Research Article

Research Trends on Cage-Free Housing System in Laying Hens: A Bibliometric Analysis

Anom Yusuf Tri Bambang Susilo[1], Muhammad Fathin Hanif[1], Bambang Ariyadi[2], Ahmad Romadhoni Surya Putra[3], Ali Agus[1]*

[1]Department of Animal Nutrition and Feed Science, Faculty of Animal Science, Universitas Gadjah Mada, Jl. Fauna, 55281, Yogyakarta, Indonesia; [2]Department of Animal Production, Faculty of Animal Science, Universitas Gadjah Mada, Jl. Fauna, 55281, Yogyakarta, Indonesia; [3]Department of Livestock Socioeconomics, Faculty of Animal Science, Universitas Gadjah Mada, Special Region of Yogyakarta, 55281, Indonesia.

Abstract | The shift towards cage-free production systems in laying hens has gained significant attention in animal production research, particularly after the ban on conventional cages. Meanwhile, a bibliometric analysis entails the use of statistical methods to discover patterns and trends in scientific publications. This approach includes studying the quantity of publications, identifying the countries with the highest productivity, and defining the main fields of research. Through this analysis, we could gain valuable understanding of the dynamics and limitations in knowledge within the field. In this case, a bibliometric analysis was conducted on the cage-free housing system in laying hens using the database Scopus and the R package Bibliometrix. Based on the findings, a total of 900 were collected, which included 799 research articles, 48 conference papers, and 54 review papers. These publications spanned from 1960 to 2023, showcasing a notable 7.14% annual growth in the number of published works. The United Kingdom, Germany, Australia, the USA and Brazil emerged as the most productive countries. Several publications have been released in various scientific journals, including Poultry Science (133 articles), Applied Animal Behaviour Science (61 articles), British Poultry Science (58 articles), Animals (57 articles), and Journal of Applied Poultry Science (25 articles). Moreover, in the past three years, the keywords were deep learning, housing condition, and anthelmintic agent. These results are expected to provide valuable insights for further investigation in this field.

Keywords | Animal welfare, Bibliometric analysis, Cage-free, Housing system, Laying hens, Research trend

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***Correspondence** | Ali Agus, Department of Animal Nutrition and Feed Science, Faculty of Animal Science, Universitas Gadjah Mada, Jl. Fauna, 55281, Yogyakarta, Indonesia; **Email:** aliagus@ugm.ac.id
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INTRODUCTION

The evolution of layer housing systems around the world is a dynamic narrative that reflects a combination of agricultural innovation, social values and ethical considerations. Throughout the years, the world of poultry housing has undergone significant changes. From traditional free-range systems to modern cage-free environments, the history of poultry housing reflects a journey of adaptation and transformation driven by diverse factors, including economic pressures, technological advances, and shifting consumer preferences (Elson *et al.*, 2011; Gynes, 1989). Historically, poultry keeping involved small-scale backyard flocks and extensive free-range systems, where hens had access to outdoor areas and exhibit their natural behaviours (Ayala *et al.*, 2020;

Chen *et al*., 2016; Snively-Martinez and Quinlan, 2019). However, the rise of industrialised agriculture in the mid-20th century led to significant changes in poultry housing practices, marked by the introduction of battery cages. These confined environments maximized egg production efficiency but sparked debates over animal welfare and ethical treatment (Englmaierová *et al*., 2014; Lawal *et al*., 2016; Van Hoorebeke *et al*., 2011). Animal welfare activists campaign for most or all of the Animal Welfare Council's five independent freedoms, which include freedom from hunger and thirst; from discomfort; from pain, injury, and disease; to express normal behaviour; and from fear and distress (Webster and Nicol, 1988).

In response to mounting concerns about hen welfare and shifting consumer preferences for more ethical food production, the poultry industry has undergone a paradigm shift towards alternative housing systems. This transition has led to the emergence of enriched colony systems and, more prominently, the widespread adoption of cage-free housing (Harper and Makatouni, 2002; Honkanen *et al*., 2006). Cage-free systems offer hens greater freedom of movement and the opportunity to express natural behaviours, aligning with consumer preferences for more humane and sustainable egg production (Rahmani *et al*., 2019; Whiley and Ross, 2015). In 1999, the EU implemented a ban on conventional cages for laying hens, which was phased in by 2012 (Appleby, 2003; European Union, 1999). The growing awareness among egg consumers is recognized to have prompted the implementation of rearing management focused on animal welfare by layer farms. Consequently, there has been a shift from the battery cage towards a cage-free rearing system (Shields *et al*., 2017). The ban also had an impact on several Non-European countries, as farmers started adopting a cage-free rearing system that considered animal welfare. In addition, several investigations have explored the advantages of cage-free system, developed appropriate rearing standards, and observed the impact on laying hens (Majewski *et al*., 2024; Oliveira *et al*., 2022; Rodríguez-Hernández *et al*., 2024).

Extensive research has been conducted on the impact of cage-free systems on egg production and animal welfare. de Luna *et al*. (2022) highlighted that cage-free systems pose challenges such as reduced profitability, higher costs, and biosecurity concerns for producers. Conversely, Chen *et al*. (2018) demonstrated that free-range rearing improved chicken welfare, as evidenced by the absence of severe gait problems in free-range chickens compared to caged ones. Furthermore, it has been emphasised that cage systems have a deleterious effect on the welfare of chickens, showing that standard battery cages are undesirable for welfare (El-Sabrout *et al*., 2022). Hubert *et al*. (2019) discovered that cage-free conditions resulted in higher microbial diversity, regardless of the source of dietary protein. This suggests a potential beneficial impact on the gut microbiota. Additionally, Schuck-Paim *et al*. (2021) pointed out that while cage-free facilities allow hens to move freely and express natural behaviours, there are concerns about higher mortality rates in cage-free flocks, potentially compromising some aspects of their welfare.

A substantial amount of scientific evidence has been published regarding cage-free systems in laying hens. However, there has been a lack of comprehensive bibliometric study that thoroughly investigates the existing literature, which hinders the promotion of further exploration in this field. Bibliometric analysis is a scientific method that involves using computer-assisted review to study all the publications on a particular topic or field. Its purpose is to discover the main research, authors, and relationships within a defined period of time (Liu *et al*., 2022; Nicolaisen, 2010). Bibliometrics is becoming more crucial in the management of the growing quantity of academic publications that consist of empirical contributions, resulting in extensive, fragmented, and contentious research findings (Aria and Cuccurullo, 2017). Therefore, this bibliometric study was carried out to examine and determine the annual publications, relevant affiliations, financial contributions, document sources, and keyword patterns that have influenced the scientific discussion on cage-free housing methods in laying hens. This study aimed to serve as a reference for researchers seeking information on ongoing research related to cage-free housing systems.

MATERIALS AND METHODS

Data sources and search strategy

This bibliometric research involved retrieving publications on cage-free housing systems from the Scopus database on November 6, 2023. The search query used was TITLE-ABS-KEY (cage-free, OR aviary, OR free-range, AND laying AND hens), which resulted in a total of 917 documents published from 1960 to 2023. Subsequently, books and book chapters were excluded. Articles were screened for eligibility by title and abstract. A total of 900 articles were eligible for bibliometric analysis. The article selection process can be seen in the flow chart (Figure 1). The scopus extraction tool was used to extract certain raw data in CSV formats. The extraction process comprised information fields pertaining to authors, affiliations, journals, keywords, research areas, citations, titles, and abstracts.

Bibliometric analysis

A bibliometric analysis study was carried out to systematically evaluate materials on the cage-free housing

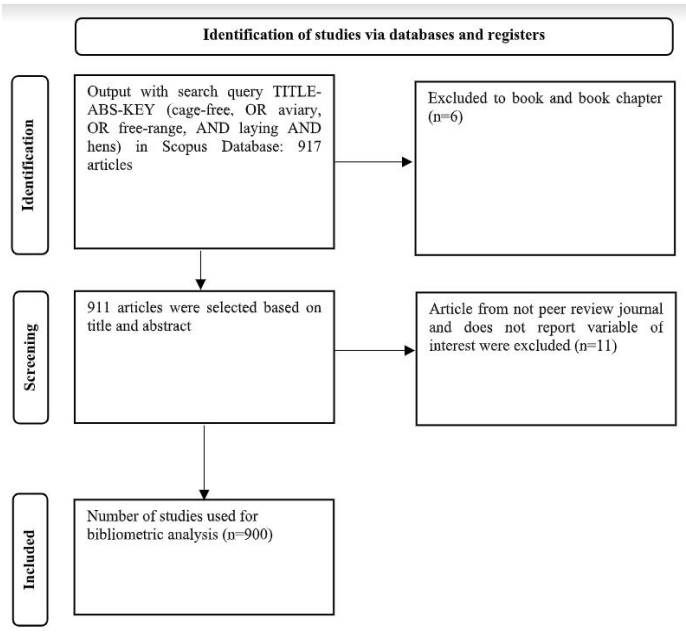

Figure 1: Flow charts of the article selection process utilized for the bibliometric analysis.

system in laying hens. The R software was used for this analysis (R programming language and RStudio version 2023.03.1). The bibliometrix R-package is an open source tool that is specifically built for bibliometric and scientometric analysis. It is available with the free and comprehensive R programming language (Rashid, 2023). The researcher used R Studio 2023.03.1 on a Windows 10 computer. This platform was utilised to collect data regarding primary publication details, annual production and citations, most cited countries, relevant sources, relevant affiliations, Word Cloud analysis, factorial analysis and thematic evolution. To launch the Biblioshiny web-interface, the developer should enter the code on RStudio using the command console. The data was imported from Scopus databases into the Biblioshiny programme for data analysis. A bibliometric analysis was performed to obtain a research output analysis of the annual publications, relevant affiliations, financial contributions, most relevant journals, document sources, and keyword patterns associated with the cage-free housing system in laying hens research area. Meanwhile, the contribution data of various research funding on cage-free housing systems in laying hens were obtained from the Analyze search results feature in the Scopus database (https://www.scopus.com) after the articles that met the specifications were selected.

RESULTS AND DISCUSSION

Annual publication output

A total of 900 documents from 246 sources were published from 1960 to 2023. These documents consisted of 88.8% research articles, 5.9% review articles, and 5.3% conference papers. A mean of 19.4 citations per document was recorded, with an average age of 8.37 years. The total number of authors was 2439, with 40 single-authored publications and an average of 4.86 co-authors per document. Table 1 displays the results, which indicate that 23.22% of the authors engaged in international collaboration. Figure 2 illustrates the annual publications and average citations from 1960 to 2023.

Table 1: General research output.

Description	Results
Timespan	1960:2023
Sources (journals, books, etc)	246
Documents	900
Annual growth rate %	7.14
Document average age	8.37
Average citations per doc	19.36
References	29183
Document contents	
Keywords plus (ID)	3436
Author's keywords (DE)	1839
Authors	
Authors	2439
Authors of single-authored docs	40
Authors collaboration	
Single-authored docs	45
Co-authors per Doc	4.86
International co-authorships %	23.22
Document types	
Article	799
Conference paper	48
Review	53

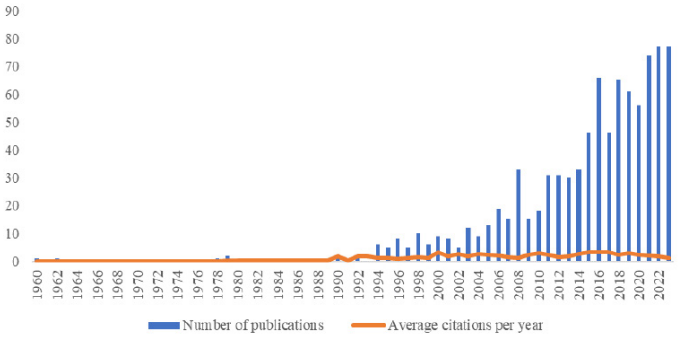

Figure 2: Trends in annual publications on cage-free housing system in laying hens.

The annual production of publications on cage-free housing system in laying hens increased steadily from one document in 1960 to 77 in 2023, with an annual growth rate of 7.14%. In 1994, there was a significant surge, with the average journal production per year rising from 0.32 articles in 1993 to 0.48 in 1994. Journal production

experienced a 120% spike in 2008, followed by a drop in 2009, and then another increase in 2011. Correspondingly, the average citations moved from 0.11 in 1962 to a peak of 1.75 in 1990, and reached 3.22 in 2017. According to Figure 3, the United Kingdom dominated the number of publications until 2000. However, Germany experienced significant growth from 12 publications in 2000 to 46 in 2001 and dominated until 2015. The United States starts to dominate cage-free publications in 2016 to 2023. The United States has the highest scientific production, followed by Germany and Australia (Figure 4).

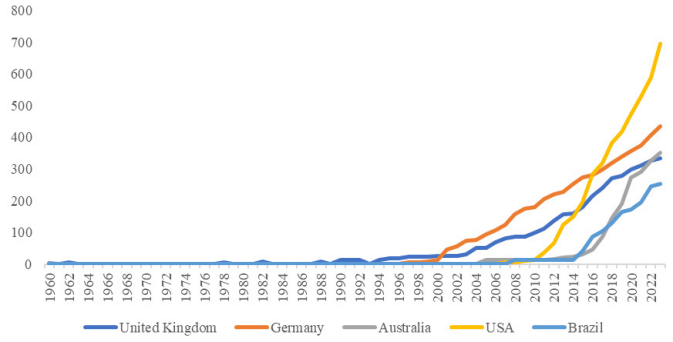

Figure 3: Annual publication trends from the top 5 productive countries.

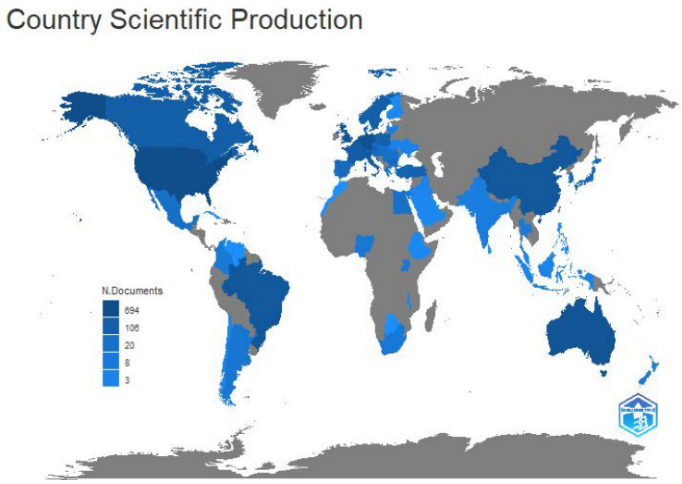

Figure 4: Country scientific production.

Contribution of Funding Agencies and Institutions

Figure 5 reveals the top five universities that published research on cage-free housing systems in laying hens. These institutions included the University of New England, Australia (4.67%), Iowa State University, USA (3.97%), University of Bristol, UK (2.54%), Michigan State University Australia (2.52%) and University of Bern, Swiss (2.49%). A summary of the top 10 funding agencies in terms of activity is shown in Figure 6. The agencies that provided the most funding were the US Department of Agriculture, USA (23 articles), the National Institute of Food and Agriculture, USA (21 articles), Conselho Nacional de Desenvolvimento Cientifico E Tecnologico, Brazil (19 articles), Biotechnology and Biological Sciences Research Council, UK (17 articles), and Egg Industry Centre (15 articles).

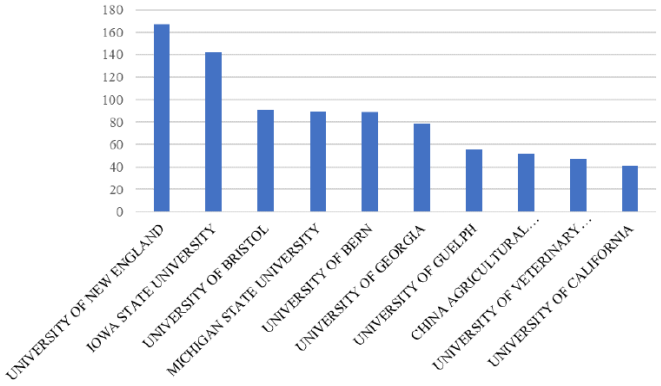

Figure 5: Most relevant affiliations of the cage-free housing system in laying hens.

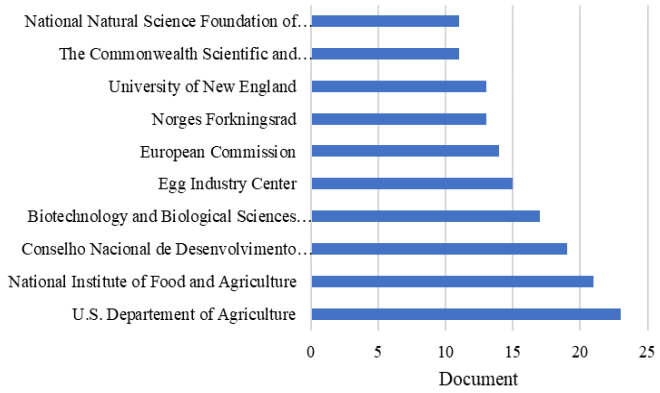

Figure 6: Contribution of various research funding on cage-free housing system in laying hens publication.

Document Sources

A total of 246 documents sources were identified, and Table 2 displays the top 10 journals that specifically cover publications on cage-free housing systems in laying hens. The Journal Poultry Science had the highest number of articles produced, followed by Applied Animal Behaviour Science, British Poultry Science, Animals, and Journal of Applied Poultry Research. Out of the top 10 journals, Poultry Science scored the highest SJR (1.1) and H-Index (162).

Keyword and Term Analysis

The Word Cloud analysis revealed that the terms female (664), animals (358), animal husbandry (351), chickens (335), and animal (330) had the greatest frequency as Keyword Plus, as shown in Figure 7. A total of 62 keywords were found from 1960 to 2023 with drinking being the earliest keyword identified (1992-1996) (Figure 8). Trending research keywords in 2023 were analysis of salpingitis, egg quality, anthelmintic agent, housing condition, and deep learning. The analysis of variance keyword has existed since 2000, but deep learning emerged in 2023.

Table 2: Top 10 most relevant sources contributing to research on cage-free housing system in laying hens.

Journal	Number of publication	Category	Quartiles/ SJR	H-Index
Poultry Science	133	Animal Science and Zoology; Medicine (miscellaneous)	Q1 / 1.1	162
Applied Animal Behaviour Science	61	Animal Science and Zoology; Food Animals	Q1 / 0.63	125
British Poultry Science	58	Animal Science and Zoology; Food Science; Genetics; Medicine (miscellaneous)	Q2 / 0.54	100
Animals	57	Animal Science and Zoology; Veterinary (miscellaneous)	Q1 / 0.68	60
Journal of Applied Poultry Research	25	Animal Science and Zoology	Q2 / 0.55	71
Animal	18	Animal Science and Zoology	Q1 / 0.9	91
Frontiers in Veterinary Science	17	Veterinary (miscellaneous)	Q1 / 0.74	54
World's Poultry Science Journal	17	Animal Science and Zoology	Q1 / 0.64	82
Archiv fur Geflugelkunde	14	Animal Science and Zoology; Food Animals	Not yet assigned quartile	30
PLoS One	14	Multidisciplinary	Q1 / 0.89	404

Figure 7: Word cloud analysis of keywords.

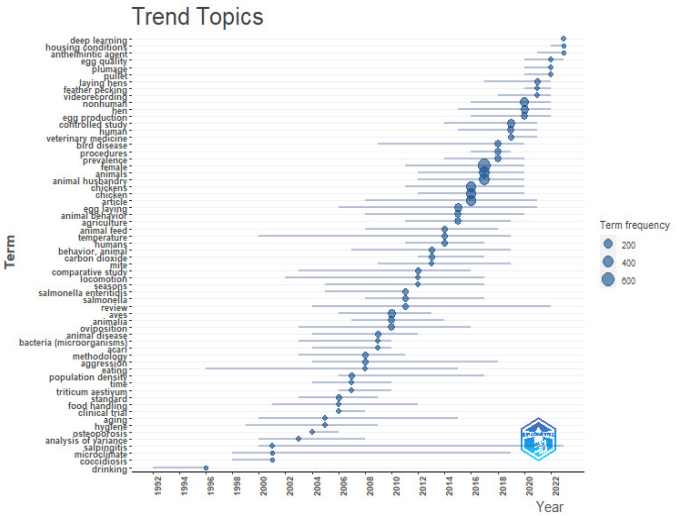

Figure 8: Trend topics of cage-free housing system in laying hens.

This research aimed to to investigate and identify annual publications, funding contributions, document sources and keyword trends that have shaped the intellectual discourse on cage-free housing systems in laying hens. The results indicated an increased number of publications in the last decade. Since the 1940s, the intensive production model, characterised by a higher stocking density and various forms of cage housing, began to gain importance (Elson *et al*., 2011). The increase in the number of publications started in 1994, presumably due to efforts by governments and markets in the United Kingdom, Australia, and the USA to encourage the improvement of layer welfare (Scrinis *et al*., 2017). The United Kingdom, as the only country that has completely banned and eliminated traditional 'battery' cages (Government of the United Kingdom, 1999) is currently participating in a renewed Europe-wide 'end the cage' campaign and petition to parliament. The campaign intends to legislate against 'furnished' cages, a kind of cage-based production that allows for additional room and the display of certain natural behaviors as opposed to outlawed conventional ones (Government of the United Kingdom, 2022). NGOs and animal welfare practitioners in the US are advocating for a transition to a cage-free production system (Shields *et al*., 2017), leading to a high number of publications on this topic. The U.S. Department of Agriculture exhibits the most funding contribution. As publications on cage-free housing systems in laying hens increase, the number of citations also increases. This occurrence may be due to the increase in research on cage-free systems at several universities.

The primary sources were Poultry Science, Applied Animal

Behaviour Science, and British Poultry Science. Recent researches in Poultry Science have focused on various aspects. A study conducted by Ciarelli *et al.* (2023) reported the impact of additional perches and genotype on the space use and navigation ability of hens in aviary housing during the laying phase. Another study described the effect of piling behaviour on the production and mortality of free-range laying hens (Armstrong *et al.*, 2023) and scratch area as an epidemiological risk factor for Spotty Liver Disease in cage-free layers in Australia (Gao *et al.*, 2023). All of these journals were written in English language, with Poultry and Applied Animal Behaviour Science included in the first quartile for Animal Science and Zoology. Meanwhile, British Poultry Science was placed in the second quartile. Poultry Science encompasses a broad range of research topics in animal production and fundamental aspects of poultry. It is the top-ranked journal, based on its Impact Factor, that focuses on publishing poultry research.

The salpingitis in cage-free housing systems has been a popular research topic from 2000 to 2023. Salpingitis, characterized by inflammation and distension of the oviduct, is a recurrent pathology in laying hens (Saraiva *et al.*, 2021). It is often associated with bacterial infections, with *Escherichia coli* being a common causative agent (Poulsen *et al.*, 2020). *Gallibacterium anatis* has also been identified as a significant pathogen leading to peritonitis and salpingitis in laying hens (Johnson *et al.*, 2011). The incidence of salpingitis, oophoritis, and egg peritonitis in commercial laying hens has been reported to be around 8.26% (Hassan *et al.*, 2015). The housing system plays a crucial role in the prevalence of diseases like salpingitis in laying hens. Enriched cage and cage-free systems have been designed to allow hens to exhibit natural behaviors and move around, but concerns have been raised about higher mortality rates in cage-free systems (Petrovič and Mellen, 2023). The prevalence of diseases like salpingitis can impact egg production and quality, emphasizing the importance of managing health conditions in laying hens to ensure optimal productivity (Wang *et al.*, 2020).

Deep learning is a concept that starts to emerge in 2023. The application of deep learning in the context of cage-free laying hens has gained attention in recent research. Yang *et al.* (2022) developed a deep learning model, YOLOv5x-hens, based on YOLOv5, to monitor hens' behaviours in cage-free facilities. Furthermore, research conducted by Petrovič and Mellen (2023) evaluated laying hen breeding conditions and egg quality in cage and cage-free systems, observing differences in hen mortality between aviaries, cages, and deep litter systems. It emphasises the importance of considering the impact of housing systems on the well-being and survival of laying hens. Additionally, Li *et al.* (2015) studied the effects of furnished cage type on the behaviour and welfare of laying hens, finding differences in standing and walking behaviour depending on cage type. This underscores the relevance of housing design in influencing the behaviour and welfare of laying hens in cage-free systems. Due to the advances in Artificial Intelligence (AI), record numbers of jobs previously performed by people have been automated. This includes many sectors such as manufacturing, transportation, and customer services (Mahmud *et al.*, 2024). In the future, there will be a greater emphasis on in-depth and extensive research in the field of deep learning. This is driven by the necessity to improve efficiency in the laying hen business through the implementation of technology in cage-free cage systems.

Moreover, recent study also focused on housing conditions in cage-free systems for laying hens. Housing conditions significantly impact the welfare, health, behaviour, and productivity of cage-free laying hens. The choice of housing system can influence various aspects of the hens' health, behaviour, and performance. For instance, studies have shown that different housing systems can influence the prevalence of keel bone fractures in laying hens, with implications for pain perception and mobility (Nasr *et al.*, 2012). Additionally, the housing system has been linked to variations in egg quality, including weight, cholesterol concentration, and shell characteristics (Lichovníková and Zeman, 2008; Zemková *et al.*, 2007). Furthermore, the housing environment can affect the stress levels, adrenal reactivity, and immune response of laying hens, highlighting the importance of providing suitable and stress-free housing conditions (Koelkebeck *et al.*, 1986; Moe *et al.*, 2010; Spindler *et al.*, 2020). The impact of housing conditions extends beyond individual health and behaviour to broader environmental and production-related factors. For example, the housing system has been associated with variations in ammonia emissions, thermal environment, and ventilation rates, which are critical for maintaining optimal air quality and thermal comfort for the hens (Liang *et al.*, 2005; Lin *et al.*, 2018; Zhao *et al.*, 2013).

Anthelmintic are frequently mentioned in research on cage-free housing systems in laying hens. Anthelmintic agents are essential for maintaining the health and welfare of laying hens in cage-free production systems. The prevalence of helminth infection in laying hens is associated with various welfare indicators, such as back feathering and foot injuries, emphasising the impact of housing systems on the health and welfare of hens (Hinrichsen *et al.*, 2016). Additionally, the possibility of helminths acting as pathogen vectors pose a potential threat to the health of livestock and humans, further highlighting the impact of helminth infection in cage-free systems (Lacharme-Lora *et al.*, 2009).

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, there have been a total of 900 publications on the topic of cage-free housing systems in laying hens from 1960 to November 6th, 2023. The highest number of publications occurred in 2022 and 2023, with 77 articles published during these years. It is likely that the number of publications will continue to increase in 2023. The United States has the highest scientific production, followed by Germany and Australia. Trending terms in publications published in 2023 are deep learning, housing condition, anthelmintic agent and salpingitis.

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NOVELTY STATEMENT

There is no research that examines research trends regarding cage-free housing systems in laying hens using bibliometric analysis.

AUTHOR'S CONTRIBUTION

The authors confirm contribution to the paper as follows: study conception and design: Ali Agus; draft manuscript preparation: Anom Yusuf Tri Bambang Susiloi, and Muhammad Fathun Hanif; revise manuscript: Bambang Ariyadi and Ahmad Romadhoni Surya Putra; data collection: Muhammad Fathin Hanif; analysis and interpretation of results: Muhammad Fathin Hanif; and All authors reviewed the results and approved the final version of the manuscript.

Conflict of interest

The authors declare that they have no conflicts of interests with any financial and organisation related to the materials discussed in the paper.

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