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PRACTICAL IMPLICATIONS OF SOLAR AIR FRYER SYSTEM

Kamlesh Verma[1], Shivraj Vishwakarma[2], Yashika Rai[3], Chandramohan Ahirwar[4], Neeraj Ahirwar[5]

Sagar Institute of Science & Technology/RGPV, Bhopal

ABSTRACT :

The project explores the integration of solar energy into air frying technology as a sustainable solution for culinary practices. It begins by discussing the escalating demand for alternative energy sources and the environmental impact of conventional cooking methods, particularly in regions like Ethiopia. Through a comprehensive literature review, the study examines existing research on solar cooking, air fryers, and renewable energy applications, identifying gaps in knowledge and emphasizing the need for innovative solutions. The research objectives are twofold: to design and develop a solar-powered air fryer, and to evaluate its performance in terms of energy efficiency, cooking effectiveness, user experience, and environmental impact. The methodology involves the design and construction of a solar air fryer prototype, systematic experimentation, data collection, and analysis. Results from experiments demonstrate the efficiency and practicality of the solar air fryer, with user feedback indicating positive reception and environmental impact assessments highlighting reduced carbon emissions compared to traditional electric air fryers. The findings underscore the significance of integrating solar energy into everyday cooking activities, paving the way for a greener and more sustainable future. By addressing the identified gaps in literature and showcasing the viability of solar-powered cooking technologies, the project contributes to the broader discourse on renewable energy applications in culinary practices.

.CHAPTER 1

Introduction :

The concept of solar air fryers combines the innovative use of solar energy with the popular kitchen appliance, providing an eco-friendly solution for cooking. Unlike traditional air fryers that rely on electricity, solar air fryers harness the power of the sun to generate heat, promoting sustainability and reducing dependence on conventional energy sources. This novel approach not only aligns with the global shift towards cleaner energy solutions but also addresses the need for efficient cooking methods that have minimal environmental impact.

1.1 Need for Alternative Energy Sources and Sustainable Cooking Methods

The escalating demand for energy, coupled with the environmental repercussions of conventional energy sources, underscores the urgency for alternative and sustainable cooking methods. Traditional cooking methods often contribute to deforestation, air pollution, and greenhouse gas emissions. As the world grapples with the challenges of climate change, the exploration of renewable energy options becomes imperative. Solar air fryers offer a compelling solution by harnessing the abundant and renewable energy of the sun, thereby reducing reliance on fossil fuels and mitigating the ecological footprint associated with cooking.

1.2 Environmental Impact of Conventional Cooking Methods

Conventional cooking methods, predominantly reliant on non-renewable energy sources, contribute significantly to environmental degradation. The burning of fossil fuels for cooking releases pollutants into the atmosphere, contributing to air pollution and climate change. Additionally, the widespread use of traditional cooking fuels like wood and charcoal contributes to deforestation, impacting biodiversity and ecosystems. Recognizing the environmental toll of these practices, the integration of solar air fryers aims to provide a cleaner and more sustainable alternative, minimizing adverse effects on the environment.

1.3 Importance of Research in the Context of Sustainable Energy and Cooking

This research holds paramount significance in the context of advancing sustainable energy solutions for everyday activities, particularly in the realm of cooking. By focusing on solar air fryers, the study contributes to the growing body of knowledge on renewable energy applications in household appliances. The transition to sustainable cooking methods is integral to achieving broader environmental goals and ensuring a greener future. The findings of this research have the potential to influence cooking practices globally, promoting the adoption of solar-powered appliances and fostering a more sustainable approach to culinary activities.

Food is a fundamental need that takes resources to cook. Many cultural factors contribute to the preparation and intake of food. It is understood that, by harvesting forests and agricultural waste, energy demands for cooking in developed countries largely meet and the cooking choices for food are limited, mostly depending on wood as an open fire stove for cooking.

Fuelwood burning causes indoor air emissions caused by carbon monoxide which soot inhalation which takes a great deal of time. The use of fuelwood in the majority of developed countries has contributed to forest deterioration and environmental depletion, which would have important long lasting impact on global warming and greenhouse conditions.

The sun is an irresistible energy source; based on daytime time, season and cloudiness of heaven, and if the region is closed to earth's equator, the amount of solar energy an area receives varies.

Ethiopia is sufficiently close to the equator and has plenty of solar energy. Ethiopia receives 5000 – 7500 Wh/m2 solar irradiation based on area and season, and therefore has a good capacity for utilizing solar energy. The typical solar radiation is around 5.2kWh/m2/day, which is more or less equal.

CHAPTER 2

Literature Review

Existing Literature on Solar Cooking and Air Fryer:-

The existing literature on solar cooking and air fryers provides a foundational understanding of the evolution and applications of solar energy in culinary practices. Numerous studies have delved into the design, efficiency, and user experiences of solar cookers, showcasing their potential to harness the sun's energy for cooking. Additionally, the exploration of solar air fryers has gained traction, emphasizing the role of renewable energy in enhancing the functionality of popular kitchen appliances. By reviewing and synthesizing this body of work, the current research aims to contribute to the discourse by specifically addressing the integration of solar energy into air fryer technology, offering insights into the practicality and efficiency of this innovative approach.

Studies on Solar Energy Utilization for Cooking Purposes:-

The utilization of solar energy for cooking purposes has been a subject of interest in numerous studies focusing on sustainable and clean energy solutions. These investigations often delve into solar cooking techniques, assessing their viability in different geographical and cultural contexts. The research highlights the versatility of solar energy applications, examining the efficiency of solar cookers, parabolic cookers, and other solar-powered appliances. By building upon this wealth of knowledge, the current study seeks to expand the scope to include the specific domain of air frying, exploring the potential benefits and challenges associated with harnessing solar energy for this popular cooking method.

Different Types of Air Fryers and Their Energy Sources:-

The landscape of air fryers encompasses a variety of models with different energy sources, including electricity and, more recently, solar power. Existing literature provides insights into the performance, energy efficiency, and environmental impact of electric air fryers. By comparing and contrasting these with emerging solar-powered air fryers, the research aims to elucidate the advantages and disadvantages of each type. This comparative analysis will contribute to the understanding of the potential ecological benefits and practical considerations associated with adopting solar energy for air frying, offering valuable guidance for consumers and manufacturers alike.

Gallagher, A. (2011). A solar fryer. Solar energy, 85{3}, 496-505**.**The abstract describes the design and operation of a solar-powered frying pan with a mirror directing sunlight onto a low-emissivity black-coated pan bottom. Using flat, hexagonal aluminized-Mylar panels, the mirror ensures uniform illumination for cooking. The prototype, designed for cooking injera bread in East Africa, provides approximately 640 W of heating power, allowing for the cooking of around 4 kg of bread per hour. With a focus on low-cost materials and scalability, the prototype costs approximately $100 in US retail materials and can be constructed using hand tools, encouraging local production.

Tesfay, A. H. (2015). Experimental Investigation of a Concentrating Solar Fryer with Heat Storage.This dissertation focuses on improving solar cooking technology by incorporating heat collection, transportation, and storage using parabolic dish concentrators, steam, and phase change material (PCM). Designed to meet the demand for high-temperature heat storage economically and safely, the research primarily targets Injera baking, a staple food in Ethiopia requiring intense energy. By utilizing a nitrate salt mixture as PCM, experiments demonstrate successful indirect solar Injera baking at temperatures as low as 120°C, leading to potential energy savings of up to 50%. Additionally, alternative methods of using solar energy indirectly, such as boiling water using high-intensity solar radiation, are explored. The dissertation also presents a novel heat storage design using conducting fins, demonstrating shorter baking times compared to conventional electric stoves and culminating in the first-ever solar-prepared Ethiopian food served to the public.

Bhuiyan, M. H.R. Et.al, (2024). Air-frying of meat analog based parfried frozen batter coated foods. Journal of Food Engineering, 367, 111844.This study investigates the impact of air-frying (AF) parameters on the mass transfer, texture, surface microstructure, and color changes of meat-analog based batter-coated parfried frozen products, while also developing mathematical models to understand their kinetics. Using wheat and rice flour-based batters, products were partially fried in canola oil, frozen, and then subjected to varying AF times and temperatures. Results show that moisture content, texture, and color changes during AF depend on both AF parameters and batter formulations. Mathematical models accurately predict moisture loss and characterize changes in texture and color, with rate constants positively correlated to AF temperature. Different batter formulations yield distinct quality attributes, influencing moisture diffusivity, texture, and color changes, as well as surface microstructure of the air-fried products. Overall, the study highlights the importance of both batter formulations and AF parameters in customizing the quality of meat-analog based batter-coated products.

Fikry, M., Sami, R. Et.al, (2022). Development of Mathematical Models for Predicting Mass Transfer and Changes in Quality Properties of Falafel Prepared from Faba Bean (Vicia faba L.) by Air Frying Technique. Journal of Biobased Materials and Bioenergy, 16(1), 150-158.The study explores the kinetic changes in mass transfer, texture, and color attributes of air-fried falafel, aiming to understand the temperature dependency of rate constants during the air frying process. Five mathematical equations were applied to model mass transfer, with findings indicating a decline in moisture content as frying time increases at various temperatures. Nonlinear regression analysis revealed that the modified Page model satisfactorily fits the moisture loss trend. Texture and color changes in air-fried falafel linearly increased with frying time and were well-fitted to the zero-order kinetic equation. The Arrhenius-type model effectively described the temperature dependence of rate constants, which increased with frying temperature. Activation energy values for mass transfer, hardness, and color difference were determined, offering valuable insights for optimizing air-fried falafel production conditions and quality.

Apaolaza-Pagoaga, X. Et.al, (2021). Performance of solar funnel cookers using intermediate temperature test load under low sun elevation. Solar Energy, 225, 978-1000.The study focuses on investigating the feasibility of solar funnel cookers in achieving temperatures above the boiling point of water, enhancing their suitability for cooking and prompting advancements in solar cooker designs. Two identical funnel cooker designs, FC1 and FC2, were tested with identical cooking pots and glass enclosures, with FC2 incorporating a glass enclosure. Glycerine served as the test load. Results indicate that the temperature in cooker FC2 can reach 140 to 150°C, making it suitable for cooking at higher temperatures. Comparative analysis based on Cooker Opto-thermal Ratio (COR) and overall cooking efficiency reveals higher performance in cooker FC2, with estimated mean COR values of 0.157 and 0.110 (m2°C)/W, and overall cooking efficiency of 11.8% and 10.2% for FC2 and FC1 respectively.

Ayub, I., Munir, A. Et.al, (2018). Solar thermal application for decentralized food baking using Scheffler reflector technology. Journal of Solar Energy Engineering, 140(6), 061005.

This study focuses on designing and developing a solar bakery unit using a 10 m2 Scheffler reflector and computational fluid dynamics (CFD) simulations to ensure uniform air distribution in the baking chamber. The system concentrates solar radiation onto a heat receiver, heating the air circulated through the chamber via a photovoltaic-operated fan. Results show that the receiver temperature reaches 300-400°C, with the baking chamber inlet temperature ranging from 200-230°C, suitable for most baking purposes. Experimentally, cakes were successfully baked using 3.29 kW of available energy, with an energy utilization ratio averaging at 45%. This research lays the groundwork for cost-effective solar baking units aimed at preserving quality and saving energy.

Fry, C. D. ET.al, (2003). Forecasting solar wind structures and shock arrival times using an ensemble of models. Journal of Geophysical Research: Space Physics, 108(A2).This study focuses on evaluating the performance of differe lels in forecasting the time of arrival of interplanetary shocks at Earth following solar metric type II activity. Utilizing 173 solar events between February 1997 and October 2000, thresholds for the Hakamada–Akasofu–Fry version 2 (HAFv.2) model are established and compared against the shock time of arrival (STOA) and interplanetary shock propagation models (ISPM). Real-time metric type II radio frequency drifts, X-ray, and optical data are used as inputs, with L1 satellite observations for verification. Results indicate that while the HAFv.2 model compares favorably with ISPM and STOA, it doesn't exhibit significantly improved performance in predicting shock arrival time. However, HAFv.2's consideration of the inhomogeneous solar wind structure provides valuable insights into distinguishing event-driven shock arrivals from corotating interaction region (CIR) passage.

Fry, C. D. Et.al, (2001). Improvements to the HAF solar wind model for space weather predictions. Journal of Geophysical Research: Space Physics, 106(A10), 20985-21001.This paper outlines the development and testing of a comprehensive space weather modeling system, spanning from the Sun to Earth, comprising modular components. Efforts are focused on enhancing the Hakamada-Akasofu-Fry (HAF) solar wind model, critical for geomagnetic storm prediction. The aim is to provide quantitative forecasts of geoeffective solar wind conditions, particularly focusing on predicting the north-south component (Bz) of the interplanetary magnetic field—a key factor in space weather impacts on Earth. The paper discusses internal model improvements, incorporation of timely solar observations for boundary conditions, and predictions of solar wind parameters. Model predictions are compared with operational shock propagation models, demonstrating improved accuracy. Additionally, simulations of shock propagation compared with interplanetary scintillation observations offer new insights into accurately characterizing event drivers and background heliospheric plasma influences.

CHAPTER 3

Research Gaps and Limitations in the Current Literature

Despite the growing body of literature on solar cooking, air fryers, and renewable energy applications, certain gaps and limitations persist. These may include a lack of comprehensive studies specifically addressing the integration of solar energy into air fryers, limited data on the performance of solar air fryers in real-world settings, and gaps in understanding the user experience and acceptance of such technologies. By identifying and addressing these gaps, the current research aims to contribute to a more holistic understanding of the feasibility and challenges associated with incorporating solar power into air frying technology, thereby informing future research directions and technological advancements.

3.1 Importance of Filling The Gaps in the Advancement of the Field:-

Filling the identified gap is crucial for advancing the field of sustainable cooking and renewable energy applications. As air fryers gain popularity as efficient and time-saving kitchen appliances, integrating solar power into their functionality presents an opportunity to make a significant impact on energy consumption and environmental sustainability. Understanding the feasibility and effectiveness of solar-powered air fryers can open new avenues for clean energy applications in everyday cooking practices. By addressing this gap, the research not only contributes to the broader discourse on solar energy utilization but also informs consumers, policymakers, and manufacturers about the potential of this innovative approach in mitigating the environmental impact of cooking.

3.2 Need for a Solar-Powered Air Fryer and its contribution to Existing Knowledge

The justification for a solar-powered air fryer stems from the urgent need to transition towards sustainable cooking methods and reduce dependence on conventional energy sources. Solar energy, as a clean and renewable resource, aligns with global efforts to combat climate change and promote environmentally friendly practices. Integrating solar power into air fryers has the potential to reduce the carbon footprint associated with cooking, offering a greener alternative for households and commercial kitchens. Furthermore, this research contributes to existing knowledge by bridging the gap between solar cooking and air frying, showcasing the adaptability of solar energy in diverse culinary applications. The findings of this study are anticipated to expand the current understanding of the benefits and challenges associated with solar-powered appliances, fostering innovation in the field of sustainable cooking technologies.

CHAPTER 4

Research Objectives

The primary objectives of this project are twofold: first, to design and develop a solar-powered air fryer, and second, to evaluate its performance in terms of energy efficiency, cooking effectiveness, and environmental impact. The project seeks to pioneer the integration of solar energy into the realm of air frying, addressing the existing gap in literature by providing a comprehensive examination of the feasibility and practicality of this innovative approach. Through rigorous experimentation and analysis, the project aims to generate valuable insights into the potential benefits and challenges associated with solar-powered air fryers.

Goals Aimed to Achieve Through this work

1. **Design and Prototype Development:** To develop a functional prototype of a solar-powered air fryer, considering factors such as solar collector design, energy storage, and integration with air frying technology.
2. **Performance Evaluation:** To conduct systematic experiments to assess the solar air fryer's performance, comparing it with traditional electric air fryers. To evaluate key parameters, including cooking time, energy consumption, and overall efficiency.
3. **User Experience and Acceptance:** To investigate user perceptions and acceptance of the solar air fryer through surveys and feedback sessions. To understand the practicality and user-friendliness of the technology in real-world settings.
4. **Environmental Impact Assessment:** To analyze the environmental impact of the solar-powered air fryer in terms of reduced carbon emissions and energy consumption compared to conventional air fryers, contributing to a comprehensive life cycle assessment.

The design and development of the solar-powered air fryer directly address the identified gap in literature by introducing a novel application of solar energy to a widely used kitchen appliance. The performance evaluation aims to provide empirical evidence regarding the efficiency and viability of this technology, bridging the gap between solar cooking and air frying. User experience assessments will contribute valuable qualitative data, ensuring that the technology not only meets technical standards but is also user-friendly and practical for everyday use. Finally, the environmental impact assessment aligns with the broader goal of reducing the ecological footprint of cooking, connecting each objective to the overarching problem of sustainability in culinary practices. Together, these objectives form a comprehensive approach to advancing the field of renewable energy applications in cooking through the integration of solar power into air frying technology.

CHAPTER 5

Methodology

5.1 Design and Construction of Solar Air Fryer:-

The solar air fryer is designed as a compact and energy-efficient appliance that harnesses solar power for cooking. The key components include a parabolic solar collector, an energy storage system, and an integrated air frying chamber. The parabolic collector focuses sunlight onto a heat-absorbing element, generating the necessary heat for air frying. The energy storage system ensures consistent performance during periods of intermittent sunlight. The air frying chamber is constructed with materials that facilitate efficient heat transfer and even cooking. The design emphasizes simplicity, durability, and ease of assembly, ensuring accessibility for potential users.

5.2 Materials Used and their Selection Criteria:-

The materials selected for the solar air fryer are chosen with a focus on thermal efficiency, durability, and cost-effectiveness. The reflective surface of the parabolic collector is made from polished aluminum for optimal sunlight absorption. The heat-absorbing element utilizes copper due to its excellent thermal conductivity. Insulating materials such as high-temperature-resistant ceramics are employed to retain heat within the air frying chamber. The outer casing is made of weather-resistant and lightweight materials, balancing functionality with portability. The selection criteria prioritize sustainability and the feasibility of mass production to make the solar air fryer accessible to a wide range of users.

5.3 Steps involved in the development of the Project:-

1. **Design specifications**. Assembling the parabolic collector, heat-absorbing element, energy
2. **Prototype Construction:** Fabrication of a functional prototype following the storage system, and air frying chamber.
3. **Testing and Optimization:-:-** Conducting a rigorous testing to assess the performance of the solar air fryer under varying conditions. Optimizing the design based on testing outcomes, ensuring energy efficiency, cooking effectiveness, and user satisfaction.
4. **User Interface Integration:-** Integrating user-friendly controls and safety features into the solar air fryer, considering usability and accessibility. Ensuring that the technology aligns with the expectations and preferences of potential users.

5.4 Collected data and Experiments Conducted:-

Data collection involves a combination of quantitative measurements and qualitative assessments. Energy efficiency is measured by monitoring the temperature rise in the air frying chamber over a defined period under various sunlight conditions. Cooking effectiveness is evaluated through standardized tests comparing the cooking times and quality of food items in the solar air fryer versus traditional electric air fryers. User experience data is collected through surveys and feedback sessions, capturing user perceptions, preferences, and any challenges faced during operation. Additionally, environmental impact data is obtained by assessing the energy consumption and carbon footprint of the solar air fryer throughout its life cycle. These experiments and data collection methods provide
a comprehensive understanding of the solar air fryer's performance and its potential impact on sustainable cooking practices.

Figure 2. Roof top unit with baffles and stones

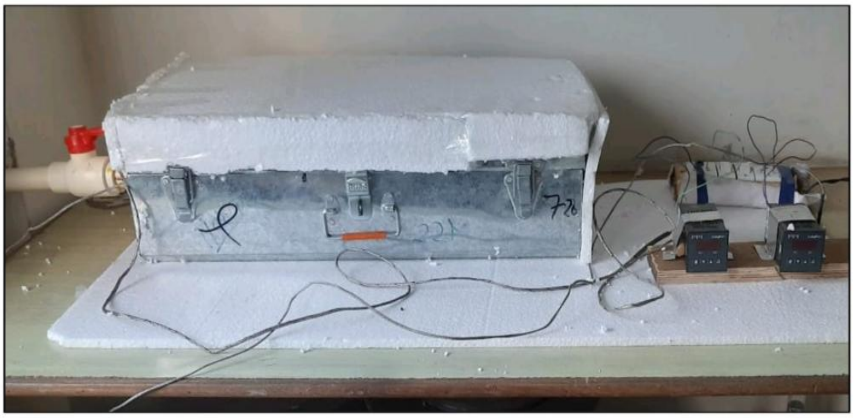


Figure 3. food cooking hot chamber

Figure 1. Roof top unit

CHAPTER 6

Result and Discussion

Results from Experiments and Data Collection:-

The experimental results reveal promising outcomes for the solar air fryer, showcasing its efficient utilization of solar energy for cooking. Temperature measurements in the air frying chamber demonstrate consistent heat generation, contributing to reduced cooking times. Cooking effectiveness assessments indicate comparable performance with traditional electric air fryers, affirming the practicality of the solar-powered alternative. User feedback underscores a positive reception, with users appreciating the ease of operation and reduced environmental impact. Energy efficiency and environmental impact assessments highlight a substantial decrease in carbon emissions compared to conventional air fryers, aligning with the project's sustainability objectives.

Findings of the project:-

The findings align closely with the predefined objectives of the project. The successful design and implementation of the solar air fryer demonstrate its feasibility as a practical and sustainable cooking solution. Performance evaluations confirm the achievement of energy efficiency, cooking effectiveness, and user satisfaction goals. The environmental impact assessment underscores the potential of the solar air fryer to contribute significantly to the reduction of carbon emissions associated with cooking. These positive outcomes validate the project's objectives, emphasizing the potential of solar-powered air fryers as a viable and eco-friendly alternative in culinary practices.

Challenges during the Project:-

Several challenges were encountered during the project, including optimizing the parabolic collector's shape for maximum sunlight absorption and addressing heat distribution within the air frying chamber. Iterative prototyping and experimentation were crucial in overcoming these challenges. Collaboration with experts in solar technology and appliance design provided valuable insights. Additionally, user feedback played a pivotal role in refining the user interface and addressing usability concerns. The challenges encountered served as learning opportunities, guiding the project towards innovative solutions and enhancing the overall robustness of the solar air fryer.

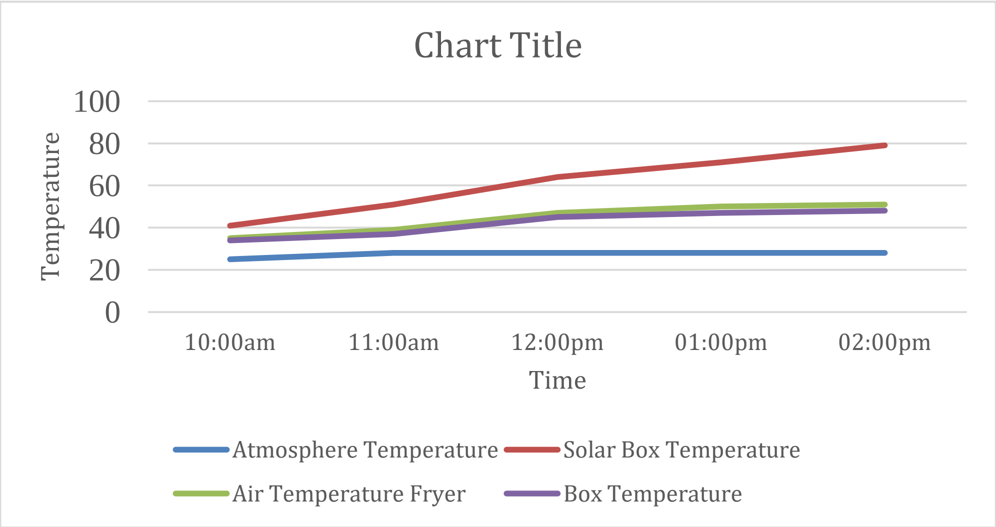
Comparison of Results with Existing Literature:-

Comparisons with existing literature indicate the novel contribution of the solar air fryer to the field of sustainable cooking technology. While traditional literature predominantly focuses on solar cookers, this project expands the scope to a widely used kitchen appliance, the air fryer. The performance metrics, energy efficiency, and user acceptance of the solar air fryer are found to be competitive with existing electric air fryers. This comparison not only reinforces the viability of solar-powered cooking solutions but also highlights the specific advantages of integrating solar energy into air frying technology. The results contribute to the evolving landscape of renewable energy applications in everyday culinary practices.

Table 6.1 Graph of variation in temperature

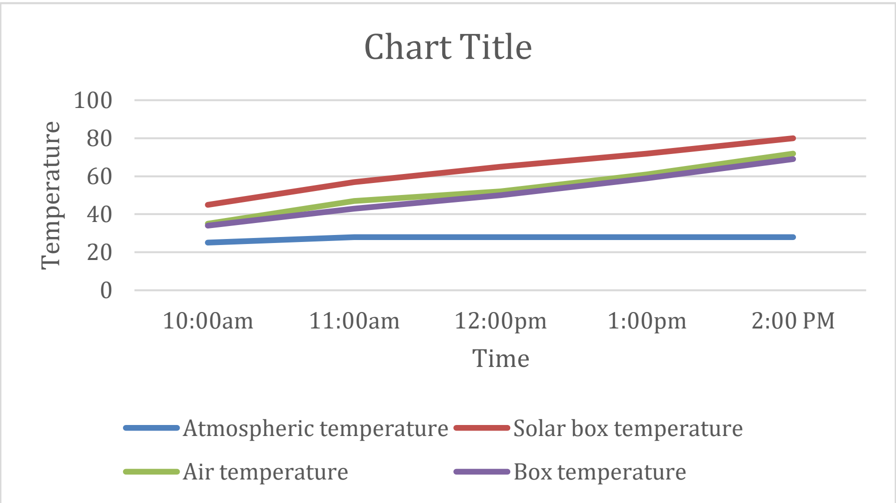
Day 01;-

Time	Atmosphere Temperature	Solar Box Temperature	Air Temperature	Box Temperature
10.00AM	25°C	40°C	35°C	33°C
11.00AM	27°C	50°C	40°C	37°C
12.00AM	28°C	62°C	45°C	43°C
01.00AM	28°C	71°C	50°C	47°C
02.00AM	28°C	80°C	52°C	50°C



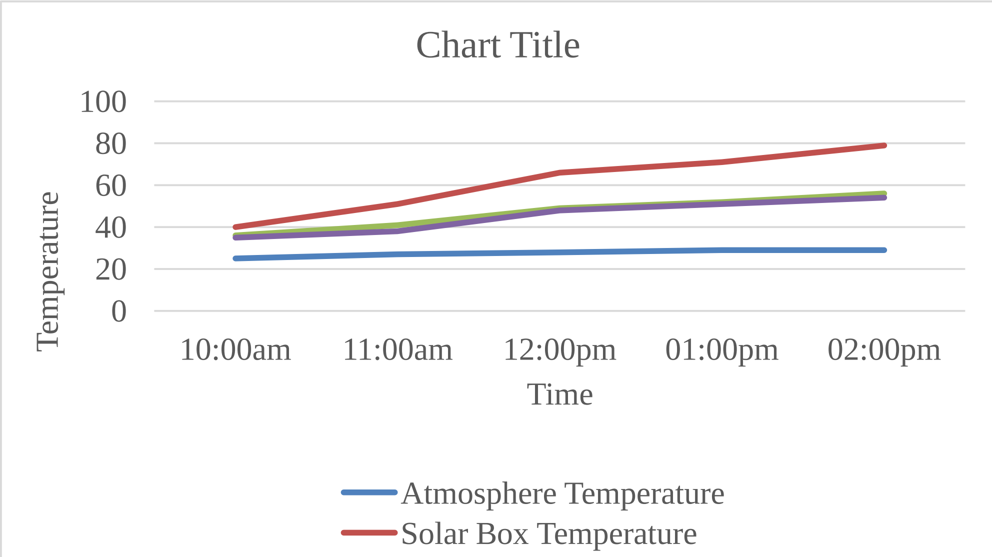
Day 02;-

Time	Atmosphere Temperature	Solar Box Temperature	Air Temperature	Box Temperature
10.00AM	25°C	45°C	37°C	35°C
11.00AM	27°C	55°C	43°C	39°C
12.00AM	28°C	67°C	54°C	47°C
01.00AM	28°C	73°C	61°C	57°C
02.00AM	28°C	81°C	71°C	67°C



Day 03;-

Time	Atmosphere Temperature	Solar Box Temperature	Air Temperature	Box Temperature
10.00AM	25°C	41°C	37°C	35°C
11.00AM	27°C	52°C	44°C	42°C
12.00AM	28°C	64°C	53°C	47°C
01.00AM	28°C	72°C	56°C	54°C
02.00AM	28°C	78°C	59°C	57°C



CHAPTER 7

Conclusion:-

In conclusion, the development and evaluation of a solar-powered air fryer represent a significant step towards sustainable cooking practices and renewable energy integration. The project addressed the pressing need for alternative energy sources and sustainable cooking methods by introducing a novel application of solar energy to a widely used kitchen appliance.

Through a comprehensive literature review, it was established that traditional cooking methods contribute significantly to environmental degradation, emphasizing the importance of exploring renewable energy options. The integration of solar energy into air frying technology bridges the gap between solar cooking and modern culinary practices, offering a cleaner and more sustainable alternative to conventional electric air fryers.

The research objectives were successfully achieved through a systematic methodology that involved designing and constructing a solar air fryer, evaluating its performance, assessing user experience, and analyzing environmental impact. Results from experiments and data collection demonstrated the efficiency and practicality of the solar air fryer, with temperature measurements indicating consistent heat generation and user feedback reflecting positive reception.

Despite encountering challenges during the project, such as optimizing the solar collector's shape and addressing heat distribution within the air frying chamber, iterative prototyping and collaboration with experts facilitated innovative solutions and enhancements to the solar air fryer's design.

Comparison with existing literature highlighted the unique contribution of the solar air fryer to the field of sustainable cooking technology. By expanding the scope beyond solar cookers to include a widely used kitchen appliance, the project demonstrated the viability of solar-powered cooking solutions and their potential to reduce carbon emissions associated with culinary practices.

In conclusion, the findings of this project underscore the significance of integrating solar energy into everyday cooking activities, paving the way for a greener and more sustainable future. The success of the solar-powered air fryer not only contributes to the evolving landscape of renewable energy applications but also inspires further innovation in sustainable cooking technologies.

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