Journal of Renewable Energy, Electrical, and Computer Engineering
Volume 4, Number 1, March 2024. 32-41
eISSN 2776-0049
DOI: https://doi.org/10.29103/jreece.v4i1.13764
Research Original Article

Efficiency of Solar Cookers with Different Geometric Shapes Over the Last Decade: A Comprehensive Review

Lisma Dian Kartika Sari✉1, Zainul Munawwir2, Chairatul Umamah3
[1,2] Mathematics Education Study Program, STKIP PGRI Situbondo, Situbondo Regency East Java, 68323, Indonesia, lismadian.ks@gmail.com, sinollonis@gmail.com
[3] Physics Education Study Program, Madura Islamic University, Pamekasan East Java, Indonesia, chairatul.physics@gmail.com
✉Corresponding Author: lismadian.ks@gmail.com | Phone: +6285808487806

Received: December 07, 2023 **Revision: January 11, 2024** **Accepted: February 20, 2024**

Abstract
Mostly in rural areas in developing countries, biomass and fossil fuels are used for cooking. These fuels have negative impacts on the environment and human health. One solution to the problem is cooking using solar-powered stoves as a clean and environmentally friendly alternative energy. In this research, a literature study was conducted related to solar cookers which are divided into several types based on their geometric shape, namely box, parabolic, tube, and panel types. This research examines the performance of solar cookers, namely solar cooker efficiency (η%). In this literature study, the development of stoves from 2012 to 2023 has been reviewed and focused on. The sub-topics discussed revolve around the details of the geometry shape of the solar cooker on the performance of the solar cooker on the parameter of heat efficiency generated. The main conclusion of this review is that box-type solar cookers are more researched than other types of solar cookers, indicating that box-type solar cookers are more in demand and more economical in the manufacturing process. The highest average heat efficiency (η%) is produced by the tube-type solar cooker and the lowest is produced by the parabolic-type solar cooker. Other parameters also affect the efficiency of solar cookers, namely the intensity of solar radiation, the type of absorber/heat storage material, the use of reflectors with the right position (zenith and azimuth angles), the use of a tight cover pan (vacuum tube) for certain types of solar cookers and the length of cooking time.
Keywords: Solar Cooker; Geometry Shape; Efficiency

Introduction
Energy use in the world is increasing rapidly along with economic growth and population growth. There are several factors that influence the amount of energy consumption and greenhouse gas emissions worldwide, one of which is cooking. Household cooking fuel consumption is increasing along with the increase in the number of family members and economic growth, which affects the production of CO2 emissions (Nugrahayu et al., 2017). Cooking activities contribute up to 10 percent of particulate matter (PM) emissions. Previous research (Al Latifa et al., 2022) showed that cooking with gas releases twice as much as 2.5 PM as cooking with an electric stove. The use of gas for cooking produces nitrogen oxide (NOx) gases, including nitrogen oxides (NO) and nitrogen dioxide (NO2), carbon monoxide (CO), and formaldehyde (CH2O or HCHO), all of which can pose health risks if not managed properly. In general, the fuel used, LPG, produces 1.51 kg of carbon dioxide per unit of consumption. As the need for cooked food increases due to the rising population, it is necessary to replace LPG with other energy sources to reduce existing CO2 emissions (P. M. Cuce, 2018).

One solution that can be done is to utilize alternative energy, namely solar energy, to meet energy needs both at the industrial and household levels. One of the utilization of solar energy is cooking using solar cookers. Solar cookers are cooking devices that utilize solar thermal energy through collectors as an energy source (Napitupulu et al., 2022). The basic principle of how solar cookers work is that heat radiation from sunlight falling on the surface of the collector is reflected to a certain point/area called the collector hot spot, this part produces a very high temperature. Based on literature studies that have been conducted, factors that can affect the performance of solar cookers include the length of cooking time, the intensity of heat radiation from the sun, and the reflectivity of the collector material (Abdul Haris Subarjo et al., 2019), the surface area of the collector (Wijayanti, 2010), and the geometry and location of the collector hot spot (Muin, 2017). Currently, there are many types of geometries of solar cookers developed, including panel-type solar cookers, box-type solar cookers (sometimes called box ovens), parabolic-type solar cookers, and tube-type solar cookers (Aliyu et al., 2021). Of all these types or types of solar cookers, they must produce different heat performance and efficiency.

The box-type solar cooker is designed to efficiently cook food using solar radiation. The cooker consists of a black tray inside the box, which maximizes heat absorption. One side of the box is made of glass to allow shorter wavelength solar radiation to enter. To minimize heat loss, two glass covers are used, and the box is made airtight with rubber strips. An insulating layer is added between the box body and the black tray to store heat and prevent heat loss (Sawarn et al., 2021). Researchers (Saxena & Agarwal, 2018) have developed a new hybrid solar box cooker (SBC) that includes an integrated trapezoidal channel, a 200W halogen lamp, and 450 small hollow copper balls to improve thermal performance, especially in forced convection mode. Testing shows that the SBC has a thermal efficiency of 45.11%, an estimated cooking power of 60.20 W, and an overall heat loss coefficient of 6.01W/m2C. This design allows for cooking food in poor indoor conditions while consuming only 210W of energy.

Box-type solar cookers have been specifically designed for use in tropical countries (Vengadesan & Senthil, 2021). The research conducted showed that making fins on the stove vessel can improve the thermal efficiency and heat transfer coefficient. The experiment was conducted for five days and the results showed that the configuration with 45 mm fins had a thermal efficiency of 56.03% and a heat transfer coefficient of 58.54 W/m2 °C. In addition, another study (Kumar et al., 2022) also tested a box-type solar cooker using the concept of extended fins and heat storage media. The results showed that the configuration with encapsulated PCM was the best, with a 52.2% increase in thermal efficiency and a 301 W/moC increase in heat transfer coefficient. This box-type solar cooker meets Bureau of India (BIS) standards and can be further developed. With improved thermal performance, the box-type solar cooker is an attractive alternative for cooking.

Materials & Methods

This research uses a literature study approach which involves a series of activities such as collecting library data, reading and recording, and processing research materials. Literature study studies reference books and similar previous research to get the theoretical basis of the problem to be studied. This can also be done by reviewing books, literature, notes, and reports related to the problem to be solved. According to Sugiyono 2014, a literature study is a study of theories, references, and scientific literature related to culture, values, and norms in the social situation being studied. In library research, the steps taken include collecting library materials related to the research objectives, using library methods in data collection, and organizing and presenting data (Sari & Asmendri, 2020).

This research is descriptive in nature which focuses on systematically explaining the facts obtained at the time the research was conducted. Descriptive research is research that aims to provide an overview of the social phenomena being studied by describing variable values based on the indicators being studied without making relationships and comparisons with several other variables. The steps in literature research (Marziqon & Purwoko, 2017) are shown in the diagram in Figure 1 below:

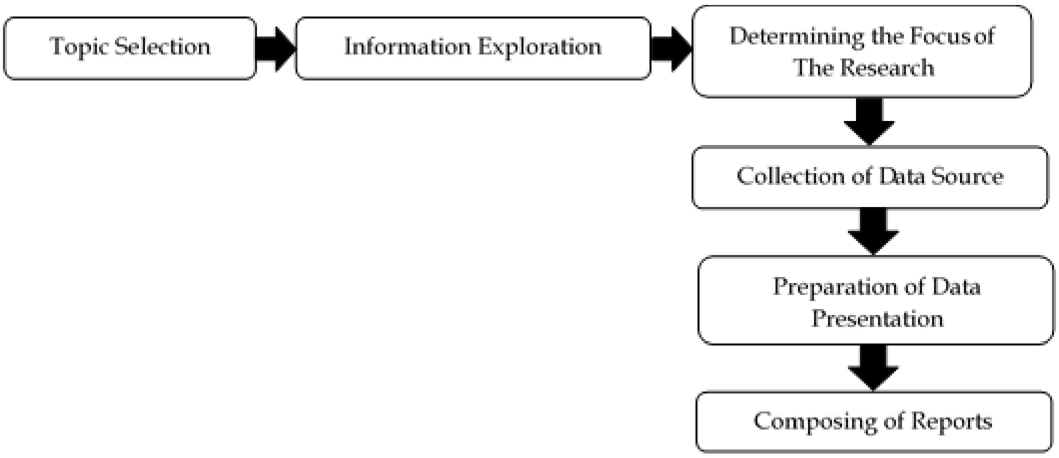

Figure 1. Library Study Research Methods

Results and Discussion

Solar cookers have been used for over a hundred years to cook food using solar energy. The technology used in solar cookers hasn't changed much since its inception. Solar cookers first receive solar radiation, which is then reflected onto cooking utensils. This reflected radiation focuses on the utensils, generating heat and cooking the food (Regattieri et al., 2016). The cookers can be used for a variety of tasks, such as cooking, boiling, baking, pasteurization, and sterilization (Aramesh et al., 2019). There are four main types of solar cookers: Box, Parabolic, Tube, and Panel types. All of them work on the same principle of cooking using solar power but vary in performance, efficiency, cost, and size, depending on their geometry and environmental parameters. You can see the details in Table 1 below.

Table 1. Solar Cookers Performance (η%) with Differences in Geometry Over the Last Decade

No	Title and Researcher	Focus of study	Geometric Details	Efficiency (η%)
1	Performance study of a box-type solar cooker employing an asymmetric compound parabolic concentrator (Harmim et al., 2012)	A new box-type asymmetrically equipped solar cooker (CPC) was designed, built, and tested	Box-type solar cooker An equipped one Parabolic optogeometrics concentrator or asymmetric Compound Parabolic Concentrator (CPC).	20,94%
2	Comparative study of	Analytical and experimental	Parabola-type solar cooker	53%

	different means of concentrated solar flux measurement of the solar parabolic dish (Skouri et al., 2013)	studies of solar parabolic concentrators	with concentrator SPC uses four Plate absorber/thin plate receiver	
3	A vacuum tube-based improved solar cooker	A new type of improved solar cooker based on the use of a single vacuum tube	Single vacuum tube type solar cooker with linear Fresnel collector 122 cm 183 cm with 17 rectangular plane glass mirror strips.	20-30%
4	Optimization of the parabolic mirror position in a solar cooker using the response surface method (RSM) (Zamani et al., 2015)	Solar cookers have been designed, built, and experimentally analyzed to develop and improve the thermal and radiation performance of solar cookers	Parabolic-type solar cooker With three mirrors that can be adjusted and placed on The parabola corresponds to the direction of the sun's movement	35,5%
5	Design, development, and testing of a small-scale hybrid solar cooker (Joshi & Jani, 2015)	The Small Scale Box type solar stove (SSB) was modified into a new photovoltaic and thermal hybrid solar stove into the Small Scale Box type Hybrid solar stove (SSBH)	Hybrid box-type solar cooker	38%
6	Kajian Kinerja Kompor Surya Dengan Variasi Susunan Absorber (Muin, 2017)	Knowing the effect of the speed of each absorber on the power capability and heat absorption efficiency	Box-type solar cooker with a box-shaped absorber configuration	26,65%
7	Development and performance studies of a novel portable solar cooker using a curved Fresnel lens concentrator (Zhao et al., 2018)	Introducing the structure and working principle of a portable solar cooker device with a curved Fresnel lens as a concentrator	Portable solar cookers use curved Fresnel lenses as concentrators.	18,9%
8	Perancangan, Pembuatan, Dan Pengujian Kompor Energi Matahari Portabel Tipe Parabola Kipas (Dwicaksono & Rangkuti, 2018)	Changing the design of the stove from a static reflector to a portable one with a parabolic type fan made from Stainless Steel Mirror 304 plate	Fan type parabolic solar cooker with reflector plate measuring Diameter: 1170 mm, Depth: 250 mm; Arch radius: 585 mm and reflector frame measuring Diameter: 1170 mm Arch radius: 800 mm	4,42%
9	Kajian Performansi Kompor Surya dengan Erythrytol Sebagai Pcm untuk Memasak Langsung dan Tidak Langsung (Gunawan et al., 2018)	To determine the thermal efficiency of the solar collector box in the charging process and the insulator cylinder in the discharging process in maintaining rice temperature	The box-type solar cooker measures 120 × 120 (cm) and in the discharging process uses an insulator cylinder measuring 30 × 45 (cm)	41,54 %
10	Box type solar cookers with sensible thermal energy storage medium: A comparative experimental investigation and thermodynamic analysis (P. M. Cuce, 2018)	Experimentally analyzing box-type solar cookers with and without thermal energy storage according to continental climate conditions in Bayburt, Turkey	Box-type solar cooker	16,9 - 27,6%
11	Introducing a Novel Design in the Realm of box type solar cookers: An Experimental Study (Zafar et al., 2018)	Introducing a new design of double-layered box-type solar cooker which has an L-shaped absorber plate with one internal plane reflector (bottom) and two external plane reflectors	Box-type solar cooker L-shaped with absorber plate, double-layered, one internal and two external reflectors	20%
12	Improving thermal power	A cylindrical solar cooker	The solar cooker is	21,2- 34,6%

	of a cylindrical solar cooker via novel micro/nanoporous absorbers: A thermodynamic analysis with experimental validation (E. Cuce, 2018)	with a microporous damper is investigated experimentally and numerically in terms of thermodynamic performance figures.	cylindrical with characteristic trapezoidal porosity	
13	Performance characteristics of a new hybrid solar cooker with air duct (Saxena & Agarwal, 2018)	A new hybrid solar box cooker (SBC) has been developed and tested for thermal performance evaluation of climatic conditions of western Uttar Pradesh, India.	Hybrid box type solar cooker (SBC).	45,11%
14	Improvement of Energy Efficiency and Effectiveness of Cooking for Parabolic-Type Solar Cooker Used with Activated-Carbon-Coated Aluminium Cooking Pot (Goswami et al., 2019)	Parabolic-type domestic solar cookers were tested for the same equipment with and without cost-effective thermal coating.	Domestic solar cooker parabolic type aluminum coated with activated carbon	22%
15	Uji Performa Kompor Surya Tipe Parabola Silinder Menggunakan Reflektor Cermin dengan Variasi Bahan Absorber (Amri et al., 2020)	Design and construction of a cylindrical parabolic type solar stove with a variety of absorber materials, namely aluminum, copper, and brass with a diameter of 41 cm x 61 cm and a thickness of 0.02 mm.	The cylindrical parabolic type solar cooker is half a tube with a diameter of 43 cm x 63 cm, has a variety of materials The absorber is aluminum, copper, and brass with a diameter of 41 cm x 61 cm and a thickness of 0.02 mm	25,57%
16	Parametric analysis and optimization of a portable evacuated tube solar Cooker (Hosseinzadeh et al., 2020)	The performance of a portable evacuation tube solar cooker along with a stainless steel tank was investigated analytically	Tube-type portable solar cooker with stainless steel tank lining	76,30%
17	Efisiensi Kompor Surya Parabola Berreflektor Cermin Untuk Menunjang Ketahanan Energi (Abdul Haris Subarjo et al., 2019)	Knowing the power and thermal efficiency of the collector on a solar cooker	Parabolic type solar cooker with a parabolic reflector diameter of 80 cm, the size of the mirror pieces on the parabolic disk is 2x2 cm, the length of the legs to maintain the height of the device is 34.5 cm and the height of the cooking utensil holder for the pan is 66.5 cm.	6,18%
18	Unjuk Kerja Solar Cooker Tipe Parabolic Dengan Diameter 100 Cm Tinggi 50 Cm (PURBA, 2020)	To determine the performance of a solar stove using an experimental method, namely a dish collector placed in a place exposed to direct sunlight with a mass of water in a 1 liter container within 3 days of observation.	Parabolic type solar cooker with a parabolic diameter of 100 cm, a height of 50 cm a focus point of 23 cm, parabolic collector area of 3,523 m²	5%
19	Pengaruh Sudut Kemiringan Ruang Masak dan Penggunaan Lensa Fresnel terhadap Performa Kompor Surya Tipe Kotak (Rachmanita et al., 2020)	Testing of the performance of a box-type solar cooker with variations in the angle of inclination of the cooking chamber and variations in the cover of the cooking chamber has been carried out	Box-type solar cooker with the size of the solar stove is 60 x 60 x 40 cm with a thickness of 0.9 cm. Variations in the cooking chamber tilt angle of 30° and a combination of fresnel glass	6,7%
20	Experimental investigation	Find out the benefits of	Box-type solar cooker with	56,03%

	of the thermal performance of a box-- type solar cooker using a finned cooking vessel (Vengadesan & Senthil, 2021)	adding aluminum fins to the lid of the cooking vessel on a solar cooker	outer dimensions of 0.5 m × 0.5 m × 0.135 m and inner dimensions of 0.385 m × 0.385 m × 0.07 m with the addition of aluminum fins on the lid of the container 45 mm long	
21	Enhancement of productivity of parabolic dish solar cooker using integrated phase change material (Senthil, 2021)	Investigating the productivity of solar cookers with phase change materials (PCM) using parabolic collectors	The parabolic type solar cooker (parabolic dish solar cooker) has a diameter of 90cm and a depth of 12cm. The area of the disk is 0.636m2 and the edge angle is 56.14°. The focal length is 0.25m.	22%
22	Design and performance characteristics of a solar box cooker with phase change material: A feasibility study for Uttarakhand region, India (Kumar et al., 2022)	To determine the thermal performance of a low-cost solar box cooker (SBC) modified through an extended fin concept and heat storage media	Box-type solar cooker with 144 small capsule-shaped aluminum containers filled with PCM and placed horizontally on top of the absorber	52,2%
23	Studi Ekperimental Penambahan Reflektor Datar Pada Kompor Tenaga Surya Tipe Parabolic (Mardwianta et al., 2023)	Making a parabolic solar cooker using Autodesk and testing a prototype of a solar cooker without additional glass, with one additional mirror and two rearview mirrors.	Shaped solar cooker parabola using Autodesk with the addition of two flat mirrors	4,87 %
24	Development and performance evaluation of tube-type direct solar oven for baking bread (Aragaw & Adem, 2022)	Developed and tested a tube-type direct solar oven that could potentially be easy to manufacture and widely produced at low cost locally in developing countries.	The tube-type solar cooker has overall dimensions (diameter and length) of 0.1 m × 1 m and a parabolic height of 0.35 m	43,9%
25	Modeling and analysis of compound parabolic concentrator integrated box-type solar cooker (Goyal & Eswaramoorthy, 2023a)	Mathematical modeling of a CPC-integrated box-type solar cooker with a selective absorbing surface was developed using the energy balance equation for each sub-system.	Box-type solar cooker with planer reflector with compound parabolic concentrator (CPC) mounted on the edge of the box-type solar cooker	34 %
26	Thermal performance enhancement on a box-type solar cooker using a triangular fin over a conventional cooking pot (Goyal & Eswaramoorthy, 2023b)	Knowing the high heat transfer rate and reduced cooking time through modifications applied to the SBC (Solar Box Cooker)	Box-type solar cooker with a rectangular design assisted by a modified fin integrated cooking pot with outer dimensions measuring 0.52 m × 0.52 m × 0.19 m and inner dimensions measuring 0.35 m × 0.35 m × 0, 10m	40,55 %

The way each type of solar cooker works is slightly different, this is one of the effects caused by differences in the design or geometry of solar cookers. From the review of solar cookers in this study, solar cookers are divided into the following 4 types of solar cookers:

Box Type Solar Cooker

In the box-type solar cooker, the inner tray is inside the body of the cooker, the cooker is black because the black color absorbs heat optimally. The box has one side made of glass so that solar radiation with shorter wavelengths can penetrate the box. To minimize heat loss, two glass covers are made and the box is airtight using rubber strips. The insulating material is used to store heat and resist heat loss and is inserted into the space between the box body and the black tray inside the box. In essence, the box-type solar cooker captures solar radiation which results in heat being generated inside the cooking chamber to cook food (Sawarn et al., 2021).

This study (Joshi & Jani, 2015) describes the development of a photovoltaic and thermal hybrid solar cooker called the Hybrid Solar Cooker (SSBH). This cooker combines photovoltaic power and solar thermal power for more efficient cooking. Five solar panels of 15 W each are installed on this cooker. The design of this hybrid box solar cooker includes the right size of solar panels, batteries, and DC heaters. The efficiency of this hybrid solar cooker was found to be 38%. Other studies (Saxena & Agarwal, 2018) have also found that box-type solar cookers can function well in various climatic conditions. Another study in Uttar Pradesh, India, tested a box hybrid solar cooker with additional trapezoidal channels and other integrated elements. The test results showed that the thermal efficiency of this solar cooker reached 45.11% with a power consumption of 210W. Thus, this type of cooker can cook food efficiently in poor indoor conditions.

Figure 2. Hybrid box-typesolar cooker (SBC) (Saxena & Agarwal, 2018)

Figure 3. Box-type solar cooker with added aluminum fins (Vengadesan & Senthil, 2021)

This research (Vengadesan & Senthil, 2021) discusses the development of a box-type solar cooker using fins and heat storage media to improve its thermal performance in tropical countries. In the first study, the box-type solar cooker was fabricated using four cylindrical aluminum vessels with and without fins having varying fin lengths. Test results showed that the 45 mm finned configuration provided a thermal efficiency of 56.03% and a heat transfer coefficient of 58.54 W/m2 °C. The second study (Kumar et al., 2022) explored the use of hollow capsules and PCMs in combination with box-type solar cookers. The results showed that the combination of a box-type solar cooker with encapsulated PCMs resulted in an increase in thermal efficiency, heat transfer coefficient, cooking power, and an overall decrease in heat loss coefficient. The box-type solar cooker was shown to meet Bureau of India (BIS) standards and has the potential to be further developed.

Parabolic Type Solar Cooker

In reflection, parabolic-type solar cookers play an important role. This is because the body of this solar cooker is made of several reflective sheet materials arranged in such a way as to form a parabola. The whole arrangement is supported by a metal frame or reflector support and wheels that allow it to stand and move to adjust the reflector body to focus on the cooking pot. Over time, the cooking pot is placed in the center of the platform on top of the reflector body. The reflector body receives solar radiation and reflects it to the bottom of the cooking pot causing a heating effect on the pot and passing it on to the food on it (Sawarn et al., 2021). The design/geometry of the parabolic trough-type solar cooker (SPC) has been designed in such a way as to obtain optimal performance as studied by (Skouri et al., 2013).

In his research, the SPC parabolic solar concentrator was made with four types of absorbers: flat plate, disk, water calorimeter (WC), and solar heat exchanger (SHE), developed at the Research and Technology Center for Energy at Borj Cedria in Tunisia (CRTEn). Observations with a variety of damper types obtained thermal energy efficiency values ranging from 40% to 77%, the concentration system achieved an average exergy efficiency of 50% and a concentration factor value of about 178. Another study also described an SPC-type solar cooker with an adjustable design of three narrow flat mirrors mounted on a parabolic curved substrate that resulted in an increase in effective efficiency and overall efficiency by 32.07% and 35.5% (Zamani et al., 2015). Although they have similarities in terms of the type of solar cooker, there are differences in the design or absorbent material used in the cooker, resulting in different solar cooker performances.

Figure 4. Parabolic type solar cooker with three mirrors (Zamani et al., 2015)

Figure 5. Activated carbon coated aluminum parabolic type domestic solar cooker (Goswami et al., 2019)

In their research (Amri et al., 2020) designed a half-tube cylindrical parabolic type solar cooker with a diameter of 43 cm x 63 cm, having various absorber materials, namely aluminum, copper, and brass with a diameter of 41 cm x 61 cm and thickness of 0.02 mm. The highest water temperature was obtained on the brass absorber solar stove in the 5th test at 80.25 oC at 12:20 a.m., and on the 4th day of testing the highest cooking power was obtained on the aluminum absorber solar stove of 18.46 W. The highest stove efficiency obtained on the aluminum stove in the 1st test of 25.57% at 13:10 a.m. WIB. The results of this study are similar to research (Goswami et al., 2019) obtained the maximum energy efficiency value on a parabolic-type solar cooker made of activated carbon-coated aluminum pan of 22% at 12.45 WIB. This shows that the efficiency value produced is influenced by the intensity of solar radiation.

Tube Type Solar Cooker

The tubular solar oven has a cylindrical container (oven) made of rolled aluminum sheet and painted black on the outside. Inside the oven is a sliding tray made of food-grade aluminum sheet metal. A high-temperature rubber door is attached to the sheet metal that closes the oven. A transparent airtight box tube made of acrylic plate that serves to hide the oven as insulation. The space between the oven and the lid is lined with wooden plates at both ends. A parabolic shape reflector made of aluminum sheet metal is used to increase the power output of the tube-type solar oven (Aragaw & Adem, 2022). This tube-type solar cooker has parameters under study, namely the absolute pressure of the vacuum shell, the absorptivity and emissivity of the absorbing layer, and solar irradiation.

Research (Sher et al., 2020) used the Taguchi method to optimize the thermal power and efficiency of solar cookers. Increasing the absolute pressure from 0.01 Pa to 100 Pa reduces the efficiency of the solar cooker by 23.07%. Increasing the absorption in the absorber layer of the solar cooker can also increase the useful thermal power by 33.76 W. Previous research (Aragaw & Adem, 2022) showed that the thermal efficiency of tube solar cookers depends on solar radiation isolation, with efficiencies of 43.9%, 42.1%, and 38.3% at average solar radiation isolation of 305 W/m2, 259 W/m2, and 232 W/m2, respectively. The results of this study indicate that solar radiation is the parameter that has the most influence on the thermal power generated in solar cookers, and the absolute pressure of the vacuum shell is the most effective parameter in optimizing the efficiency of solar cookers.

Panel Type Solar Cooker

Panel-type solar cookers are a combination of box and tube-type solar cookers, one example of which is the asymmetric CPC solar cooker. This solar cooker uses a reflector to concentrate solar radiation onto a heated absorber plate. The air in the room is heated by convection from the absorber plate, and the air currents moving in the ducts carry additional heat. The incoming air has a temperature that is assumed to be uniform with the average temperature of the air in the room, but immediately becomes warm when it reaches the absorber plate. The heated air then moves through the ducts and out the top duct to transfer heat flux to the food or water in the pan placed on the floor. This configuration creates a hot air current that circulates within the stove box. Thus, this type of solar cooker can be used for cooking using solar energy (Harmim et al., 2012).

Figure 6. Box-type solar cooker with optogeometric concentrator (Harmim et al., 2012)

Figure 7. Portable solar cooker using Fresnel lens (Zhao et al., 2018)

Research has been conducted to develop panel-type solar cookers and the latest portable solar cookers. The panel-type solar cooker is equipped with a compound parabolic concentrator (CPC) on the edge of the cooker to collect solar radiation. The energy efficiency obtained reached 34% when using a water load of 3.5 kg and a specific boiling time of 22.58 minutes (Goyal & Eswaramoorthy, 2023a). It has been studied previously (Zhao et al., 2018) that a new portable solar cooker with a Fresnel curved lens as a concentrator can facilitate manual tracking of solar radiation at zenith and azimuth angles. In performance testing, the solar cooker was able to achieve the highest average temperature of about 361°C when irradiation was carried out with an intensity of 712 W/m2. The maximum energy efficiency of the system was 22.6% when cooking pork. All types of food cooked with this solar cooker reached the food-grade standard. The results of this study show progress in the development of efficient solar cookers that can be used for cooking with solar energy.

Based on the results of the literature study review in this study, the results of the average percent efficiency value (η%) on solar cookers for each type are shown in Figure 8 Review of Percent Efficiency Value (η%) Based on Solar Cooker Type below.

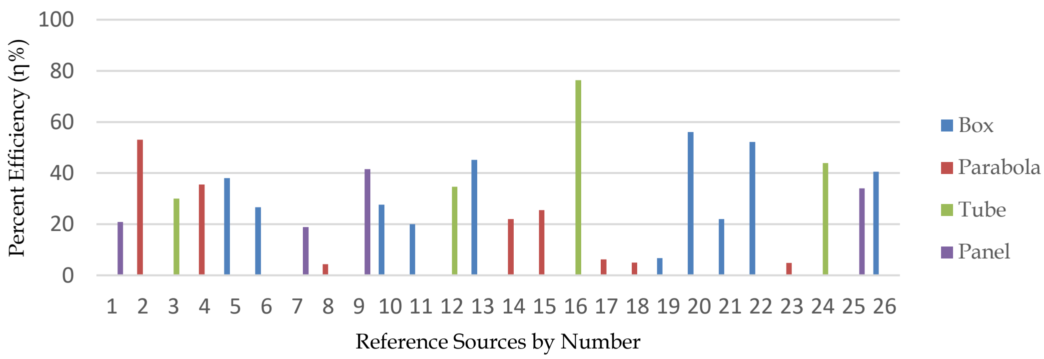

Figure 8. Review Of Percent Efficiency (η%) Based on Solar Cooker Type

Based on Figure 8, it can be seen that the parabolic type solar cooker has the lowest average percent efficiency (η%) value compared to other types of solar cookers, which is 18.492%, and the highest average percent efficiency value is obtained in the tube type cooker, which is 46.097%. This can occur because the parabolic geometry design that has been designed is still not fully what is planned or expected. One study (Mardwianta et al., 2023) explained that the parabolic-type solar cooker design that had been made was thought to have weaknesses during the reflector manufacturing process, the reflector made of mirror pieces was difficult to arrange neatly in a parabola which could result in a split focal point. In addition, during the data collection process, this parabolic-type solar cooker requires a tight pan cover because if it is not tight enough, heat loss can occur.

The geometry design of the tube-type solar cooker positively affects the efficiency of the solar cooker due to the high absolute pressure of the vacuum shell. This can increase the efficiency of heat derived from solar radiation, making this type of solar cooker more efficient compared to other types of solar cookers (Sher et al., 2020). However, there are several other factors that also affect the performance of solar cookers, such as the intensity of solar radiation, the type of absorber or heat storage used, the use of reflectors with the right zenith and azimuth angles, the use of tight vacuum tubes, and the length of cooking time. Further research is needed to identify these factors and determine how they affect the resulting thermal energy efficiency of the design that has been established to achieve optimal thermal efficiency.

Conclusions

In this study, the quantitative criterion of solar cooker performance, namely percent efficiency (η%) in the last decade of 2012 to 2023, was reviewed. This study emphasized whether there is an effect of the geometry of the shape of the solar cooker on the heat efficiency generated through article analysis. The findings of the reviewed literature for solar cooker performance i.e. percent heat efficiency (η%) are as follows:

- There are more studies related to box-type solar cookers than parabolic, tube, or panel types, indicating that box-type solar cookers are more in demand and more economical in the manufacturing process.
- Most of the research presented on solar cookers is experimental and limited to numerical research. Meanwhile, modeling can reduce experimental costs and guarantee an optimized design.
- The results of the calculation of average heat efficiency (η%) from 26 literature/reference sources that have been described, obtained the highest average efficiency value in tube-type solar cookers and the lowest in parabolic-type solar cookers.
- Based on the results of the presentation related to optimizing the performance of solar cookers, in this case, knowing the heat efficiency (η%) of each type of solar cooker, it is known that the design/geometry of solar cookers is not the only parameter/factor that affects the performance of solar cookers.
- Other parameters/factors affect the percent value of the heat efficiency of solar cookers, including the intensity of solar radiation, the type of absorber/absorber heat storage, the use of reflectors with the right position (zenith and azimuth angles), the use of a tight cover pan (vacuum tube) for certain types of solar cookers and the length of time in the cooking process.

Further research needs to be carried out related to other factors that affect the performance of solar cookers such as solar radiation intensity or absorber coating materials on solar cookers to be able to produce more optimal performance. This template is designed to assist you in preparing your manuscript; it is an exact representation of the format expected by the editor. To use this template, please just *Save As* to your document, then copy and paste your document here. The work should not have been published or submitted for publication else-where.

Acknowledgments

You may wish to thank those who have supported you and your work. Personal acknowledgements will be limited to appropriate professionals who contributed to the paper, including technical assistance and/or financial material support.

References

Abdul Haris Subarjo, A. H. S., Benedictus, M., & Anugrah Budi, W. (2019). *Efisiensi Kompor Surya Parabola Berreflektor Cermin Untuk Menunjang Ketahanan Energi*.

Al Latifa, R., Sari, K. E., & Meidiana, C. (2022). Faktor Rumah Tangga yang Mempengaruhi Emisi CO2 di Kelurahan Jodipan, Kota Malang. *Planning for Urban Region and Environment Journal (PURE)*, *11*(3), 89–100.

Aliyu, H., Talib, C. A., Aliyu, F., & Mani, B. U. (2021). Inclusion of Sustainable Progress STEM in Education For Renewable Energy Into Nigeria's Secondary School Curriculum. *3rd International Conference on Food, Agriculture and Veterinary*, 1–19.

Amri, A. A., Nuruddin, M., & Rachmanita, R. E. (2020). Uji Performa Kompor Surya Tipe Parabola Silinder Menggunakan Reflektor Cermin dengan Variasi Bahan Absorber. *Jurnal Energi Dan Manufaktur*, *13*(1), 8–14.

Aragaw, Y. T., & Adem, K. D. (2022). Development and performance evaluation of tube-type direct solar oven for baking bread. *Heliyon*, *8*(11).

Aramesh, M., Ghalebani, M., Kasaeian, A., Zamani, H., Lorenzini, G., Mahian, O., & Wongwises, S. (2019). A review of recent advances in solar cooking technology. *Renewable Energy*, *140*, 419–435.

Cuce, E. (2018). Improving thermal power of a cylindrical solar cooker via novel micro/nano porous absorbers: A thermodynamic analysis with experimental validation. *Solar Energy*, *176*, 211–219.

Cuce, P. M. (2018). Box type solar cookers with sensible thermal energy storage medium: A comparative experimental investigation and thermodynamic analysis. *Solar Energy*, *166*, 432–440.

Dwicaksono, M. B., & Rangkuti, C. (2018). Perancangan, pembuatan, dan pengujian kompor energi matahari portabel tipe parabola kipas. *PROSIDING SEMINAR NASIONAL CENDEKIAWAN*, 41–48.

Goswami, A., Basu, S., & Sadhu, P. K. (2019). Improvement of energy efficiency and effectiveness of cooking for parabolic-type solar cooker used with activated-carbon-coated aluminium cooking pot. *Global Challenges*, *3*(12), 1900047.

Goyal, R. K., & Eswaramoorthy, M. (2023a). Modeling and analysis of compound parabolic concentrator integrated box type solar cooker. *Materials Today: Proceedings*, *72*, 1047–1055.

Goyal, R. K., & Eswaramoorthy, M. (2023b). Thermal performance enhancement on a box-type solar cooker using a triangular fin over a conventional cooking pot. *Solar Energy*, *258*, 339–350.

Gunawan, S., Napitupulu, F. H., & Ambarita, H. (2018). Kajian Performansi Kompor Surya dengan Erythrytol Sebagai Pcm untuk Memasak Langsung dan Tidak Langsung. *Talenta Conference Series: Energy and Engineering (EE)*, *1*(1), 67–74.

Harmim, A., Merzouk, M., Boukar, M., & Amar, M. (2012). Performance study of a box-type solar cooker employing an asymmetric compound parabolic concentrator. *Energy*, *47*(1), 471–480.

Hosseinzadeh, M., Faezian, A., Mirzababaee, S. M., & Zamani, H. (2020). Parametric analysis and optimization of a portable evacuated tube solar cooker. *Energy*, *194*, 116816.

Joshi, S. B., & Jani, A. R. (2015). Design, development and testing of a small scale hybrid solar cooker. *Solar Energy*, *122*, 148–155.

Kumar, A., Saxena, A., Pandey, S. D., & Joshi, S. K. (2022). Design and performance characteristics of a solar box cooker with phase change material: A feasibility study for Uttarakhand region, India. *Applied Thermal Engineering*, *208*, 118196.

Mardwianta, B., Subarjo, A. H., & Cahyadi, R. D. (2023). Studi Ekperimental Penambahan Reflektor Datar Pada Kompor Tenaga Surya Tipe Parabolic. *JURNAL SURYA ENERGY*, *6*(1), 31–40.

Marziqon, T., & Purwoko, B. (2017). Studi Kepustakaan Mengenai Landasan Teori Dan Praktik Konseling Expressive Writing. *Jurnalmahasiswa. Unesa. Ac. Id*.

Muin, A. (2017). Kajian Kinerja Kompor Surya Dengan Variasi Susunan Absober. *Machine: Jurnal Teknik Mesin*, *3*(1), 15–20.

Napitupulu, R. A. M., Manurung, C. S. P., Naibaho, W., & Sihombing, S. (2022). Pengaruh Material Reflektor Terhadap Kinerja Kompor Energi Surya. *SPROCKET JOURNAL OF MECHANICAL ENGINEERING*, *3*(2), 94–105.

Nugrahayu, Q., Nurjannah, N. K., & Hakim, L. (2017). Estimasi emisi karbondioksida dari sektor permukiman di kota Yogyakarta menggunakan IPCC guidelines. *Jurnal Sains \& Teknologi Lingkungan*, *9*(1), 25–36.

PURBA, J. S. (2020). Unjuk kerja solarcooker type parabolic dengan diameter 100 cm tinggi 50 cm. *Jurnal Ilmiah MAKSITEK*, *5*(2), 139–150.

Rachmanita, R. E., Suryanto, G. D., & Siswanto, M. (2020). Pengaruh Sudut Kemiringan Ruang Masak dan Penggunaan Lensa Fresnel terhadap Performa Kompor Surya Tipe Kotak. *JTT J. Teknol. Terpadu*, *8*(1), 1–12.

Regattieri, A., Piana, F., Bortolini, M., Gamberi, M., & Ferrari, E. (2016). Innovative portable solar cooker using the packaging waste of humanitarian supplies. *Renewable and Sustainable Energy Reviews*, *57*, 319–326.

Sari, M., & Asmendri, A. (2020). Penelitian kepustakaan (library research) dalam penelitian pendidikan IPA. *Natural Science*, *6*(1), 41–53.

Sawarn, H., Shukla, S. K., & Rathore, P. K. S. (2021). Development in solar cooking technology in the last decade: a comprehensive review. *IOP Conference Series: Materials Science and Engineering*, *1116*(1), 12046.

Saxena, A., & Agarwal, N. (2018). Performance characteristics of a new hybrid solar cooker with air duct. *Solar Energy*, *159*, 628–637.

Senthil, R. (2021). Enhancement of productivity of parabolic dish solar cooker using integrated phase change material. *Materials Today: Proceedings*, *34*, 386–388.

Sher, A., Mazhar, S., Azadi, H., & Lin, G. (2020). Smallholder commercialization and urban-rural linkages: effect of interest-free agriculture credit on market participation of rice growers in Pakistan. *Land*, *10*(1), 7.

Skouri, S., Bouadila, S., Salah, M. Ben, & Nasrallah, S. Ben. (2013). Comparative study of different means of concentrated solar flux measurement of solar parabolic dish. *Energy Conversion and Management*, *76*, 1043–1052.

Vengadesan, E., & Senthil, R. (2021). Experimental investigation of the thermal performance of a box type solar cooker using a finned cooking vessel. *Renewable Energy*, *171*, 431–446.

Wijayanti, F. (2010). *Uji kinerja kompor surya dengan variasi bentuk geometri dan luas kolektor*. Universitas Gadjah Mada.

Zafar, H. A., Khan, M. Y., Badar, A. W., Tariq, R., & Butt, F. S. (2018). Introducing a novel design in the realm of box type solar cookers: An experimental study. *Journal of Renewable and Sustainable Energy*, *10*(4).

Zamani, H., Moghiman, M., & Kianifar, A. (2015). Optimization of the parabolic mirror position in a solar cooker using the response surface method (RSM). *Renewable Energy*, *81*, 753–759.

Zhao, Y., Zheng, H., Sun, B., Li, C., & Wu, Y. (2018). Development and performance studies of a novel portable solar cooker using a curved Fresnel lens concentrator. *Solar Energy*, *174*, 263–272.