves to increase heat absorption area without increasing dimensions of the solar dryer. This study investigates the performances of a solar collector with fins and baffles numerically and experimentally. It was found that the experimental efficiency and outlet temperature are about 47.27% C, respectively. While the predicted efficiency and outlet temperature are about 52.01% and°and 60.1ºC, respectively 64.9ºC **(Panuwat Pawakote et al 2008).**

4.1.5 Blower

A blower fan is also used for delivering the hot air to the surface of the product to be dried. Solar dryer gives faster drying rates, reduces humidity and risk of spoilage and improves the quality of the product. Air blower is used to increase the velocity of the air. The air blower sucks the air from suction pipe and blows it to other side through pipe. The specification of blower is 220-240v, 50-60Hz, 500W, Speed 0-16000/minute. It is observed that the drying time taken to dry same quantity of product in forced convection is less than the natural convection. The red chilies were dried by natural convection in three days reducing the weight from 610 grams to 243 grams. Whereas the same quantity of red chilies were dried by forced convection with the use of air blower in two days reducing the weight from 610 grams to 230 grams **(Sushrut S. Halewadimath et al 2005).**

4.1.6 Tray

The tray is used widely in the dryer because of its simple design. In this system, the trays are fixed at their positions. A good arrangement of trays inside dryer, the system design eliminates or reduces the non-uniformity of drying throughout the drying chamber. In this design perforated trays is used because it has advantage as the hot air passes through this perforates which helps to remove moisture content uniformly.

Drying chamber designed in such a way that it consists of 4 trays which would hold drying products. Its dimension is about 70×52×4.25 cm (l×b×h). About 12 liters of product volume can be placed in each tray. Hence the total capacity of the trays is approximately 50 liters. Rusting can be avoided by using aluminum as the material for trays. The main reason for using aluminum is because aluminum meshes are light weight, strong and there is significant resistance for atmospheric corrosion. Wooden frames are used for each tray. Due to the usage of wire mesh heated air passes through these trays and the product gets evenly dried on both sides **(Ajith Gopi et al 2016).**

4.2 Performance prediction on the design to study feasibility and advantages of modified solar dryer

The performance prediction on the design shows there is no need of change in direction according to sun rays because of rotating reflectors, as this reflectors rotates and absorbs energy. Reflectors will not higher temperature due to which proper cooking would takes place. This design is suitable for cooking in summer and also suitable for summer and non-summer period.

Dryer with reflector attained 6.6% more temperature than dryer without reflector. Observation in summer for dryer with reflector was not taken since boosting up of temperature inside the dryer was not required. Solar cookers having reflector achieved higher temperature as compared to the cooker without reflector. This was expected because of extra solar radiation provided by the mirror. The maximum temperature attended by cooker with reflector was 119°C, 115°C and 104.25°C in winter and 139°C, 137.5°C and 126°C in summer on upper tray, middle tray and lower tray. Solar cooker with reflector achieved 35 to 40 per cent more temperature as compared to without reflector. In Solar Dryer cum Cooker device F, and F, Value of SDC for solar cooker with reflector was 0.119 and 0.120 and 0.32 and 0.30 in winter and summer. Time required for cooking of rice, tur dal, moong dal was 90, 130 and 100 minutes in winter and 60, 90 and 75 minutes in summer. For solar dryer unit of SDC the efficiency in drying of maize, wheat and Potato was found to be 15.55 %, 10.89 % and 10.42 % in winter where was in summer it was 12.97%, 8.90 % and 10.16% respectively **(S..H. Sengar et al 2005).**

Results and discussion

By the rotating reflectors the absorption of heating in the equipment occurs in a proper way. This novel design will be on upper end or on the higher end. By comparing this equipment with the other existing ones the results shows it is more feasible because of these rotating reflectors i.e solar cooker would be more feasible than solar dryer. Experiments can be done for different food materials which may show more acceptable and beneficial.

CHAPTER 5

SUMMARY AND CONCLUSION

Summary

- The solar dryer cum cooker was designed for drying and cooking of food materials, mainly suitable for fruits and vegetable.
- A solar collector of the size of 0.49 m^2 was designed along with separate drying chamber. Inlet and outlet holes were provided for exhaust air.
- Two PVC pipes with valves were provided for carrying hot air to drying chamber. While working as cooker, the holes and valves were closed and during drying operation they were opened.
- The solar cooker cum dryer was designed and fabricated for cooking and drying of food materials.
- The average heat utilization factor and coefficient of performance of the dryer were 0.2 and 0.8 respectively. Solar cooker could be effectively used as dryer.
- Solar intensity on collector surface was about 8 to 10 % more than that of horizontal surface.
- The maximum heat utilization factor is 0.57 & minimum is 0.10. Similarly the COP was also calculated and presented . The maximum COP was 0.80 & minimum was 0.43.

Conclusion

As the design facilitates the mechanism of solar drying and solar cooking which is enhanced by using lens reflectors lens as to reflect the sunlight to the glass area of the solar dryer cum cooker This mechanism would significantly increase the rate of solar drying and solar cooking .The lens reflectors would be advantage for maximum area covered to harvest solar energy inform of solar radiation which would result in better solar cooking. The flar plate collector with thin fin is to dessipitate the access solar energy present available in the solar cooking compartment would dessipitate to the solar drying compartment. The blowers will help the hot air to circulate within the drying compartment. The maximum harvest of solar energy with the help of lens and glass would enhance the solar drying and solar cooking mechanism on the basis of the finding's of investigation following conclusions were drawn. Solar intensity on collector surface would be around 8 to 10% more than that of horizontal surface.

CHAPTER 6 RECOMMENDATIONS

The Model novel solar dryer cum cooker is a efficient come economically reliable prototype model which can facilitate drying and cooking process at the same time , which directly will result to minimise the time of drying cum cooking

For the based on the design mechanism proposed model for a prototype model and can be fabricated for experimental trails on various types of vegetables

And therefore study can also be conducted on different level of drying and solar cooking

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