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Food cooking systems based on induction technologies: A systematic mapping study

Andrés Felipe Solis Pino[1], William Cujar-Escobar[2], David Armando Revelo Luna[3] Julio Eduardo Mejía[4], Yesid Ediver Anacona Mopan[5*]

[1,2,3]*Corporación Universitaria Comfacauca-Unicomfacauca Popayán, Colombia.*
[4]*Universidad Nacional Abierta y a Distancia - UNAD Popayán, Colombia.*
[5]*Corporación Universitaria Comfacauca-Unicomfacauca Popayán, Colombia.*

Corresponding author: Yesid Ediver Anacona Mopan (*Email: asolis@unicomfacauca.edu.co*)

Abstract

Induction cooking technology offers enhanced energy efficiency and environmental benefits over traditional methods. However, its widespread adoption faces challenges such as power requirements, material selection, and integration with renewable energy sources. This systematic mapping study analyzes the current state of induction cooking technology, identifies key challenges and trends, and provides insights for future research and development. It conducted a systematic mapping study in five major databases to retrieve relevant studies published between 2013 and 2024. After applying inclusion and exclusion criteria, 58 primary sources focused on induction cooking systems, renewable energy integration, and related technologies were analyzed. Results show a positive trend in scientific publications related to induction cooking, with the half-bridge inverter and full-bridge topology being the most employed. Significant challenges include power requirements during prolonged use, topology, material selection, and integration of renewable energy sources. Emerging trends include the application of deep learning techniques, flexible induction stoves, and the use of gallium nitride technology. The review also highlights the need for standardized validation methodologies and material optimization for improved efficiency and user safety. This literature mapping provides a comprehensive overview of the current landscape of induction cooking technology and is a valuable resource for researchers, engineers, and policymakers.

Keywords: Electromagnetic induction heating, Food cooking devices, Induction cooking, Renewable energy, Systematic Mapping Study.

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1. Introduction

Humans have basic physiological needs for survival, and one of them is food. Food provides energy and is essential for growth and development [1]. The emergence of fire allowed people to change their eating habits, which enabled them to use nutrients better and move from eating raw and tasteless products to consuming cooked foods [2, 3]. This improved the taste and digestibility of food and allowed the preparation of healthier foods, eliminating harmful elements such as bacteria like Escherichia Coli, Campylobacter, Salmonella, and Shigella [4]. Cooking food is an everyday activity in domestic and social settings [5]**.** For this reason, various devices are used to carry out this activity, such as electric, biomass, wood, propane, methane, green hydrogen, blue hydrogen, alcohol, oil, kerosene, and induction stoves, among others [6]. These devices are essential in today's society and play an important role in reducing diseases affecting human beings.

The most commonly used cooking devices worldwide operate with wood, electric energy, or gases, such as propane and methane [7]. The stoves used are associated with the area where they are used. In rural areas, most of the population uses wood or charcoal stoves because of their low cost and the type of energy they use [8].

Currently, the means used for cooking food in rural areas are rudimentary and can contribute to health problems because the smoke produced by burning elements harms people [9]. When inhaled, it can generate pathologies such as chronic obstructive pulmonary disease (COPD), emphysema, or bronchitis, besides increasing the probability of pneumonia and even lung cancer [10, 11]**.** Other alternatives are electric stoves that use heating elements to increase the temperature of pots and pans [12]. However, these devices could be more efficient in terms of energy [13] which is inconsistent with the economic condition of the inhabitants of rural areas. To address this problem-specific solutions, such as propane gas stoves, have been created to address this issue; however, the high increase of Liquefied Petroleum Gas (LPG) in recent years makes it difficult for the community to acquire this energy source [14] besides other factors such dependence on imported gas and the non-renewable value of the hydrocarbon [15]. Therefore, it is necessary to use clean and unlimited sources for cooking that are environmentally and socially friendly.

The importance of exploring alternative combustion and energy sources for food preparation is evident, as this would help to reduce health problems caused by burning combustion sources (wood and charcoal) and help to avoid excessive energy consumption. A currently accepted solution is electromagnetic induction heating [16] which comprises transferring heat to a ferromagnetic material, which, when in contact with the magnetic field lines, will cause the container to heat quickly and uniformly, avoiding thermal energy losses, unlike conventional stoves [17].

The following research aims to collect, extract, and synthesize the empirical evidence of food cooking devices using induction technologies as the primary heating method through a Systematic Mapping Study (SLM). This will allow for establishing and clarifying the main aspects, detailing the current status, advances, challenges, and relevant technologies in the domain.

This systematic mapping focuses on the general domain of the induction principle applied to domestic cooking systems, in contrast to other studies focusing on specific elements, such as converters and inverters, and their performance. This is the case of Vishnuram, et al. [18] which reviews the topologies used by induction cooking systems and the modeling of inverters and converters. From the above, these studies obviate general elements, such as the main applications, challenges, or problems in the area, which are fundamental to establishing new research perspectives in the domain.

The article is divided into eight stages: SLM planning, data extraction strategy, execution stage, results, and analysis of results. Finally, the conclusions drawn from the research are presented.

2. Systematic Mapping Study Planning

Systematic mapping study is a widely accepted method for collecting and extracting information from various databases and scientific repositories on a specific topic or area, enabling researchers and readers to trace precise routes of inquiry through an organized, systematic, and reproducible process [19]. In addition, it helps to delimit the scope of the study through critical questions, reducing the risk of error and facilitating the attainment of accurate conclusions [20]. The current systematic mapping follows guidelines proposed by Petersen et al. in Petersen, et al. [21] and includes elements described by Solis and Hurtado [22] and Kitchenham, et al. [23]. The study has been divided into five stages, as depicted in Figure 1.

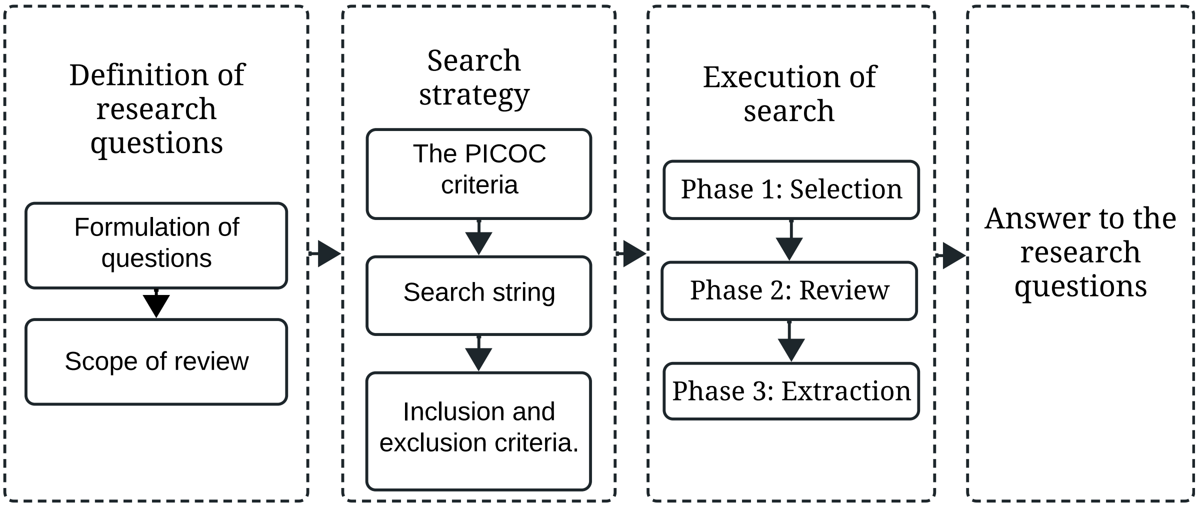

Figure 1.
The methodology used for the systematic mapping study considers Petersen's proposal.

2.1. Definition of the Research Questions

The research questions have been designed to clarify the scope of the study and to determine the context in which new trends in induction stoves are being implemented, how their energy supply is being managed, which technologies are driving their development, and the potential impact of these elements on the reduction of diseases, and their efficiency compared to other alternatives. Table 1 presents the research questions, their motivations, and corresponding answers, which are critical for analyzing and categorizing the information.

Table 1.
Research questions.

Questions	Motivating	Answers
What is the frequency of research publications that perform induction technology developments related to the food cooking process and renewable energies?	To allow an analysis of the frequency of publications in the area of interest to know how cooking systems based on induction technologies and renewable energies are received.	Primary articles are analyzed according to their date of publication in an annual period.
Are validation methodologies for induction cookstoves being applied on an ad-hoc basis or following an already proven standard or methodology?	To know the status of the current validation methodologies to guarantee the efficiency of the different induction systems applied in domestic cooking aimed at clean energies.	• Experimental • Simulation • Combination of both. • Without validation.
What is the current state of research on the use of materials and renewable energy approaches in dual-energy supply induction cookstoves, and what are the key findings related to their efficiency and environmental impact	To study the trend and acceptance of induction stoves with dual-power supply, the use of two types of energy as energy supply.	To be solved in detail when answering the research questions.
What are the main problems, risks, and challenges in induction stoves with a dual power supply?	To know in which context the induction systems with dual power supply, as well as to analyze the alternatives and solutions proposed to achieve a higher and higher degree of efficiency of this novel technology.	• Topologies • Materials • Frequencies • Switching
In what context are the main contributions to mastering alternative food preparation methods with energy-supplied induction cookstove techniques?	To find out in what context food cooking systems based on induction technology and the use of energy supply are being supported in addition to knowing how they contribute to the environment and the lack of knowledge on the subject.	• Academic • Industrial • Both
What is the efficiency of the proposed induction systems, and how do they contribute to the domain?	Analyzing the efficiency achieved from the different proposals of induction systems and knowing the advantages or	To be resolved at the time of answering the research questions in the results and analysis of results

	disadvantages of the proposed induction systems.	section.
What future trends regarding algorithms, materials for induction, and novel energies, among others, are being applied in the domain?	To expose which future trends are being investigated and implemented in the different research that promote the continuous evolution of food cooking systems based on induction technology in the approach of clean energies.	To be resolved at the time of answering the research questions in the results and analysis of results section.
What technologies, approaches, or techniques relate renewable energies to the induction cooking of food?	Identify the main contributions generated concerning renewable energies applied to induction stoves.	To be resolved at the time of answering the research questions in the results and analysis of results section.

2.2. Search Strategy

The PICOC (Population, Intervention, Comparison, Outcomes, and Context) criteria were applied to organize and structure the concepts systematically and methodically to create search chains that covered all relevant aspects[24]. This allowed for constructing a search string (Table 2) that was used to systematically and methodically gather information from IEEE Xplore, Scopus, ACM Digital Library, ScienceDirect, and Web of Science databases, which are suitable and valid for engineering research [25]. It should be noted that the search string included the title, abstract, and keywords for all databases except ScienceDirect, as this website does not allow search strings with over eight Boolean connectors. As a result, the search string had to be narrowed, prioritizing the most important words related to the area of interest. In addition, it conducted a manual search on Google Scholar (using the relevance criterion of the search engine [22] to include the most significant research in the relevant domain in this study. It limited the search in the selected databases to a temporal window of 10 years, including all studies published between 2013 and December 2024.

Table 2.
Search string used in the review.

"Induction cooking" **OR** "Induction stove" **OR** "Induction cooktop" **OR** "Induction hob" **OR** "Industrial furnace" **OR** "Direct fired heater" **OR** "cooking" **OR** "food preparation" **OR** "cooking system" **OR** "cooking technology" **OR** "dual power supply" **OR** "double power supply" **OR** "induction cooking" **OR** "electromagnetic induction cooker" **OR** "stove" **OR** "kitchen") **AND** ("Electromagnetic induction" **OR** "Magnetic induction" **OR** "Induction coil" **OR** "Induction heating" **OR** "Induction principle" **OR** "Maximum power point tracking" **OR** "MPPT" **OR** "Photovoltaic system" **OR** "PV" **OR** "PV system" **OR** "Solar Panels" **OR** "Solar power system" **OR** "photovoltaic cells" **OR** "photovoltaic panels" **OR** "solar cells").

2.3. Criteria For Selection of Primary Studies

Continuing with the systematic mapping study planning and following the methodology of Petersen, et al. [21] inclusion and exclusion criteria (Table 3) were applied to support the determination of the most relevant articles that would help answer the previously posed questions and obtain reliable results [26]. Therefore, a study is accepted if it meets all the inclusion criteria listed in Table 3, while if it meets at least one of the exclusion criteria, it is considered a rejected article.

Table 3.
Inclusion and exclusion criteria.

Inclusion criteria
Studies submitted in English that consider the development and prototypes of induction stoves with dual power supply (mains and photovoltaic system) or related work that contributes to the mastery of food cooking using induction technologies.
Full papers published in peer-reviewed journals, conferences, or congresses.
The research presents a concrete solution to the area of technologies applied to food cooking and/or renewable energies.
Exclusion criteria
The primary study does not present a concrete solution to the area of materials and renewable energies.
Studies that are not accessible in full text.
Studies that present non-peer-reviewed material.
Secondary or tertiary studies that report and analyze the results of another research.
Duplicate publications by the same authors.

3. Data Extraction Strategy

At this stage, the goal is to collect and extract all information that can significantly contribute to the research so that answers can be generated to the research questions based on these data (Table 1). It is important to note that, during this process, inclusion and exclusion criteria are used to ensure the accuracy of the results. Subsequently, research was conducted on double-fed induction kitchens, which refer to kitchens with two energy supply options that can operate either with solar energy (photovoltaic systems) or through the electric grid, and the design of these kitchens was also analyzed.

On the other hand, three cases were explored. First, the increasing importance of renewable energies in reducing environmental pollution; second, the health problems caused by traditional kitchens; and third, the economic impacts of these kitchen types.

4. Execution Stage

The execution stage of the research process involves three phases, as described below. The online tool Parsifal [27] was utilized to facilitate the orderly execution of the literature mapping/review process.

Phase one comprised applying the search string to the five databases specified in the search strategy, resulting in a total of 1703 studies. These articles were screened based on their titles, abstracts, and keywords, and inclusion and exclusion criteria were applied to eliminate research that may have been filtered out due to noise in the search string and to eliminate duplicate research by the same authors. This resulted in a total of 113 documents. In phase 2, a thorough reading of the articles was conducted, using the criteria listed in Table 3, which resulted in 58 articles. Finally, in phase 3, the relevant information was extracted from the articles and used to answer the research questions.

5. Results and Discussion

The results of the execution stage indicate that a total of 1703 studies were identified in Phase 1 (Figure 2). Scopus was the database that provided the most significant number of research studies, accounting for 45.5% of them. The other bibliographic databases contributed the following percentages of studies: ACM Digital at 10.8%, ScienceDirect at 8.3%, Web of Science at 19.5%, and IEEE Xplore at 15.7%. Other sources accounted for 0.2%.

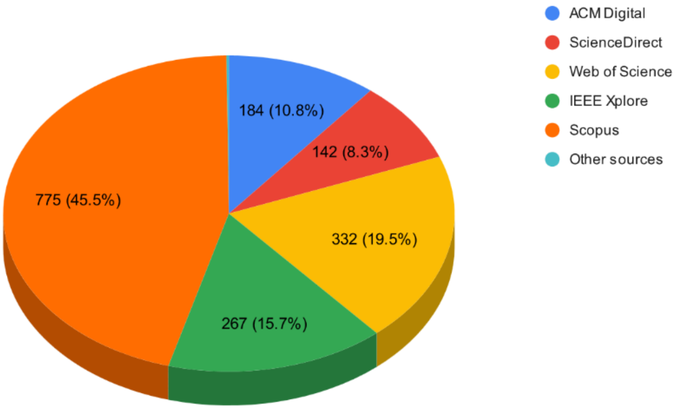

Figure 2.
Contributions from each of the scientific databases.

In phase 3, 58 articles were accepted as primary sources. Figure 3 illustrates a detailed breakdown of the studies contributed by each bibliographic database before and after being evaluated. ACM Digital did not contribute any relevant studies to the domain of interest. ScienceDirect had a low acceptance rate, with only one contribution to this review. On the other hand, Web of Science, IEEE Xplore, and Scopus were the most effective repositories for collecting relevant bibliographic evidence in the domain, as they contributed 93.1% of the primary articles.

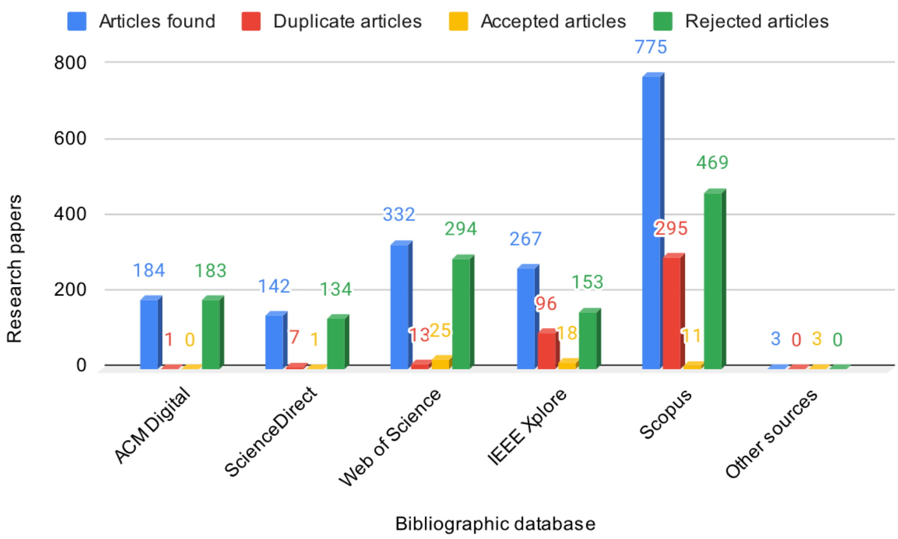

Figure 3.
Articles contributed by each academic database and search engine before and after being evaluated.

5.1. Answers to the Research Questions

The following section addresses the questions posed in the literature review process using the information obtained from the accepted primary sources.

5.1.1. What Is the Frequency of Research Publications That Perform Induction Technology Developments Related to The Food Cooking Process and Renewable Energies?

The application of the principle of electromagnetic induction to food cooking systems is a relatively understudied field compared to other domains, such as medical sciences [28] or material sciences [29] which suggests that it is a nascent field in which the foundations are popularizing this type of technology further. Figure 4 illustrates the annual publication frequency of food cooking systems based on induction technology until March 2022. There was a low rate of publications in 2013, 2014, and 2016 and no publications in 2015, indicating a need for significant advances in this domain. This may be because of the exploration of the application of the principle of induction in the domestic field and with clean energies. Subsequently, there was a steady increase in research in this area starting in 2017, when the application of these technologies was more extensively explored. The years with the most significant number of published studies were 2018 and 2019, accounting for 41.2% of the published studies. Finally, a decrease in published studies is observed in the years 2020, 2021, and 2022, which may be because of external factors such as the COVID-19 pandemic [30] which has resulted in a decrease in research time [31]. Finally, the number of publications increased in 2023 and 2024, which indicates that research in this area is being resumed.

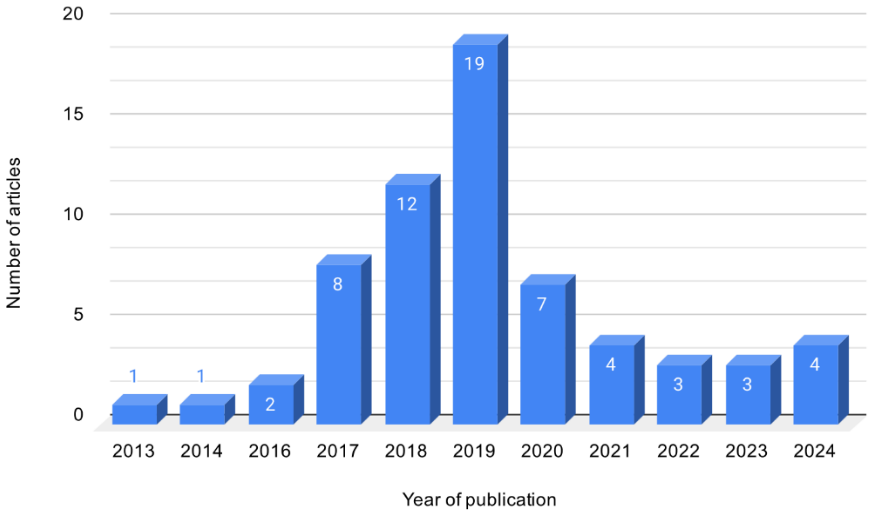

Figure 4.
Distribution of annual publications related to induction cookstoves.

5.1.2. Are The Validation Methodologies for Induction Cookstoves Being Applied Ad-Hoc or Following an Already Proven Standard or Methodology?

In the past five years, the development of induction technologies for food cooking has gained importance, leading to the analysis of various validation methods for the proposed prototypes. The review shows no standard or mandatory protocol for validating these systems beyond apparent cases such as proof-of-concept or case studies. Specifically, it has been identified that some researchers test their findings using methods such as simulation [32] or experimentation [33] and even, in some cases, a combination of both [34].

Figure 5 illustrates the various methods used to validate induction technologies in the food cooking domain. It can be seen that 19% (11 articles) of the investigations validate their findings through experimental tests in a controlled environment, either on a small or large scale, to verify the system's behavior. Additionally, 29.3% (17 articles) use simulation to verify the proposed method or technology, utilizing different software such as Matlab/Simulink [35] to validate their proposal. Finally, 43.1% (25 articles) use a combination of simulation and experimentation as a verification method for the hardware, software, or project.

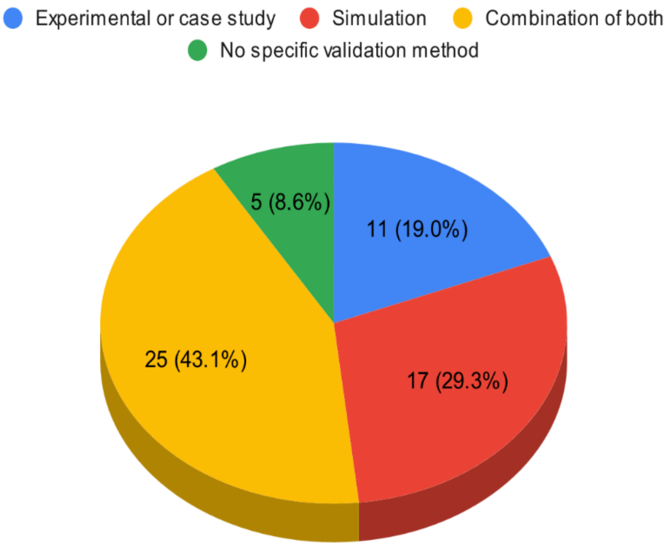

Figure 5.
Validation methods for proposals made from academia and their respective prototypes.

If the focus is on simulations, several programs mentioned in the articles were used as part of the research and verification process for the forms mentioned above of validation (experimental, simulation, and combination). These programs include Matlab [36], Multisim [32], Proteus [37], COMSOL Multiphysics [38], PSIM [39], Simulink [40], LabVIEW [41], Spice [33], PSpice [34], OrCAD PSpice [42], LTspice [43], among others. Figure 6 shows that Matlab (29.5%) is the most commonly used program in simulations, reinforcing its position as a leader in engineering in various domains. It is also worth noting that the different Spice forks (PSIM, PSpice, and OrCAD PSpice) are viable alternatives, as they have been used in multiple studies of induction and firing systems.

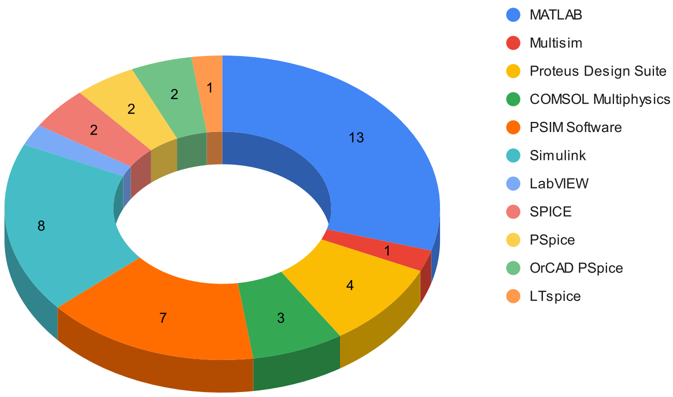

Figure 6.
Software simulation alternatives are used to plan and validate the proposals.

Subsequently, 8.6% (5 articles) did not have a verifiable validation method, as of Kumar, et al. [44] which focuses on collecting and providing information on different inverter typologies (quasi-resonant, half-bridge, and full-bridge), output power control techniques (phase shift and asymmetrical pulse width modulation), among others. Although these contributions are valuable in compiling existing information, they do not provide empirical evidence.

It should be noted that not all articles in this field involve physical projects. Some are based on simulated proposals, making validating their results in a real-world environment difficult. Analysis of the available studies suggests that software can help organize and streamline the research process and facilitate searching for the most effective technologies, tools, or materials for prototype implementation [45].

5.1.3. What is the Current State of Research on the Use of Materials and Renewable Energy Approaches in Dual-Energy Supply Induction Cookstoves, and What are the Key Findings Related to their Efficiency and Environmental Impact?

The use of dual-energy supply in induction cookstoves, which allows for operation with grid connection and alternative energy sources, has received limited attention in the scientific literature. However, several studies have demonstrated promising results about the relationship between materials and tools applied to the system and various topologies, frequencies, and fast response components.

In a study by [46] an environmentally friendly dual-type induction system with automatic switching between solar and electric energy is proposed. The system utilizes a half-bridge inverter, and it may be beneficial to investigate the behavior of alternative topologies, such as quasi-resonant or full-bridge inverters, for comparison with conventional induction cookstoves. In this line, Soni, et al. [47] conducted a study that explores the potential for hybridizing propane gas and conventional electric power as energy sources in induction cookstoves. While this approach may reduce reliance on a single energy source, it is essential to note that propane gas combustion still has negative environmental impacts [48].

These studies demonstrate that using dual-energy sources in induction cookstoves is feasible, even with less efficient energy sources such as photovoltaics. This highlights the efficiency of the induction principle. However, the limited number of studies in this area suggests that further research is needed to improve efficiency, optimize materials for induction cookstoves, and enhance user safety.

5.1.4. What Are the Main Problems, Risks, and Challenges in Induction Stoves with a Dual Power Supply?

Applying induction technology in food cooking systems can present challenges, particularly regarding power requirements during extended use [49]. The high frequencies involved in using these technologies require careful selection and evaluation of the appropriate topology, such as quasi-resonant [50], half-bridge [51], or full-bridge [34], as it significantly affects the transferred heat power. The choice of vessel materials is also significant, as they must be ferromagnetic for effective power transfer. Non-ferromagnetic materials are unsuitable for induction cookstoves due to their low permeability and resistivity [52].

Integrating photovoltaic systems with domestic induction cookstoves is complex due to the high cost of the equipment and the challenge of maintaining a constant delivered power [53]. However, ongoing innovation in this area makes it a viable option. Proper power control is also crucial for the system's performance.

In this line, some cases are analyzed in general that seek to provide solutions to the challenges mentioned above; it should be noted that they are proposals focused on some specific areas, so their results cannot be generalized to all cases, but they are of great importance for possible future improvements. It finds a specific approach from the point of view of dual power supply in Sibiya and Venugopal [46] improving the efficiency of the induction cooking system; however, it presents some inefficiency when increasing the firing level, so from this contribution, it is suggested the use of two inverters with class D and DE half-bridge topology, allowing to handle both high and low power output. Likewise, Annie, et al. [54] generate a proposal that is simulated and validated with PSIM software, where they seek to design a topology based on the quasi-resonant parallel inverter with the approach of IGBTs which have a fast-switching speed and generate lower losses, which could generate higher efficiency in induction stoves, besides the fact that this system uses solar energy as input and thus reduce the use of natural gas. In this context, Mounika, et al. [42] use the OrCAD PSpice program for the design and validation of a full-bridge series resonant inverter that handles two frequencies with the purpose that the heating can apply to ferromagnetic and non-magnetic materials besides employing the ADC method for power regulation. These investigations indicate ongoing efforts to improve and contribute to developing induction technology in the dual power supply and specific aspects of domestic induction systems. It focused these proposals on specific areas, and their results may only be generalizable to some cases.

There have been concerns about potential health risks associated with using induction technology due to the electromagnetic fields generated by these devices. To assess the potential impacts of these fields on human health, research has been conducted, including a study by Nagatomo, et al. [55] that investigated the potential for interference with unipolar pacemakers or cardioverter defibrillation implants due to electromagnetic induction. This study found that the worst-case scenario could occur in patients with a unipolar implant placed very close to the vessel plate in an induction cookstove, and it was recommended that the patient maintain a safe distance of at least 50cm from the furnace.

In addition to electromagnetic fields, induction cookstoves may also produce radiation. Guidelines and standards have been established to protect public health and safety, such as the Spanish standard NTP 698, which specifies that acceptable radiation exposure levels for humans are 100 micro-Teslas. Adhering to these standards is essential in developing and commercializing induction cookstove prototypes [56].

One of the main challenges in developing induction cookstoves is selecting suitable materials for the vessels, as only ferromagnetic materials can be used because of their high efficiency and low resistivity and permeability [42]. This has led to the creation of commercial “all metal induction” cookstoves, which utilize the conduction principle in a magnetic grid to heat any material, albeit with reduced efficiency. Consequently, this type of system needs to improve its efficiency to make it more viable for commercial use [57].

The frequency at which induction cookstoves operate is crucial in their design and implementation, as it affects the efficiency of vessel heating. Commercial induction cookstoves typically operate between 20KHz and 100KHz. The topology and components must also be carefully evaluated to ensure high-frequency handling and optimal safety and performance [58]. In addition, precise output power control is essential for induction cookstoves, as unchecked power can cause harmonic distortions that degrade system performance [44].

5.1.5. In What Context are the Main Contributions to Mastering Alternative Food Preparation Methods with Energy-Supplied Induction Cookstove Techniques?

Most contributions to the development of alternative methods for food preparation using induction cookstoves are being made within the academic domain, as demonstrated by Figure 7 which shows that 96.6% (56 articles) of research in this area are based in academia. These studies focus on various aspects of induction cookstove design and operation, including architectures [32], algorithms [52], topologies [59], and materials, to improve the efficiency of these devices. Induction cookstoves are widely popular because of their efficiency compared to conventional cooking systems, which can negatively impact health, the economy, and the environment.

Besides improving the efficiency of induction cookstoves, it has also researched using renewable energy sources as an energy supply for these devices, including incorporating photovoltaic systems and dual power supply (electric grid and solar energy). This can provide greater autonomy, particularly in areas without a fixed electrical grid or where there are shortages of liquefied petroleum gas [37] or reliance on wood or charcoal burning[32].

Only a tiny percentage (1.7%) of research on food cooking systems based on the induction principle originates from the industry. One such study presents new knowledge about a multi-resonant inverter that reduces the size of an induction cookstove and the heating losses of non-ferromagnetic vessels[60]. In addition, 1.7% of the research in this area combines academic and industrial contexts, providing empirical evidence on the electromagnetic forces acting on utensils in induction heating systems using methods such as Maxwell's tensor and finite elements [61].

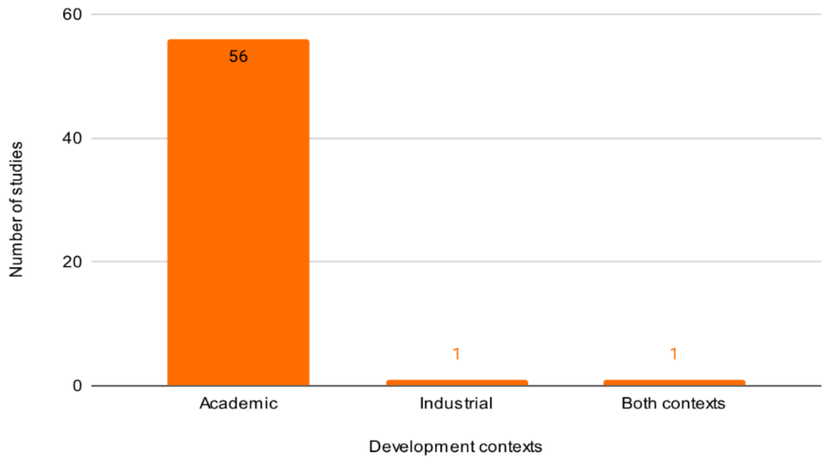

Figure 7.
Context of the proposals made in induction stoves in cooking devices.

These findings suggest that academia is making many proposals for induction cooking systems, which could indicate a mature field seeking to strengthen its foundations and incorporate new hardware and software technologies. In the coming years, it will probably implement these proposals at the industry level, leading to greater adoption and technological advancement of these devices at the commercial level. Therefore, it is essential to continue fostering collaboration between academia and industry to promote innovation and economic growth.

5.1.6. What is the Efficiency of the Proposed Induction Systems, and How Do they Contribute to the Domain?

Users widely accept induction cookstoves because of their rapid heating, safety, and ease of cleaning [62]. As the population becomes increasingly aware of the potential scarcity of liquefied petroleum gas and the negative impacts of burning wood, kerosene, and other materials on pollution and health, it is important to determine the efficiency of induction cookstoves to understand if this technology is suitable for all contexts. In the present research, it has been found that some proposals for induction cookstoves are only validated and implemented through simulation, while others developed into prototypes with high efficiencies.

In a study by Sibiya and Venugopal [46], an induction cookstove with a dual power supply using photovoltaic and electric power is proposed. The cookstove operates at three fixed frequencies of 30KHz, 45KHz, and 65KHz, and individual test results indicate system efficiencies of 91.42%, 80.96%, and 57.12%, respectively. These results suggest that as the firing level increases, the efficiency decreases. In a study by Dande and Markande [37] a domestic induction cookstove using solar energy as the sole power source is proposed, achieving an efficiency of 80% at a frequency of 25KHz.

In Adhikari, et al. [32] they analyzed the efficiency of an induction cookstove system through simulation. A commercial AC induction cookstove is evaluated and found to have an average efficiency of 85.56% through experimental testing. It then analyzed the induction cookstove circuit using Multisim software and evaluated a proposed DC induction cookstove with output powers from 500 W to 1500 W based on design and simulation with Proteus and Multisim software. The proposed system is found to have an average efficiency of 90.10%. It is important to note that simulations are approximations of the natural world and may not fully capture the complexity of real-life systems, so they should be validated through experimental testing.

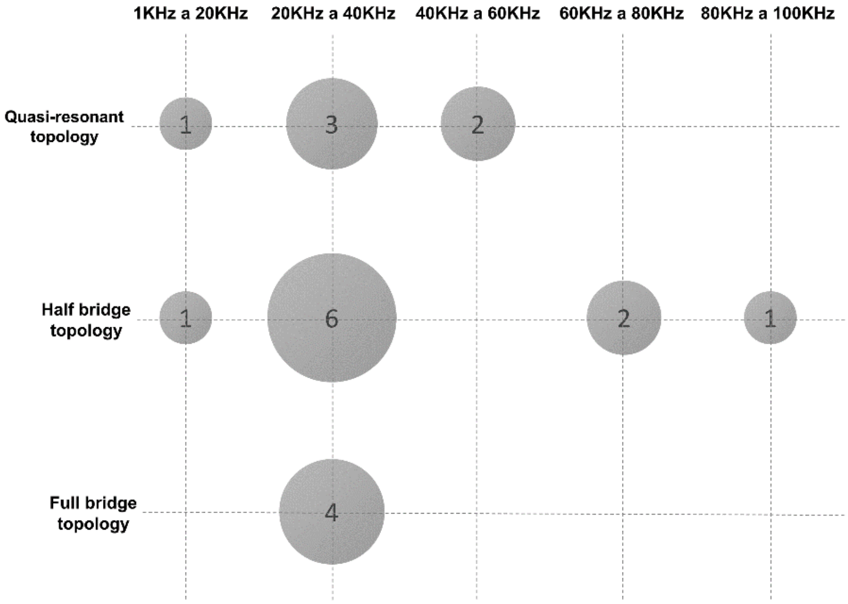

Figure 8.
Bubble chart relating the topologies used in induction stoves concerning operating frequency.

The graph in Figure 8 illustrates the frequencies utilized in induction systems. The plotted data suggests that most research has focused on utilizing frequencies within the 20-40 kHz range for induction heating. This range is chosen because of the high efficiency of electromagnetic waves at these frequencies for devices with high magnetic permeability, resulting in higher heating levels. It is worth noting that it is primarily derived from the proposed frequencies depicted in the graph from academic research, as professional induction heating devices tend to utilize more complex and costly electronic technologies [63]. In this line, A study [64] has demonstrated that using electromagnetic frequencies near 100 kHz can effectively eliminate ripple currents in specific materials and geometries because of resonance with the natural frequency of ripple current oscillation. The efficacy of this method may vary depending on the material and geometry of the object on which it is applied; thus, it is crucial to conduct testing and evaluation before implementation. Some observe that lower frequencies may have decreased effectiveness because of their longer wavelength. In comparison, higher frequencies may be less effective because of higher attenuation in the medium and reduced ability to penetrate the material and interact with the ripple current.

5.1.7. What Future Trends Regarding Algorithms, Materials For Induction, and Novel Energies, among Others, are Being Applied in the Domain?

Electromagnetic induction involves the production of eddy currents and hysteresis and is a technology used in induction cooking [44]. Researchers are exploring various methods and materials to improve the safety, efficiency, and performance of induction stoves, such as flexible stoves [65], deep learning techniques [62] renewable energy sources [66], and gallium nitride (GaN) composite technology [58]. These efforts aim to advance the field and introduce new trends in the domain of induction cooking.

Flexible induction stoves, which allow the placement of vessels of various sizes on the stove surface, are a trend in the field of induction cooking. These stoves utilize small inductors or coils that distribute heat over the entire surface [67]. Inverters are commonly used in flexible stoves to control the output power, and there are two main types: conventional inverters, which only handle a single output and have lower yields, and multiple output inverters, which offer higher performance but at a higher cost. A multi-output resonant inverter for multi-coil induction heating devices has also been proposed to improve induction stoves further, as it enables higher efficiency in the coil system, smooth switching, precise output power control, and independent management of each coil [59].

It has also applied deep learning techniques in induction cooking, as demonstrated in a study by Villa, et al. [68] where a convolutional neural network was trained to identify the equivalent impedance of the load and distinguish between pots on the stove surface. This is important as an incorrectly positioned pot can decrease resistance, increase current, and damage the electronic components' power. Deep learning in induction stoves could enable new features, such as recognizing commonly used pots, alerts when a pot is misaligned, monitoring system usage, and tracking utensil deterioration.

5.1.8. What Technologies, Approaches, or Techniques Relate Renewable Energies to Induction Cooking?

Some proposals have been made to use renewable energies in induction stoves, but their results have yet to be generalized in the industry. Increasingly, these systems are being sought to operate with clean energy sources, such as solar energy, using photovoltaic systems [66]. For example,Sibiya and Venugopal [46] proposed an induction stove that can operate both with a photovoltaic system and with the power grid using the auto-switching method, which allows using the energy available at each moment. The case of Adhikari, et al. [32] focuses on designing and simulating an electromagnetic induction heating system using a photovoltaic system as an energy source to reduce the consumption of LPG and biomass. Proteus and Multisim software allows for analyzing the system's behavior and preparation for future development in a physical prototype.

The above speaks to the fact that renewable energy is an underexplored domain, and induction cookstoves are becoming a knowledge gap that can be further explored through empirical evidence.

6. Discussion

This systematic mapping study provides a comprehensive overview of the current state of induction stove technology, mainly focusing on dual-energy supply systems and the integration of renewable energy sources. The findings reveal a growing interest and research efforts in this domain, as evidenced by the increasing number of publications in recent years.

One notable observation is the lack of a standardized validation methodology for induction stove systems. While researchers have employed various approaches, including simulations, experimental testing, or a combination of both, a universally accepted protocol is yet to be available. Developing a standardized validation framework could facilitate more consistent and comparable evaluations across different induction stove designs and implementations.

The results highlight the potential of dual-energy supply systems, which integrate conventional electric grid and renewable energy sources, such as photovoltaic systems. These hybrid approaches can enhance energy resilience, reduce reliance on non-renewable resources, and contribute to sustainability goals. However, the limited number of studies in this area suggests that further research is needed to optimize such systems' efficiency, reliability, and cost-effectiveness.

Interestingly, the findings reveal that most contributions to induction stove technology are currently being made within the academic domain. While this indicates a strong focus on fundamental research and technological advancements, it also highlights the need for increased collaboration between academia and industry to facilitate the successful commercialization and widespread adoption of these technologies.

The reported efficiencies of the proposed induction stove systems vary considerably, ranging from approximately 57% to over 90%, depending on factors such as operating frequency, topology, and power output. This variability underscores the importance of continued efforts to enhance the efficiency and performance of induction stoves, as improved efficiency can lead to energy savings and reduced environmental impact.

Notably, the review identified several emerging trends and future directions in induction stove technology. These include exploring flexible stove surfaces, applying deep learning techniques for intelligent control and monitoring, and utilizing advanced materials and semiconductor technologies, such as gallium nitride composites. These developments could improve further functionality, safety, and user experience of induction stoves.

The findings suggest that integrating renewable energy sources remains an underexplored area of induction stove technology, with limited empirical evidence. As the demand for sustainable and environmentally friendly cooking solutions grows, further research into the seamless integration of renewable energy sources with induction stove systems could yield promising results.

7. Threats to Validity

While this systematic mapping study aimed to review the current state of induction stove technology comprehensively, several potential threats to validity should be acknowledged.

Publication Bias: There is a risk of publication bias, as studies with positive or significant findings are more likely to be published than those with null or negative results. Consequently, the review may need to be more accurate with successful developments in induction stove technology while underrepresenting failed attempts or challenges. To mitigate this, a thorough search across multiple databases, including lesser-known sources, was conducted to increase the likelihood of including a broader range of findings.

Search String Limitations: The search string used in this review may have captured only some relevant studies due to potential omissions or inconsistencies in keywords and terms used across different publications. While the search string was carefully constructed using the PICOC criteria, some pertinent studies may have been inadvertently excluded.

Data Extraction Errors: Despite rigorous efforts to extract data accurately from the included studies, there is a risk of human error during the data extraction process. Mistakes in interpreting or recording information from primary sources could lead to inaccurate results and conclusions.

Rapidly Evolving Field: Induction stove technology is rapidly evolving with continuous developments and advancements. As this review only included studies published until December 2024, more recent research efforts, particularly those published after the search window, may not have been captured, potentially affecting the comprehensiveness of the findings.

Generalizability Concerns: While the review aimed to provide a broad overview of induction stove technology, the generalizability of the findings may be limited. Many of the included studies focused on specific aspects or applications of induction stoves, and their results may only be universally applicable to some contexts or scenarios.

Despite these potential threats to validity, the systematic approach employed in this review, including the rigorous search strategy, inclusion and exclusion criteria, and data extraction methods, aimed to mitigate these risks as much as possible. However, it is essential to interpret the findings within the context of these limitations and to exercise caution when generalizing the results to broader contexts.

8. Conclusions

Induction stoves have emerged as a viable alternative for cooking food in the domestic environment because of their efficiency, lower energy consumption, and cost. In this systematic mapping study, the current domain of induction cookstoves is analyzed, where the results suggest it is a booming field for the scientific community, with a positive trend in the frequency of scientific publications. The main contribution of this research is to deepen the domain of induction stoves, determine their efficiency, and examine the latest techniques, technological trends, and challenges in this field, establishing empirical evidence in a field where information is not abundant.

The results of a systematic analysis show no universally accepted method for validating proposed devices, though a trend toward utilizing a combination of experimental and simulation methodologies has been observed. Matlab and Simulink have frequently used programs for this purpose. Regarding topologies, the half-bridge inverter and full-bridge topology are the most employed in induction systems, with frequencies of use at 50% and 30%, respectively. These topologies are critical for the efficiency and performance of the system. It has also been noted that switching frequencies in the range of 20-100 KHz are often used because of the minimal amount of acoustic noise generated at these frequencies.

One emerging technological trend in induction cookstoves is incorporating dual power supply systems that utilize both photovoltaic and conventional energy sources. Additionally, the application of machine learning algorithms has the potential to enhance the performance of these systems.

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