Panorama of photovoltaic energy in poultry in Paraná
Panorama da energia fotovoltaica na avicultura de corte no Paraná
Panorama de la energía fotovoltaica en la avicultura en Paraná

Abstract
Brazil stands out before other countries for having a gigantic area for food production. Paraná is the state that stands out among the nation's states with its gross production value (VBP), which in these values are the agricultural and livestock productions such as poultry farming. Moreover, Paraná stands out for having a high solar irradiation, which leads rural entrepreneurs to seek the use of renewable energies as electric energy, especially photovoltaic energy. With that, the present study refers to a qualitative systematic review, whose objective was to conduct an analysis of the scientific production on the panorama of solar photovoltaic energy in poultry farming in the state of Paraná, in the period from 2012 to 2021. The bibliographical search was carried out in the databases: Scopus and Scielo including others described on the theme, searching for information from government agencies responsible for production indicators, growth and development. This review showed that the State of Paraná has a great potential for photovoltaic solar energy generation, by the levels of solar radiation which is inserted and also for having the largest poultry herd in Brazil.

Keywords: Rural sustainability; Electrical energy; Solar energy.

Resumo
O Brasil se destaca perante outros países por possuir uma área gigantesca para a produção de alimentos. O Paraná é o Estado que se destaca entre os Estados da nação, com seu valor bruto de produção (VBP), que nestes valores estão as produções agrícola e pecuárias como a avicultura de corte. Além disso, o Paraná se destaca por possuir uma alta irradiiação solar o que leva aos empresários rurais buscarem utilizar as energias renováveis como energia elétrica principalmente a energia fotovoltaica. Com isso, o presente estudo refere-se a uma revisão sistemática qualitativa, cujo objetivo foi conduzir uma análise da produção científica sobre o panorama da energia solar fotovoltaica na avicultura no estado do Paraná, no período de 2012 a 2021. A busca bibliográfica foi realizada nas bases de dados: Scopus e Scielo incluindo outros descritos sobre o tema, buscando informações de órgãos governamentais responsáveis por indicadores de produção, crescimento e desenvolvimento. Esta revisão mostrou que o Estado do Paraná possui um grande potencial de geração de energia solar fotovoltaica, pelos níveis de radiação solar o qual está inserido e também por possuir o maior rebanho de aves de corte do Brasil.

Palavras-chave: Sustentabilidade rural; Energia elétrica; Energia solar.

Resumen
Brasil se destaca de otros países por tener un área gigantesca para la producción de alimentos. Paraná es el estado que se destaca entre los estados de la nación, con su valor bruto de producción (PVB), que en esos valores son
producciones agrícolas y pecuarias como la avícola. Además, Paraná se destaca por tener una alta irradiación solar, lo que lleva a los empresarios rurales a buscar el uso de energías renovables como energía eléctrica, principalmente la energía fotovoltaica. Así, el presente estudio se refiere a una revisión sistemática cualitativa, cuyo objetivo fue realizar un análisis de la producción científica sobre el panorama de la energía solar fotovoltaica en aves de corral en el estado de Paraná, de 2012 a 2021. La búsqueda bibliográfica se realizó en las bases de datos: Scopus y Scielo, entre otras descritas sobre el tema, buscando información de los organismos gubernamentales responsables de los indicadores de producción, crecimiento y desarrollo. Esta revisión mostró que el Estado de Paraná tiene un gran potencial para la generación de energía solar fotovoltaica, debido a los niveles de radiación solar en los que se inserta y también porque tiene el mayor rebaño de pollos de engorde de Brasil.

**Palabras clave:** Sostenibilidad rural; Energía eléctrica; Energía solar.

1. **Introduction**

Producing food in Brazil, specifically chicken meat, represents great economic importance in the country, generating more than 4.1 million direct and indirect jobs, as well as contributing 11.5% of Brazilian exports, in 2019 the Brazilian production of chicken meat totaled 13.2 million tons, with more than 51 million units of cutting dies. The state of Paraná is the leader in the country, contributing 33.46% of slaughter and 35.85% of chicken exports. Brazil, on the other hand, appears in third place in the world ranking of production and first in the ranking of exports (EMBRAPA, 2021) and (Lacerda et al., 2019).

Aviaries are known as confinement modules that require large volumes of electricity, the challenge is to feed enough energy so that these modules do not come to harm the environment and result in a good supply of generated energy (Souza & Molento, 2015).

In this scenario, photovoltaic generators come in, which are electric energy generation systems that use the most abundant renewable energy source, which is the use of solar radiation (Lira et al., 2019). This form of energy has several benefits, such as ease of installation, not requiring large areas and not generating waste, which is important for the environment, in the south of Brazil, in the west of Paraná, the solar irradiance is affected due to the seasonality, presenting with greater intensity in the summer months and low with incidence in the winter (Barbosa et al., 2017) and (Francisco et al., 2019) and (Stefanello et al., 2018).

In this scenario, in the present study we seek to understand the panorama of photovoltaic solar energy in poultry in the state of Paraná through a qualitative systematic review of the literature of articles on the subject. From the analysis, we present an overview of these studies in the last 10 years.

2. **Methodology**

This study derives from a *Systematic Bibliographic Review – SBR* research, defined by (Dessbesel et al., 2018) and (Godinho & Caneppele, 2021), which presents a research model, where the main data of the literature on a given topic is used, thus building a bibliographic survey present reliable data for the next surveys. The review was guided in stages, namely: survey of the theme, planning phase of the systematic review, selection of journals, application of exclusion and data inclusion filters, critical evaluation and finally data synthesis (Teixeira et al., 2010). The structure of the work had the following format: Survey of the theme: planning phase of the systematic review, in which the theme was defined, as it was subdivided from the central theme Solar Rural Energy.

i. Planning phase of the systematic review: collecting keywords in scientific articles in the area in order to select the keywords for data collection

ii. Selection of databases: the databases chosen were the Scientific Electronic Library Online - Scielo® and Scopus® by Elsevier, which brings together national and international scientific journals. The keywords for the search were “Photovoltaic energy” and “Broiler poultry” and “Gross production value” and “Parana”.

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iii. Applications of data exclusion and inclusion filters: after searching the databases, it was necessary to define the inclusion and exclusion criteria for the research.

As inclusion criteria, we selected:

a) Publications in the periods from 2012 to 2021 and in English and Portuguese;
b) Only articles with research and articles and review.

Exclusion criteria:

a) Theses and dissertations, conference proceedings (national and international) dealing with scientific research, literature review and theoretical essays;
b) Not available in full;
c) Articles for more than 10 years.

iv. Data collection: 172 papers were found among research and review articles in the Scielo database and 73 in the Scopus database. The first inclusion criterion related to studies from 2012 to 2021 was applied and resulted in 134 at Scielo and 44 at Scopus. For the exclusion criteria (b, c), we finished with 64 in Scielo and 30 in Scopus. After being saved in a digital Mendeley® platform, we read the titles and the research summary, resulting in 29 in the Scielo database and 19 in the Scopus database.

v. Critical evaluation: a critical evaluation of the studies (data) was carried out according to the central objective of the review, analyzing the potential of energy generation and the panorama of solar energy in the State of Paraná / Brazil.

vi. Summary of data: qualitative systematic review, that is, a careful analysis of the panorama of solar energy used in broiler poultry in Paraná.

**Figure 1** - shows the steps taken to collect the data for the systematic bibliographic review.
3. Results and Discussion

The configured search generated a total of 48 articles. After a selection by reading the titles and abstracts, the publications were considered potentially eligible and were read in their entirety. At the end of the analysis, it was completed with fifty articles that completed the conditions of inclusion for the study and are listed in this section. The selected articles were published between 2012 and 2021.

The articles analyzed have the highest production in 2020, in which there is an increase of 23% in relation to the previous year. Of the 48 articles analyzed, 23 in the Portuguese language (48%), while in the English language, 25 corresponding articles (52%).

Chart 1 organizes the analyzed works, as a result of the systematic review, with the authors' name, year and title.

<table>
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<th>N°</th>
<th>Autor/Autores</th>
<th>Titulo</th>
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<td>Becerra-Díaz &amp; Ando Junior, 2021</td>
<td>Investigation of the effect temperature on the performance of the photovoltaic solar design for the western Region of Paraná - Brazil</td>
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Source: Authors (2022).
This study is dedicated to analyzing the work related to electrical energy obtained from photovoltaic systems for the benefit of poultry in the state of Paraná. For that, the results are divided into four parts, they are: presentation of research in which there is an evaluation of the agricultural sector in Paraná; information on poultry farming in Brazil and Paraná; description of photovoltaic energy and the benefits of its application in rural areas.

Some patterns can be identified among the different publications 21% of the selected articles referred to Normative Resolution n° 482/12 or the new Normative Resolution n° 687/15. 62% of the selected publications are directly related to the keyword "Photovoltaic", 35% with "Solar energy", 19% with "Renewable energy" and 5% with "Poultry".

3.1 Paraná in the agricultural sector

In 2019, agricultural production in the state of Paraná totaled R$ 97.7 billion, a value 3% higher than that recorded in 2018. The production of animal protein was highlighted, mainly the broiler chicken reaching 18% of the participation of the main crops (Alves, 2020).

3.2 Broiler poultry in Brazil and Paraná

In the researchers analyzed, we verified that the broiler production chain stands out in the Brazilian economy, the third largest world producer and the main exporter of international chicken meat Souza and Molento (2015), in addition to the State of Paraná being the main producer and exporter the country of this important source of animal protein, according to Figure 2.

**Figure 2** - Largest broiler producers and exporters per ton in 2019.

Figure 2 shows the largest broiler producers by states in Brazil, with an impressive advantage for Paraná in relation to the second place which is Santa Catarina, with more than 120% of chickens produced. This production shows that the electric energy market can expand more and more with great security, in addition to bringing sustainable benefits and cost reduction for production.

According to Souza and Molento (2015) in the State of Paraná, twenty-nine units approved by the Ministry of Agriculture were identified to export to a general list of countries and/or the European Union.

Despite the economic relevance of Brazilian poultry production, animal welfare regulation is scarce at the farm level.
Souza & Molento, 2015). Thermal comfort inside the premises considerably interferes with production, therefore the control of the internal environment of the aviaries becomes essential for the success of the activity (Santos et al., 2014). Thermal comfort is of paramount importance for poultry productivity, the body increase of only 4°C is already characterized as hyperthermia in birds, and the decrease of 8°C is sufficient for hypothermic condition (Marangoni, 2019).

The aviaries require large amounts of electrical energy, mainly the Dark-House system, which consists of an automated system using exhaust fans, evaporative panels, water system, feed distribution, air circulation control, temperature and light (Sreenath et al., 2020). Broiler poultry producers are changing the internal lighting systems of the aviaries to photovoltaic energy, considering that in the medium and long term costs tend to reduce significantly, in addition to working with sustainable managements (Paulus et al., 2019).

3.3 Photovoltaic energy and its application in rural areas

Photovoltaic solar energy has emerged as a sustainable electric generation option, applicable in remote locations where expansion of the conventional grid requires investments with prohibitive costs in relation to solar generation (Barbosa et al., 2017). Constituting a strategic renewable source for Brazil due to the high levels of irradiation, presenting a positive solar potential for electricity generation (Stefanello et al., 2018) and (Imai et al., 2020).

The state of Paraná has a daily average irradiation over a year of 1.960 MW (MegaWatts), it is located among the states with the greatest photovoltaic potential, with São Paulo being the main with 7,100 MW/means and Roraima with 65 MW/means being the state with the lowest photovoltaic potential (Rosa & Gasparin, 2016).

These results can be compared with those obtained by Stefanello; Marangoni and Zeferino (2018) and Perazzoli et al. (2020), which recorded the performance of photovoltaic systems in the state of Paraná, due to the average levels of irradiation, according to Figure 3.

![Figure 3 - Average irradiation in the state of Paraná.](image)

Source: Perazzoli; Gobbi and Tiepolo (2020).

The energy conversion factor for photovoltaic systems, it was found that, according to Figure 3 that at the beginning and at the end of the year the electricity generated exceeds the middle of the year compared to the months of May, June and July due to the lower photoperiod characteristic of autumn and winter seasons. Analyzing the data in the Figure, it is possible to conclude that Paraná has great potential to advance in this area. Currently, solar radiation is one of the most relevant renewable energy sources (Lima et al., 2020).

Taking advantage of the energy from the Sun, which is an inexhaustible and free source according to the time scale of life on planet Earth (Chanchangi et al., 2020). Photovoltaic use consists of transforming solar energy into electrical energy due
to the effects of solar radiation on a semiconductor metal plate (Albuquerque et al., 2017). The solar radiation incident in the Earth’s atmosphere is formed by direct radiation, which reaches the surface without undergoing deviation in its path and which produces sharp shadows, and the diffuse radiation that originates from multi-directions due to the scattering in the atmosphere outside the beam straight through molecules, aerosols and clouds (Perazzoli et al., 2020).

Finally, in several ways photovoltaic solar energy is approached, with appreciation for consolidating the habit for the use of renewable energies. To promote the installation of photovoltaic panels, Resolution n° 482 of 2012 from the National Electric Energy Agency (ANEEL) was created and was updated by the new Normative Resolution n° 687/1, with some incentives for its application, although it should be noted that the regulation still does not offer sufficient guarantees to significantly boost the sector (Barboza et al., 2016); (Lira et al., 2019) and (Mustafa et al., 2020).

The resolution governs the micro and mini generation of energy by consumers, allowing users to install generator systems and generate their own energy, and the surplus energy can be exported to the electric grid and generate credit on the energy bill (Didoné et al., 2014).

In the aviaries for solar photovoltaic system equipment Paulus; Bortolini and Primieri (2019) they studied application in rural property in the municipality of Tupãssi, Paraná where they presented appropriate solar energy production, adequately supplying the energy of the five aviaries, satisfying the economic viability from the project. Following the same approach Barboza et al., (2016) developed a study on a possible alternative to promote the economic, social and environmental balance of rural properties, obtaining the following results, the producer needs around 30,126 KWh/year of energy electricity, with aviary consumption of: aviary 1 - 6,068 KWh/year and aviary - 2 6,620 KWh/year.

The application of solar energy systems has several positive aspects that justify the implementation: They generate the minimum of environmental impact and high generation potential according to irradiation levels, they provide for the reduction of CO emissions, they are easy to install and low maintenance, the plates generating energy vary from 20 to 25 years, and in some cases can reach 30 years Barboza et al. (2016) and Gönen and Kaplanoğlu (2019) and the negative aspects can be: high costs, specialized labor for maintenance, waste generation.

The authors Chanchangi et al., (2020), mention that there was a notable growth due to the price decrease, disagreeing with the previous statement. In the study by Gönen and Kaplanoğlu (2019) he mentions that it is possible to mitigate the environmental impact of waste by reusing materials for the production of photovoltaic modules. Another author points out that photovoltaic installations generate impacts on bird populations due to habitat loss and collision mortality (Visser et al., 2019).

In the study by Pimentel da Silva and Branco (2018) they state that 22 out of 32 impacts are classified as positive, 4 a neutral and 6 require further study.

4. Final Considerations

After analyzing the articles presented, it was found that solar energy can be used in poultry houses in the city of Paraná, as it has a good location for the installation of photovoltaic devices for electrical generation, in addition to being a state with one of the highest average irradiations. throughout the year and mainly because it has the largest poultry flock in Brazil. Considering the support for resolution n° 482 of 2012 that encourages the use of clean energy, the strategy of incorporating solar power plants in poultry farms seeks to reduce energy costs and aim at a sustainable future.

Based on the systematic review worked on the Scopus® and Scielo® databases according to the inclusion and exclusion search parameters, the state of the art of this theme was visualized and was presented in general. It is possible to observe that the production of scientific literature is still scarce, with a significant increase in publications starting in 2014, which is a topic that needs further research and dispersion of knowledge through publications, in addition to the fact that the
topic was very specific. Very little information was found involving the city of Paraná with solar energy. Demonstrated a great gap to be researched, this topic needs to be discussed more comprehensively by the scientific community and contains a list of motivation for new scientific works for future publications.

References


