From Traditional Feeding to Precision Feeding: A Bibliometric Analysis of Machine Learning-Based Approaches

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***Abstract*—** The integration of machine learning into animal nutrition has led to the emergence of precision feeding and precision livestock farming as key approaches for improving sustainability and efficiency in livestock production. This study aims to provide a bibliometric analysis of scientific publications on machine learning applications in precision feeding and livestock systems. Data were collected from the Web of Science Core Collection using keywords related to "precision feeding," "precision livestock farming," and "machine learning." The analysis was performed using the Bibliometrix R package to evaluate publication trends, leading contributors, and research patterns. The results showed a rapid increase in scientific production, particularly after 2020, indicating growing research interest in this field. China and the United States were identified as the leading contributors, while international collaboration was found to be relatively limited. The findings also highlight the increasing use of machine learning techniques to enhance feed efficiency and support sustainable livestock management. As a conclusion, this study demonstrates that machine learning-driven precision feeding is a rapidly evolving research area with significant potential for future development.

***Keywords*—** Machine learning, Deep learning, Artificial intelligence, Precision feeding, Feed efficiency, Livestock, Data-driven agriculture, Bibliometrics.

I. Introduction

The livestock sector is undergoing a continuous transformation to meet the growing global population and the resulting increase in demand for animal protein. In this transformation, traditional animal feeding practices are being replaced by more efficient, sustainable, and data-driven systems. The high share of feed costs in total production costs has made optimizing feeding strategies a critical necessity [1]. In this context, precision feeding approaches developed in recent years contribute to both economic and environmental sustainability by enabling rations to be adjusted to the individual needs of animals [2].

The concept of precision feeding is considered a key component of precision livestock farming (PLF) systems, which are addressed within a broader framework. Precision livestock farming aims to continuously monitor and analyze the physiological and behavioral characteristics of animals through sensor technologies, data collection systems, and automation tools [3]. Thanks to these systems, parameters such as feed consumption, growth performance, and health status can be monitored in real time, thus enabling more informed feeding decisions [4].

At the heart of this technological transformation are machine learning and artificial intelligence. Machine learning algorithms offer significant advantages in prediction and decision-support processes by extracting meaningful patterns from large, complex datasets. Successful applications have been reported in many areas, particularly in livestock farming, including feed consumption estimation, growth performance modeling, disease detection, and increased feed efficiency [5,6]. For example, Random Forest, Support Vector Machines (SVM), and deep learning-based models stand out as effective tools for predicting animal performance with high accuracy [7].

Traditional feeding systems generally involve fixed-ration applications based on herd averages, but this approach ignores individual differences and can lead to inefficient resource utilization. In contrast, machine-learning-supported precision feeding systems enable the development of more dynamic and adaptable feeding strategies by analyzing data at the individual-animal level [8]. This approach enhances feed efficiency while simultaneously mitigating environmental impacts, such as nitrogen and phosphorus emissions [2].

In recent years, the number of published studies on machine learning and precision feeding has increased significantly. However, bibliometric studies that systematically reveal the general trends, research focuses, and development directions of scientific production in this field are limited. Bibliometric analyses contribute to understanding the processes of scientific development by making quantitative and qualitative evaluations of publications in a specific research area [9]. Such analyses provide researchers with important information for identifying gaps in the existing literature and shaping future research directions.

The aim of this study is to examine the literature on machine

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learning-based precision feeding and precision animal husbandry approaches using bibliometric methods to reveal research trends in this field and to shed light on future research directions. In this context, studies indexed in the Web of Science database were analyzed to evaluate the development of scientific production on the subject, key research themes, and prominent approaches.

II. MATERIALS AND METHODS

In the current study, the bibliometric analysis method was used to examine the scientific development of machine learning-based precision feeding and precision animal husbandry approaches in the field of animal nutrition. Bibliometric analysis is a widely used method for revealing scientific trends, research foci, and collaborations by enabling the quantitative evaluation of publications in a particular research area [9].

Research data was obtained from the Web of Science Core Collection database, which provides comprehensive and high-quality indexing of scientific publications. During the data collection process, the following search query was used to cover publications related to the subject area:

("precision feeding" OR "precision livestock farming") AND ("machine learning" OR "artificial intelligence" OR "deep learning").

The obtained bibliographic data were analyzed and visualized using the Bibliometrix package in R software [10]. Within the scope of the analysis, the number of publications by year, the most productive countries, institutions, and authors, and the most frequently used keywords were determined. In addition, citation analyses were carried out to identify prominent studies in the literature. Keyword co-occurrence analyses were performed, and network-based visualization techniques were used to reveal the conceptual structure in the research area. Thanks to these analyses, research trends and thematic concentrations in the field of machine learning-based precision feeding and precision animal husbandry were evaluated in detail.

III. RESULTS AND DISCUSSION

Examining the general statistics of the bibliometric dataset presented in Figure 1 shows that the studies included in the analysis were published between 2017 and 2025. This clearly demonstrates that the research area is a relatively new and current field of study.

Fig. 1. Overview of the bibliometric data.

A total of 465 documents and 153 sources (journals, etc.) were analyzed, indicating that the topic is addressed across a wide range of publications. The high annual growth rate of 73.34% indicates that academic interest in machine learning-based precision feeding and precision animal husbandry has increased rapidly in recent years.

The dataset includes 1807 authors, demonstrating the field's interdisciplinary nature and the contributions of numerous researchers. The average document age was 5.98 years, supporting the idea that the literature largely consists of current studies.

Furthermore, the average number of citations per document (31.24) indicates that the studies examined have a significant impact on the literature. The average annual citation rate of 17.07 indicates that the studies attract attention and receive citations quickly.

The use of 18,454 references demonstrates that the studies are grounded in a strong literature base and indicate a deepening of the field academically.

Overall, these findings reveal that machine learning-based precision feeding and precision animal husbandry is a rapidly growing, highly impactful, and dynamic research area in recent years.

Figure 2 presents the change in the number of scientific publications over the years in the field of machine learning-based precision feeding and precision animal husbandry. The findings reveal that the publication process, which began in 2017, has shown a significant upward trend, especially in recent years.

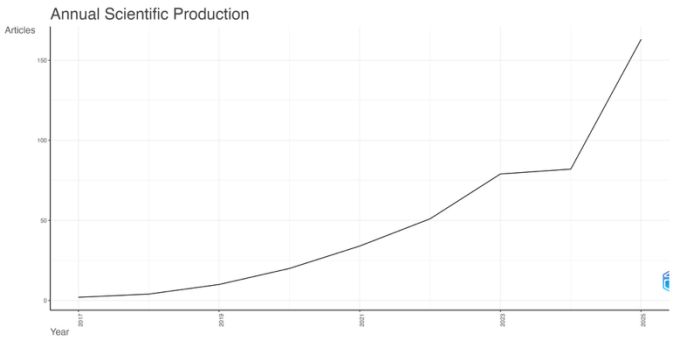

Fig. 2. Annual scientific production in machine learning-based precision feeding and livestock systems.

The number of publications was quite limited between 2017 and 2019, but the upward trend accelerated from 2020 onwards. This increase became particularly pronounced after 2021, with a significant jump observed in 2023. The increase continued at a more moderate pace in 2024, but the number of publications rose sharply in 2025, reaching its highest level. This trend demonstrates the accelerated integration of machine learning and artificial intelligence technologies into the livestock and animal nutrition fields over the past few years. In particular, the development of digital agriculture applications, sensor technologies, and data-driven decision support systems has played a significant role in increasing scientific output in this area. Overall, the upward trend observed in Figure 2 indicates that machine learning-based precision feeding and precision livestock approaches are a rapidly developing research area that is expected to gain even greater importance in the future.

Figure 3 shows the journals (sources) with the most publications in the field of machine learning-based precision feeding and precision animal husbandry. The findings reveal that certain journals play a more dominant role in this research area within the literature.

According to Figure 3, the journal with the highest number of publications is clearly in the lead, followed by other sources with lower publication numbers. This indicates that the research area is concentrated around certain core journals. The prominence of journals specializing in agriculture, animal husbandry, and agricultural engineering reveals that, despite the interdisciplinary nature of the study, the field is primarily located within applied agricultural sciences. However, the inclusion of numerous journals with lower publication counts shows that machine learning applications are not limited to animal husbandry but are spreading across disciplines such as data science, engineering, and environmental sciences. This supports the field's multidisciplinary nature and its interest to different research communities.

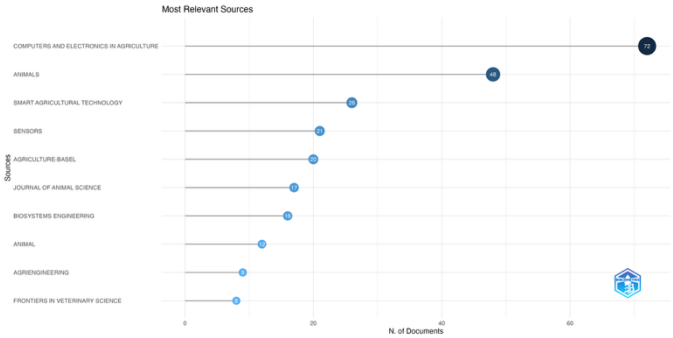

Fig. 3. Most relevant sources in machine learning-based precision feeding and livestock research.

Overall, Figure 3 reveals that while machine learning-based precision feeding and precision animal husbandry studies are concentrated in certain leading journals, they are spread across a broad publication ecosystem.

Figure 4 presents the countries that have made the greatest contributions to machine learning-based precision feeding and precision livestock farming, along with their collaboration structures (SCP: Single Country Publications; MCP: Multiple Country Publications).

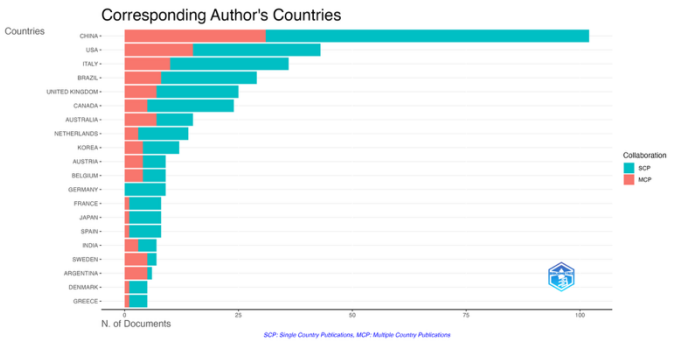

Fig. 4. Global distribution of publications and collaboration networks in precision feeding and machine learning.

The findings show that China has by far the most publications. China is followed by the United States and Italy, respectively. This reveals that this research area is concentrated in countries with particularly large research infrastructures.

Another important finding for Figure 4 is that single-country publications (SCP) are more prevalent than multi-country collaborations (MCP) in countries' publication output. In particular, a significant portion of publications is carried out at the national level in countries such as China and the USA. This shows that these countries have strong domestic research capacity.

However, it is noteworthy that international collaborations (MCP) show a more balanced distribution in countries such as Italy, the United Kingdom, Canada, and the Netherlands. These countries are more integrated into global research networks and more open to interdisciplinary collaborations.

In addition, countries such as Brazil, Australia, and Korea also make significant contributions to the field, and research output is increasingly spread across a wider geographical area.

In general, these findings reveal that the field of machine learning-based precision feeding and precision animal husbandry attracts global interest but is dominated by certain countries. Furthermore, the limited level of international collaborations suggests that global research networks in this field could be further strengthened in the future.

Results showed that the scientific production in machine learning-based precision feeding and precision livestock farming has increased markedly in recent years, indicating a rapidly expanding and evolving research field. The findings also revealed that the literature is dominated by a limited number of countries, particularly China and the United States, while international collaborations remain comparatively moderate. Additionally, the high citation impact and growing number of publications highlight the increasing importance of data-driven approaches in animal nutrition and livestock systems. Overall, the results demonstrate that this field is emerging as a dynamic and influential area of research with significant potential for future development.

IV. CONCLUSION

This study provides a comprehensive bibliometric overview of the scientific literature on machine learning applications in precision feeding and precision livestock farming. The results reveal a significant, sustained increase in research output over recent years, highlighting the growing importance of data-driven approaches in animal nutrition and livestock management.

The results indicate that scientific production in this field is largely dominated by a limited number of countries, particularly China and the United States, while international collaborations, although present, remain relatively limited. This suggests considerable potential to strengthen global research networks and enhance knowledge exchange across countries.

Furthermore, the increasing number of publications and their citation impact demonstrate that machine learning-based approaches are becoming integral tools for improving feed efficiency, optimizing animal performance, and reducing environmental impacts. These advancements reflect a shift from traditional feeding strategies toward more precise, individualized, and sustainable livestock production

systems.

Overall, this study highlights that machine learning-driven precision feeding is an emerging and rapidly evolving research area with high scientific and practical relevance. Future studies should focus on expanding interdisciplinary collaborations, integrating advanced technologies, such as sensors and real-time monitoring systems, and developing more robust, scalable models to support sustainable livestock production.

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