

A comprehensive systematic review and bibliometric analysis of housing on growth and reproductive performance of rabbits

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ABSTRACT: Rabbit production contributes to animal protein supply and farm income, but housing directly affects welfare, growth and reproductive efficiency. Evidence on rabbit housing is dispersed and sometimes inconsistent. This study systematically reviewed and bibliometrically mapped research on the relationship between housing systems and rabbit growth and reproductive performance. Records were retrieved from Scopus using a structured Boolean search, screened according to PRISMA 2020, and analysed with Bibliometrix in R and VOSviewer. From 130 records, 28 studies met the final eligibility criteria. Hungary recorded the highest country output with 30 documents, followed by Italy with 28 and India with 24, while Italy had the highest country citation count with 55 citations. The most highly cited document in the dataset was the 2007 study by Cabezas and Moreno with 48 citations. Keyword co-occurrence analysis identified four connected themes: housing, welfare and reproductive outcomes; growth performance and physiology; nutrition and feeding systems; and controlled experimentation across housing systems. Collaboration was concentrated mainly in European networks, with limited African representation despite contributions from Egypt, Ethiopia and Nigeria. These findings show that rabbit housing is a life science issue linking animal welfare, physiology, reproduction and food production. Future research should broaden geographical coverage and compare housing systems using integrated welfare and productivity indicators.

KEYWORDS: Growth performance, Housing system, Rabbits, Reproductive performance, Welfare

INTRODUCTION

Rabbits (*Oryctolagus cuniculus*) are efficient small livestock species that contribute meat and farm income in many production systems [1]. Their short generation interval, rapid growth and ability to convert fibrous feed resources into animal protein make rabbit production relevant to food and agricultural life sciences. Production efficiency, however, depends not only on genetics and nutrition but also on the environment in which the animals are housed.

Housing is a direct component of rabbit welfare because it determines available space, flooring, social contact, ventilation, thermal conditions and opportunities for species typical behaviour. Inadequate or poorly managed housing can alter behaviour, physiological responses, health and productive performance [2-4]. Environmental enrichment and appropriate housing design can reduce abnormal behaviour and improve the expression of normal activity [5]. Current welfare research therefore treats housing as both a biological and a management factor rather than simply a physical enclosure [6].

Growth and reproductive performance are central outcomes in rabbit production. Growth rate affects time to market and production efficiency [7], while reproductive performance depends on factors such as parity, litter size, weaning age and reproductive rhythm [8, 9]. Stress can also affect feed intake and biological performance [10]. Evidence from housing studies indicates that the effects of individual, group and enriched systems are not uniform across growth, welfare and reproductive outcomes [11-13].

The literature illustrates this complexity. Individual housing has been associated with higher growth in some fattening studies, whereas group and alternative systems may improve behavioural opportunities but can introduce competition, aggression or injury risks [14-16]. Other work has shown that floor type, pen design and management strategy can modify performance and behaviour within group systems [17, 18]. These mixed findings make it difficult to draw conclusions from isolated experiments alone.

Accordingly, a systematic synthesis is needed to describe how the field has developed, identify the major research networks and clarify the main themes linking housing with growth and reproductive performance. This

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review addresses three research questions: (1) What is the scientific performance of authors, institutions and countries researching the effects of housing on rabbit growth and reproductive performance? (2) How do authors, institutions and countries collaborate within this research area? (3) What major themes and evidence patterns characterize research on different rabbit housing systems and their relationships with growth and reproductive performance?

METHODOLOGY

Article search and identification

This study combined a systematic literature review with bibliometric analysis. Study identification and screening were structured according to the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA 2020), to improve transparency and reproducibility [19]. The review process involved defining the research questions, developing the search strategy, identifying records, applying eligibility criteria, extracting bibliographic information, analysing the retained records and reporting the findings. Comparable review designs have also been used to integrate systematic evidence synthesis with bibliometric mapping [20, 21].

Scopus was used as the bibliographic database because it provides broad multidisciplinary coverage and exports the citation metadata required for bibliometric analysis. Search terms were developed around four concepts: housing, growth, reproduction and rabbits. Synonyms and related terms were combined with the Boolean operators AND and OR. The search was applied to titles, abstracts and keywords to retrieve records relevant to the review questions. The final search expression was:

(impact OR influence OR effect OR consequences OR implication OR outcome) AND (breeding OR reproduction OR "reproductive performance" OR parturition OR prolificacy OR "body weight" OR "feed efficiency" OR "carcass quality") AND ("growth rate" OR "growth performance" OR production) AND (housing OR "housing system" OR confinement OR management OR "cage system" OR "pen system" OR "intensive system" OR "group housing" OR "individual housing" OR "animal welfare" OR "floor type") AND ("*Oryctolagus cuniculus*" OR "breeding does" OR "lactating does" OR rabbits OR "rabbit doe").

Protocol used detailing inclusion and exclusion criteria

After retrieval, records were screened using predefined inclusion and exclusion criteria. The review focused on empirical studies relevant to rabbit housing, growth, reproduction, welfare or closely related performance outcomes. Review articles were excluded to avoid duplicating secondary evidence, and only English language records were retained. Titles, abstracts and full record information were then examined for relevance to the review questions. The initial search returned 130 records. Nineteen review articles were excluded, leaving 111 empirical records. Nine non English records were then excluded, leaving 102 records. Two duplicates were removed, leaving 100 records for eligibility assessment. Screening of titles, abstracts and available content excluded a further 72 records, resulting in 28 studies for the final systematic and bibliometric analyses. The selection process is summarized in Figure 1.

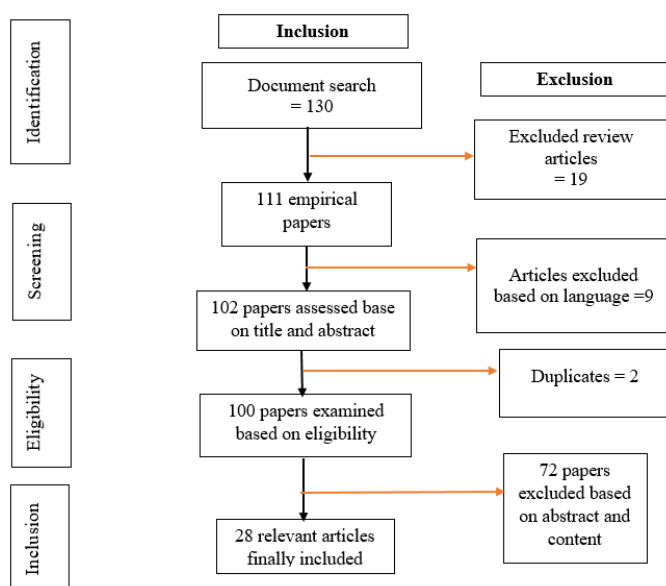


Figure 1. PRISMA flow chart. Source: Authors' screening process based on PRISMA 2020 [19].

RESULTS AND DISCUSSION

Performance analysis

The geographical distribution in Figure 3 shows that research production was concentrated in Europe, followed by Asia and Africa. This concentration is important for interpreting the evidence because housing performance is influenced by climate, production intensity and management conditions. Broader geographical coverage would therefore strengthen the applicability of future findings to diverse rabbit production environments.



Country Scientific Production



Figure 4 shows the country contribution pattern. Hungary recorded the highest output with 30 country attributed documents, followed by Italy with 28 and India with 24. Spain and Switzerland each recorded 9, the Czech Republic 8, Belgium and Egypt 4 each, and Ethiopia and Nigeria 3 each. The pattern confirms a strong European contribution and also shows that African participation, although limited, is represented by Egypt, Ethiopia and Nigeria. The country pattern should be interpreted as a description of the bibliographic dataset rather than as a direct measure of national research funding or production capacity. Nevertheless, the limited representation of several regions identifies an evidence gap. More studies from tropical and low resource production settings would improve the life science evidence base on how climate and housing interact with rabbit health, welfare and productivity.

Figure 5 presents citation totals by country. Italy had the highest citation count with 55 citations, followed by Canada with 48 and Hungary with 47. Spain recorded 39 citations, India 20, Ethiopia 17, the Czech Republic 13, Switzerland 10, Nigeria 5 and Pakistan 3. These results show that publication volume and citation influence are related but not identical indicators of research activity.

Figure 6 ranks the most globally cited documents represented in the dataset. The highest cited document was the 2007 study by Cabezas and Moreno, with 48 citations, which examined translocation success and habitat improvement in wild rabbits [26]. The next leading document was the 2009 study by Rebollar and colleagues on parity order and reproductive management in rabbit production systems [27]. Together, these highly cited records illustrate the field's links with habitat management, reproduction and productive performance.

Figure 7 shows the most relevant affiliations. Kaposvár University recorded the largest contribution with 19 documents. The University of Bern and the University of Padova each recorded 7 documents, while the University of Naples Federico II recorded 6. Several other institutions contributed five or four documents. The concentration of output in a relatively small group of institutions helps explain the dense European collaboration patterns observed later in the network analysis.

Figure 8 identifies Livestock Science and World Rabbit Science as the leading publication sources in the dataset. Other recurrent sources include Animal, Animals, the Indian Journal of Animal Sciences, Livestock Research for Rural Development and Meat Science. The distribution indicates that research on rabbit housing is situated at the intersection of animal science, welfare, production and meat quality.

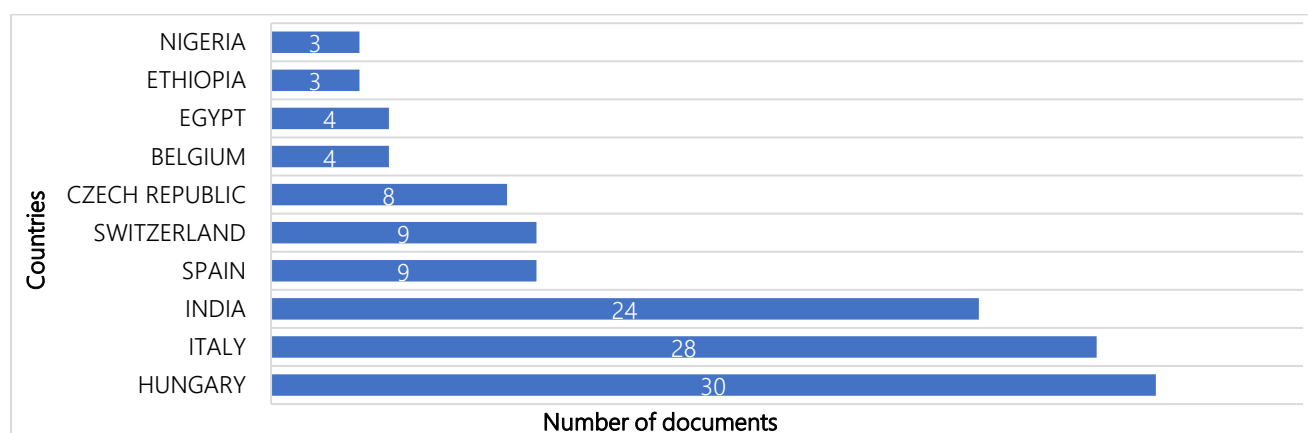


Figure 4. Country scientific production. Source: Authors' analysis of the Scopus dataset using Bibliometrix.

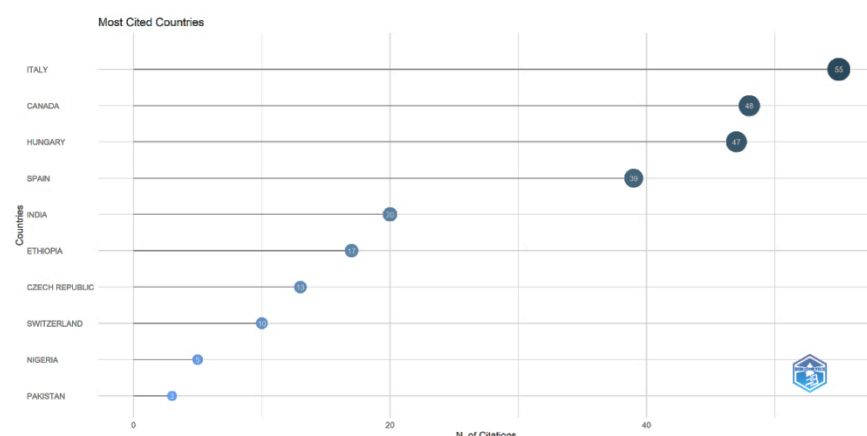


Figure 5. Most cited countries. Source: Authors' analysis of the Scopus dataset using Bibliometrix.

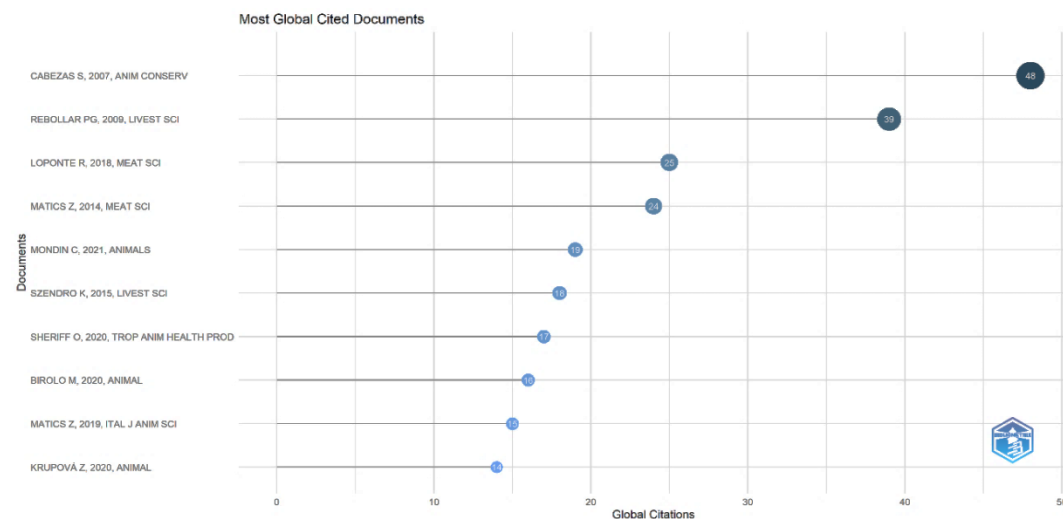


Figure 6. Most globally cited documents. Source: Authors' analysis of the Scopus dataset using Bibliometrix.

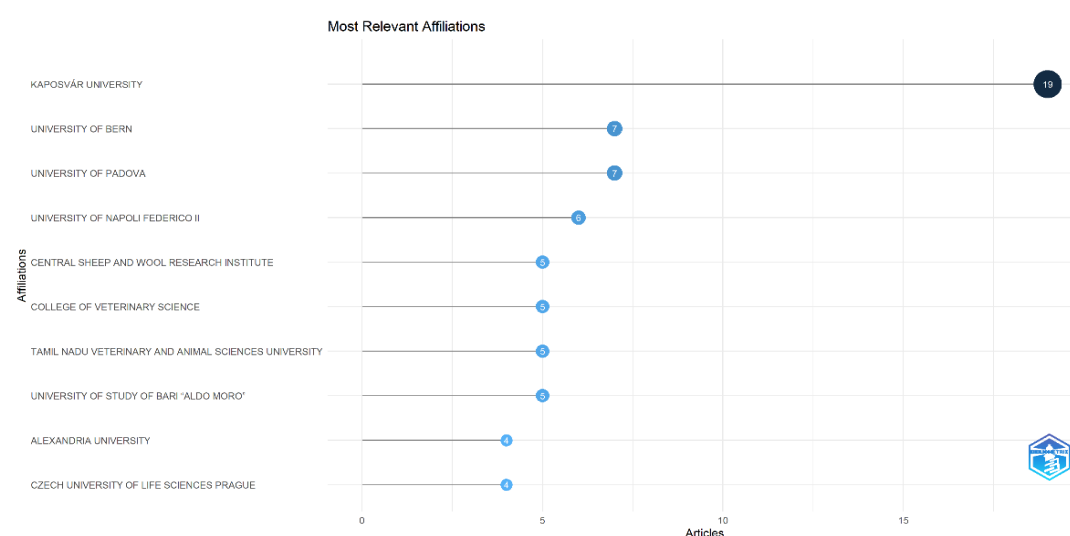


Figure 7. Most relevant affiliations. Source: Authors' analysis of the Scopus dataset using Bibliometrix.

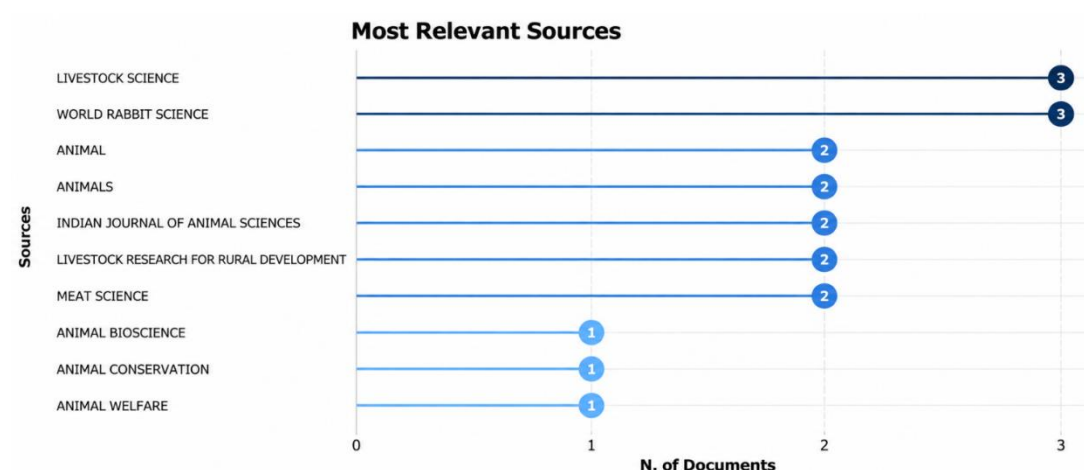


Figure 8. Most relevant publication sources. Source: Authors' analysis of the Scopus dataset using Bibliometrix.

Science mapping

Science mapping complements performance analysis by examining relationships among publications, concepts and research actors [28, 29]. In the present study, keyword co-occurrence, co-citation, country collaboration, author collaboration, institutional collaboration and bibliographic coupling were used to describe the conceptual, intellectual and social structure of the field.

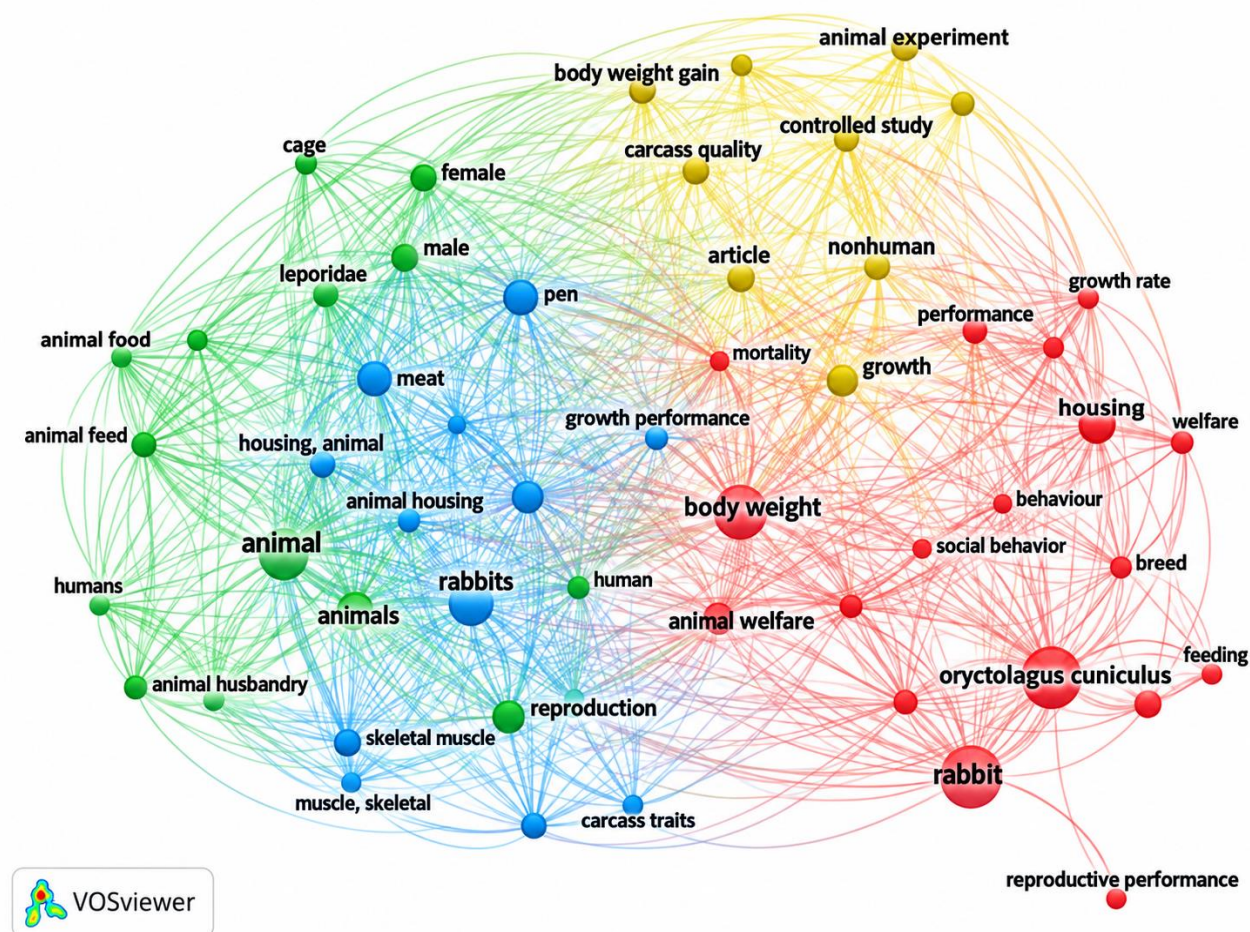


Figure 9. Keyword co-occurrence network. Source: Authors' analysis of the Scopus dataset using VOSviewer.

The keyword co-occurrence network in Figure 9 contains four closely connected thematic clusters. The red cluster is centered on housing, animal welfare and reproductive performance. The yellow cluster emphasizes growth, body weight and physiological performance. The green cluster links nutrition, feeding and meat related outcomes, while the blue cluster is dominated by controlled studies and experimental housing terms. The overlap among clusters shows that housing is studied as a multidimensional life science factor that interacts with welfare, physiology, feeding and reproduction.

Red cluster: Housing welfare and reproductive outcomes

The red cluster links terms such as housing, animal welfare, behaviour and reproductive performance. Its structure indicates that a substantial part of the literature evaluates housing not only by productivity but also by the welfare and reproductive consequences of the environment provided to rabbits.

Yellow cluster: Growth performance and physiology

The yellow cluster is organized around growth, body weight, body weight gain and performance. These terms reflect the use of measurable biological outcomes to evaluate how housing conditions influence development, feed use and production efficiency.

Green cluster: Nutrition and feeding systems

The green cluster contains terms associated with animal feed, meat quality, husbandry and related production characteristics. This cluster demonstrates that housing is often evaluated together with feeding and product quality, rather than as an isolated management variable.

Blue cluster: Experimentation and controlled studies in different housing systems

The blue cluster contains terms such as controlled study, animal experiment and housing related experimental descriptors. It reflects the strong experimental orientation of the literature and the use of controlled comparisons to test the effects of housing design, stocking arrangement and management conditions. Taken together, the four



The word cloud in Figure 10 reinforces the keyword network. *Oryctolagus cuniculus*, body weight, rabbit, animal, female, breeding, reproduction and animal welfare are among the most prominent terms. Their relative prominence confirms that the literature is strongly focused on the biological consequences of housing for growth and reproductive function.

Terms related to pens, animal husbandry and feeding show that management and physical housing are frequently considered together. Reproduction and breeding terms also indicate sustained attention to doe performance and the biological processes that determine flock replacement and productivity. Meat quality, carcass traits and production terms connect housing research with food production outcomes. This link is relevant to life science because changes in housing may affect both animal well being and the quantity or quality of animal products available to consumers. The presence of controlled study and animal experiment terms reflects the experimental basis of much of the field. Overall, the word cloud supports the interpretation that rabbit housing research integrates welfare, physiology, nutrition, reproduction and production outcomes.



Figure 11. Reference co-citation network. Source: Authors' analysis of the Scopus dataset using VOSviewer.

Figure 11 presents the co-citation structure of the references. In a co-citation map, references located within the same cluster are cited together more often than would be expected from isolated citation patterns. The map therefore identifies groups of studies that have jointly shaped the intellectual foundations of rabbit housing research.

The network indicates a cluster of foundational work on housing conditions and growth, a cluster emphasizing behaviour and welfare, and a cluster associated with quantitative assessment of performance and reproduction.

The proximity of these groups shows that welfare and production research are not separate literatures but are commonly connected through shared references.

The welfare oriented portion of the map is particularly relevant to current rabbit production because it connects social housing, enrichment and behavioural outcomes with growth and reproductive performance. These links support the use of integrated outcome measures when comparing housing systems.

The co-citation structure also highlights the methodological role of performance measurement and statistical analysis. This confirms that the field has developed through repeated comparison of biological outcomes under different housing and management conditions rather than through descriptive housing studies alone.

Figure 12 shows the strongest country collaboration links among Italy, Hungary and Switzerland. Italy occupies an intermediary position, with visible links to both Hungary and Switzerland. The network therefore suggests that European collaboration has played a major role in the development of this research area.

The absence of a visible direct link between some countries should not be interpreted as evidence that no collaboration exists outside the displayed threshold. Instead, the map summarizes the strongest relationships represented in the dataset. The limited number of visible country links nevertheless indicates scope for broader international collaboration, particularly with underrepresented regions.

The author collaboration network in Figure 13 shows several connected research groups. Authors such as Gerencsér, Szendrő and Dalle Zotte occupy prominent positions within the displayed network, while other authors link smaller clusters. This structure reflects a field in which repeated collaboration among specialist groups has contributed to cumulative knowledge on housing, welfare and rabbit performance.

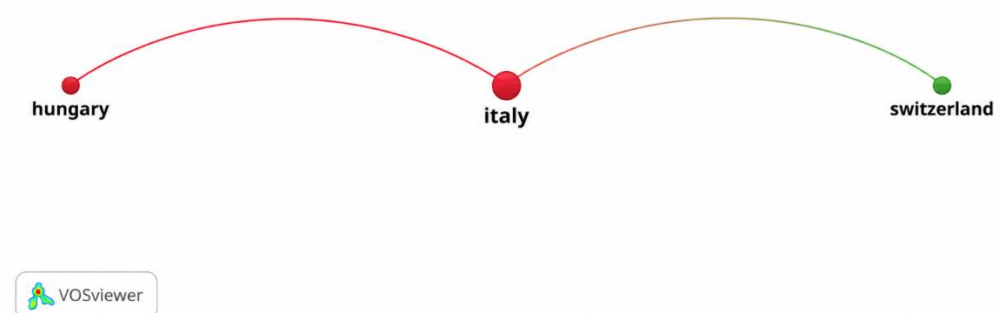


Figure 12. Collaboration between countries. Source: Authors' analysis of the Scopus dataset using VOSviewer.

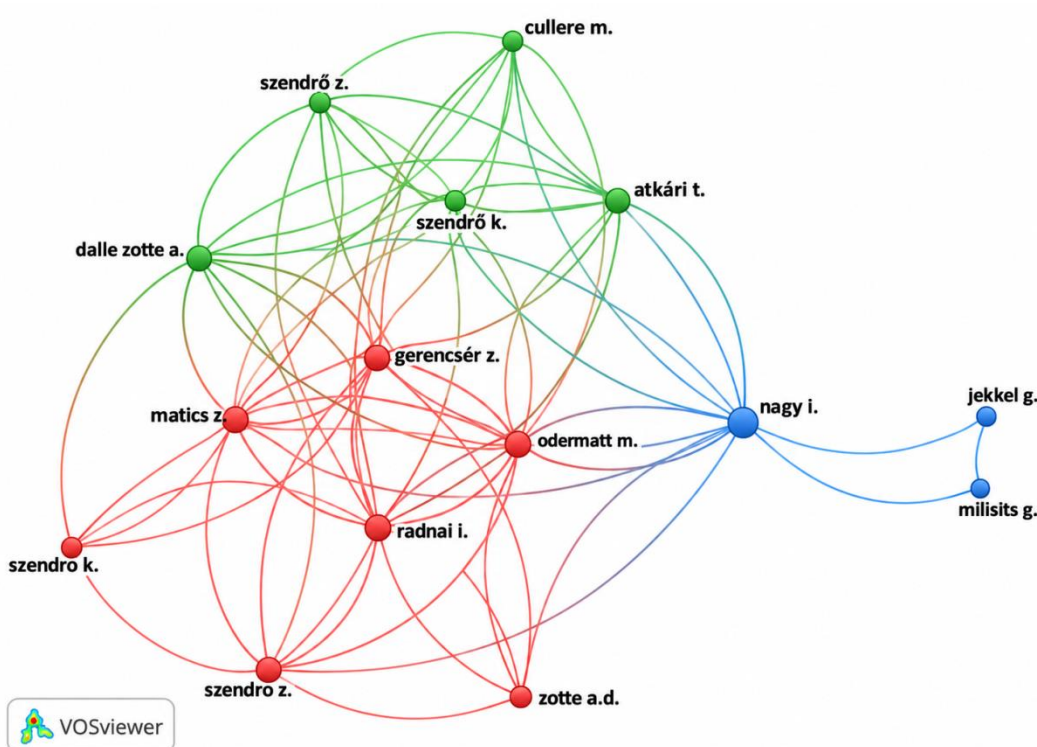


Figure 13. Collaboration among authors. Source: Authors' analysis of the Scopus dataset using VOSviewer.

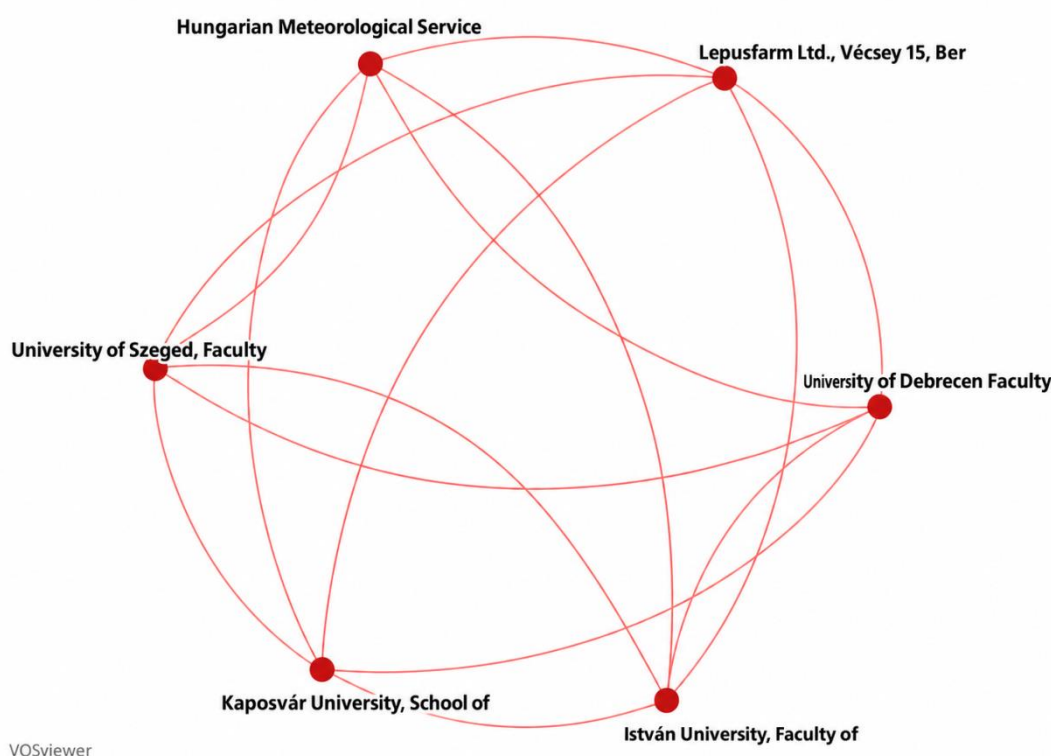


Figure 14. Collaboration among organizations. Source: Authors' analysis of the Scopus dataset using VOSviewer.

Figure 14 presents collaboration among organizations. Each node represents an institution and the connecting lines indicate co-authorship relationships between institutions represented in the bibliographic dataset.

Kaposvár University and institutions associated with Szent István University occupy prominent positions in the network. Other connected institutions include the University of Debrecen and agricultural and animal science units represented in the dataset. The pattern is consistent with the strong country level contribution of Hungary and neighboring European research networks.

The density of institutional links indicates repeated sharing of expertise across organizations. Such collaboration is valuable in animal and life science research because housing studies often require combined expertise in animal behaviour, reproduction, physiology, nutrition and production management.

The map also contains non university organizations, including industry and public service actors. Their presence suggests opportunities for translating research findings into commercial housing design, farm management and welfare practice. Expanding these links to institutions in underrepresented regions could improve the relevance of future housing research across different production environments.

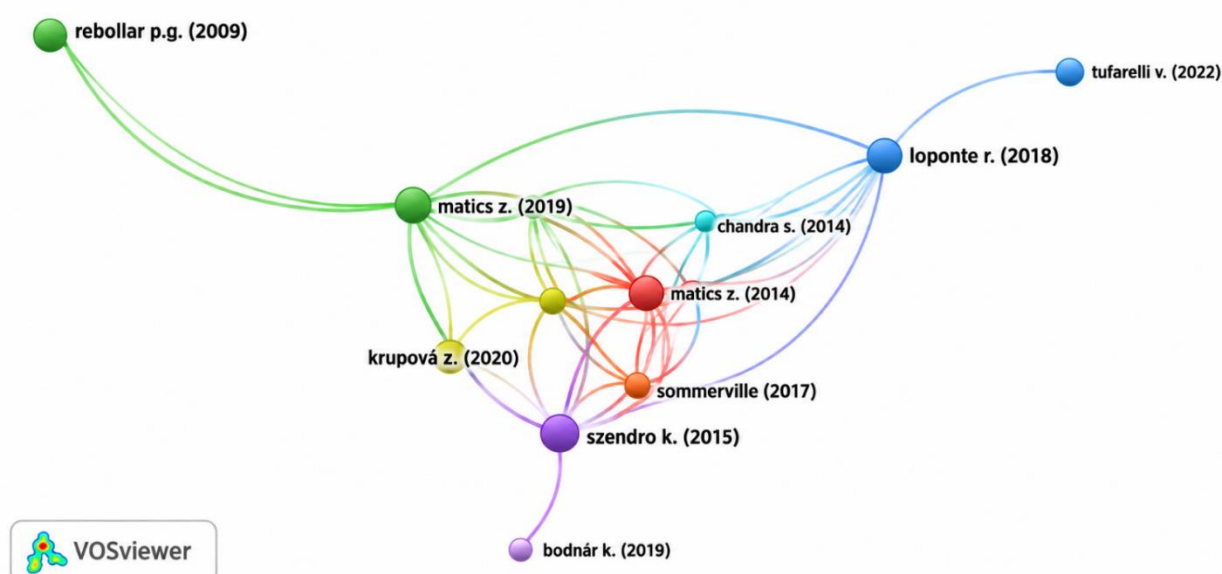


Figure 15. Bibliographic coupling by documents. Source: Authors' analysis of the Scopus dataset using VOSviewer.

Bibliographic coupling, presented in Figure 15, links documents that cite common references. Stronger coupling indicates greater similarity in the knowledge base used by the documents and helps identify groups of studies addressing related questions.

The coupling network separates the literature into several connected groups that broadly reflect reproductive management, production efficiency, welfare, housing design and biological performance. The overlap among these groups is consistent with the keyword and co-citation analyses, which show that housing research is multidisciplinary and that welfare and productivity outcomes are frequently examined together.

The network also shows that no single theme completely dominates the field. Instead, different lines of research share common references and contribute complementary evidence on how housing conditions interact with rabbit growth, reproduction, welfare and management.

CONCLUSIONS AND RECOMMENDATIONS

This study systematically reviewed and bibliometrically mapped research on the relationship between rabbit housing, growth and reproductive performance. From 130 records initially retrieved from Scopus, 28 studies met the final eligibility criteria. Analysis with Bibliometrix and VOSviewer showed that the literature is concentrated in a relatively small number of countries, institutions and research groups, with Europe contributing the strongest publication and collaboration networks.

Hungary recorded the highest country output in the dataset, while Italy had the highest citation total. The most cited document was the 2007 study by Cabezas and Moreno. Keyword analysis identified four connected themes: housing, welfare and reproductive outcomes; growth performance and physiology; nutrition and feeding systems; and controlled experimentation across housing systems. These themes demonstrate that rabbit housing is a life science issue because it directly connects the physical environment with behaviour, physiology, reproduction, growth and food production.

Future research should broaden geographical participation, particularly in African, Asian and other underrepresented production environments, and should compare housing systems using standardized measures of welfare, growth, reproductive performance and health. Greater collaboration across animal science, veterinary science, nutrition and farm management will help generate housing recommendations that protect rabbit welfare while supporting efficient and sustainable production. The findings of this review provide a structured evidence base for researchers, producers and decision makers seeking to evaluate rabbit housing using both biological and productivity outcomes.

DECLARATIONS

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Data availability

The bibliographic dataset and analysis files used in this review are available from the corresponding author on reasonable request.

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Authors' contributions

Peter Asiedu: conceptualization, methodology, supervision, writing review and editing. Musa Amara Mohammed: literature search, data curation and writing original draft. Moses Addo Nartey: data curation, validation and writing review and editing. Josephine Darkowaa Nketia: literature search, data curation and writing original draft. All authors reviewed and approved the final manuscript.

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Consent for publication

All authors reviewed and approved the final manuscript and consent to its publication.

Competing interests

The authors declare that they have no competing interests.

Ethics approval

Not applicable. This study analysed published bibliographic records and did not involve direct experimentation on animals or human participants.

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