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The Role of Algae Use in Ruminant Nutrition in Reducing Enteric Methane Emissions: A Bibliometric Analysis

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Abstract

Ruminant livestock is a significant source of greenhouse gas emissions due to methane produced during enteric fermentation. In recent years, the use of algae in ruminant diets has attracted attention because of its potential to reduce methane production. In this study, the literature on the use of algae in ruminant nutrition was analyzed using bibliometric methods. Data were obtained from the Web of Science Core Collection database and evaluated using the Biblioshiny (R) program. A total of 129 publications were examined, and the results indicated a marked increase in academic interest in this field in recent years. Keyword analysis revealed that "rumen fermentation," "methane production," and "*Asparagopsis taxiformis*" were the most prominent terms. In conclusion, algae-based feeding strategies stand out as an important research area for sustainable livestock production.

Key Words: *Ruminant nutrition, Enteric methane emission, Algae, Bibliometric analysis, Asparagopsis taxiformis*

Ruminant Beslemede Alg Kullanımının Enterik Metan Emisyonunun Azaltılmasındaki Rolü: Bibliyometrik Bir Analiz

Özet

Ruminant hayvancılık, enterik fermantasyon sonucu oluşan metan emisyonları nedeniyle önemli bir sera gazı kaynağıdır. Son yıllarda alglerin ruminant rasyonlarında kullanımı, metan üretimini azaltma potansiyeli nedeniyle dikkat çekmektedir. Bu çalışmada, ruminant beslemede alg kullanımına ilişkin literatür bibliyometrik yöntemlerle analiz edilmiştir. Veriler Web of Science Core Collection veri tabanından elde edilmiş ve Biblioshiny (R) programı ile değerlendirilmiştir. Toplam 129 yayın incelenmiş olup, sonuçlar son yıllarda bu alana yönelik akademik ilginin belirgin şekilde arttığını göstermiştir. Anahtar kelime analizinde "rumen fermentasyon", "metan üretimi" ve "*Asparagopsis taxiformis*" öne çıkmıştır. Sonuç olarak, alg temelli besleme stratejileri sürdürülebilir hayvancılık açısından önemli bir araştırma alanı olarak öne çıkmaktadır.

Anahtar Kelimeler: *Ruminant besleme, Enterik metan emisyonu, Algler, Bibliyometrik analiz, Asparagopsis taxiformis*

Introduction

Global climate change has necessitated a reassessment of the environmental impacts of the agriculture and livestock sectors (Place, 2014). Ruminant animals produce methane as a result of anaerobic fermentation processes occurring in the rumen, and this gas is released into the atmosphere (Shrestha et al., 2013). Since methane has a higher global warming potential compared to carbon dioxide, reducing greenhouse gas emissions originating from livestock has become an important area of research (Klieve, 2009).

Methane produced during rumen fermentation not only poses an environmental problem but also leads to an energy loss of approximately 2–12% of the energy intake by the animal (Singh et al., 2005). This results in decreased efficiency in animal production. Therefore, reducing methane emissions is of critical importance both for environmental sustainability and for improving production efficiency.

Various feeding strategies have been developed to reduce methane emissions. These include lipid supplementation, the use of ionophores, plant secondary metabolites, and various feed additives (Martin et al., 2010; Jakhmola et al., 2010). However, some of these methods have limited effectiveness or present constraints in terms of long-term applicability. At this point, algae, particularly marine macroalgae, have emerged as a natural and effective alternative (Wasson et al., 2022; McGurrin et al., 2023).

The effects of algae on rumen fermentation are attributed to the bioactive compounds they contain (Maia et al., 2019). In particular, some species of red algae have been reported to significantly reduce methane production by suppressing methanogenic microorganisms (Machado et al., 2016). Among these, *Asparagopsis taxiformis* has been one of the most extensively studied species due to its high methane mitigation potential (Kinley et al., 2016). It has been demonstrated that incorporating *Asparagopsis taxiformis* into ruminant diets can reduce methane

emissions by up to 99% (Wanapat et al., 2024). This presents significant opportunities for both environmental sustainability and improved efficiency in animal production.

In recent years, the number of studies in this field has increased rapidly. However, there is a need to evaluate the overall trends of the literature, research focuses, and scientific collaboration networks from a holistic perspective. Bibliometric analyses are widely used as an important method to reveal the development and structure of a specific research field (Wang and Ma, 2016).

The aim of this study is to examine the academic literature on the role of algae in reducing enteric methane emissions in ruminant nutrition using bibliometric methods, and to identify the development trends, main research topics, and collaboration networks in this field.

Materials and Methods

This study followed a structured five-stage methodology consisting of research design, data collection, data analysis, data visualization, and interpretation (Zupic and Čater, 2015).

Data source and Search Strategy

The primary data source of the study was the Web of Science (WoS) Core Collection database, utilizing the SCI-Expanded and ESCI indexes. A targeted search strategy was applied using combinations of the keywords "algae," "microalgae," "seaweed," "ruminant," "methane emission," and "enteric methane."

The search was limited to the period between 2007 and 2025. Only peer-reviewed articles published in English were included in the analysis. A total of 129 publications were retrieved, and the data were exported from the database on March 5, 2025.

Prior to analysis, the dataset was reviewed, duplicate records were removed, and data cleaning was performed by standardizing author names, keywords, and institutional information.

Data Analysis and Visualization

Data analysis was conducted using the R programming language and the Biblioshiny interface (Wei and Jiang, 2023). The study examined annual publication trends, keyword co-occurrence analysis, author productivity, and collaboration networks.

Additionally, Bradford's Law was used to identify core journals, and Lotka's Law was applied to evaluate author productivity (von Ungern-Sternberg, 2000). To facilitate better interpretation of the findings, annual publication graphs, keyword maps, and country collaboration networks were visualized.

Results

General statistics of the bibliometric data obtained within the scope of the study are presented in Table 1. According to the analysis results, a total of 129 publications were published in 63 different sources between 2007 and 2025, and these publications were produced by 627 different authors. The annual growth rate was calculated as 3.93%, indicating that interest in this research area has increased over time.

Table 1. General bibliometric statistics

Description	***Results***
Timespan	2007:2025
Sources (Journals, Books, etc)	63
Documents	129
Annual Growth Rate %	3,93
Document Average Age	3,7
Keywords Plus (ID)	491
Author's Keywords (DE)	373
Authors	627
Authors of single-authored docs	2
Single-authored docs	2
Co-Authors per Doc	6,17
Journal Article	129

When the distribution of publications by years is examined, a clear increasing trend is observed, especially in recent years. As shown in Figure 1, there has been a notable rise in the number of publications after 2020, and this period has become a time frame in which studies in the literature have intensified. This increase indicates a growing interest in alternative strategies aimed at reducing methane emissions in ruminant nutrition.

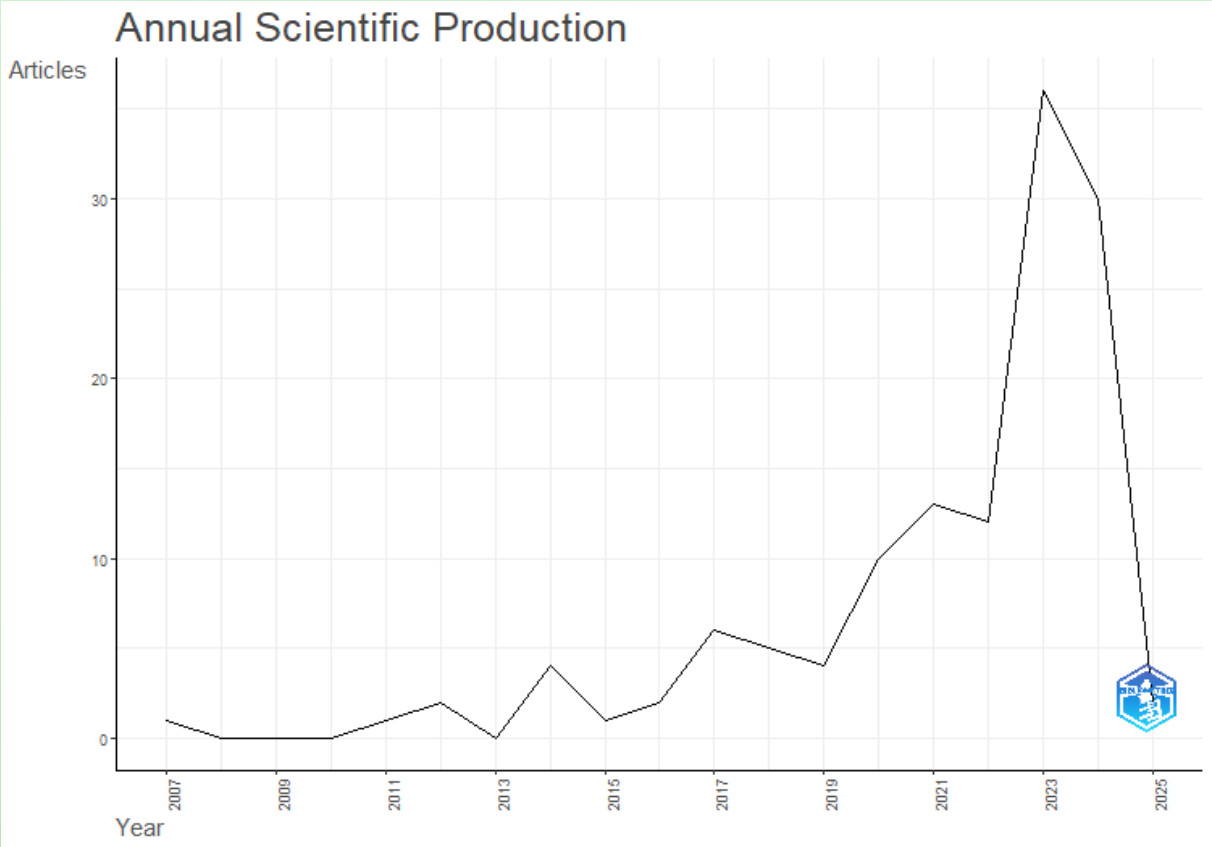

Figure 1. Annual scientific production

The results of the keyword analysis are presented in Figure 2. Examination of the word density map shows that the terms "rumen fermentation," "methane production," and "Asparagopsis taxiformis" are among the most frequently used keywords. This finding indicates that the studies largely focus on rumen fermentation processes and the mechanisms of methane formation. In addition, it is understood that certain algae species, particularly *Asparagopsis taxiformis*, have become a major focus of research in the literature.

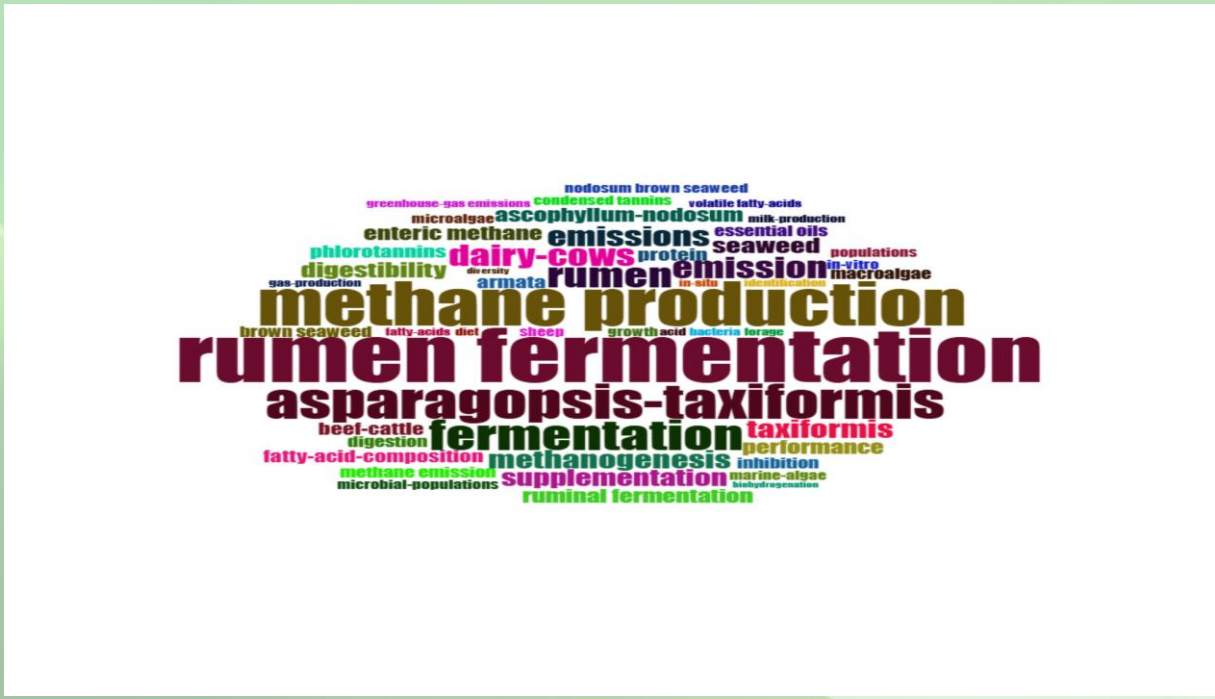

Figure 2. Keyword frequency distribution (word cloud)

The results of the international collaboration analysis are presented in Figure 3. Examination of the map shows that the studies have largely been conducted within the framework of international collaborations. In particular, strong collaboration networks are observed among Australia, the United States, and European countries. This indicates that the research field has gained global importance and that scientific output is shaped by international interaction.

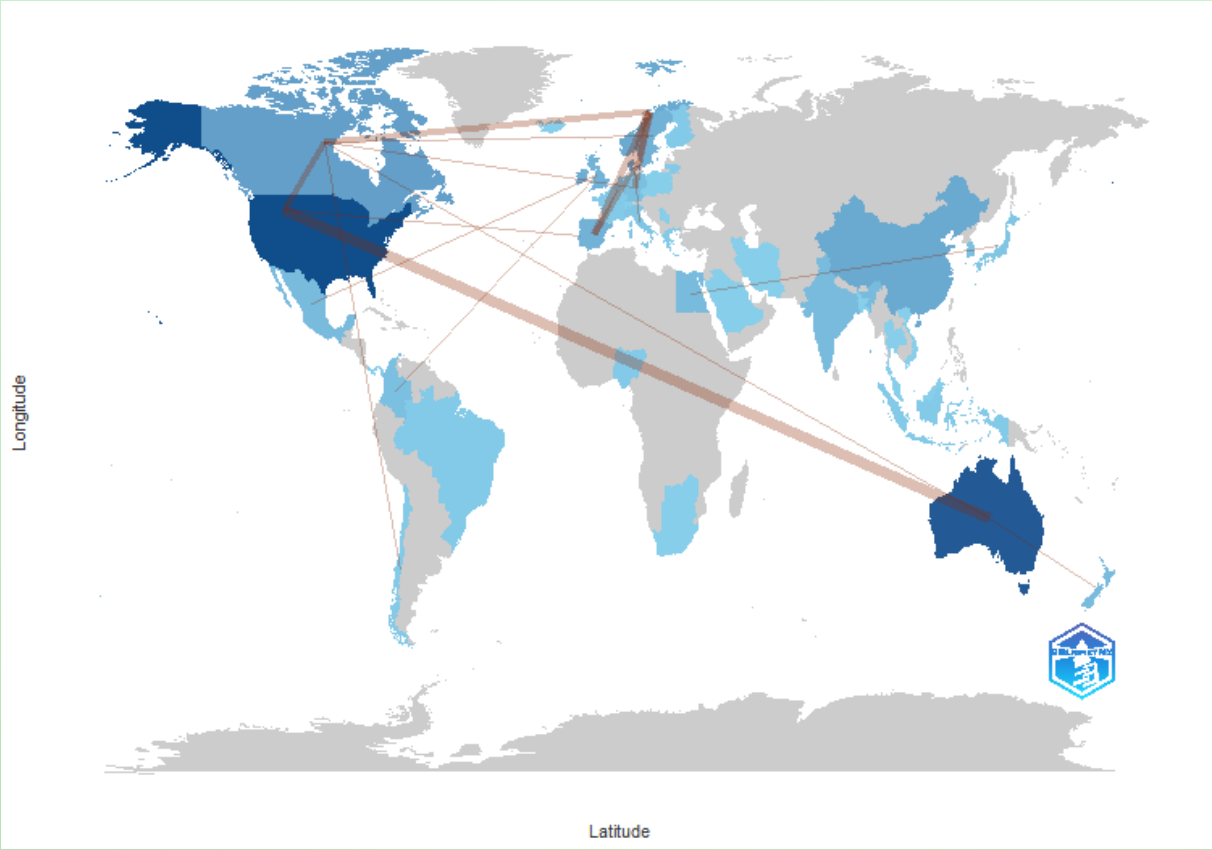

Figure 3. Country collaboration map

Discussion

The findings obtained from this study reveal that research on the use of algae in ruminant nutrition has gained significant momentum, particularly in recent years (Dubois et al., 2013; Sofyan et al., 2022). The increase in the number of publications reflects the growing global awareness of reducing greenhouse gas emissions and the rising interest in sustainable livestock systems.

Keyword analysis indicates that studies are largely focused on rumen fermentation and methane production. Methane production in the rumen is a complex biochemical process carried out by methanogenic microorganisms, and suppressing this process is one of the primary targets for reducing methane emissions (Hook et al., 2010).

In particular, the prominence of *Asparagopsis taxiformis* in the literature is associated with the bioactive compound it contains (bromoform), which directly inhibits methane formation. Studies have shown that even low inclusion levels of this algal species (1–2% of the diet on a dry matter basis) can significantly reduce methane production (Kinley et al., 2020).

However, most of the existing studies consist of short-term experimental research. The long-term effects on animal performance, product quality, and animal health need to be investigated more comprehensively. Additionally, production costs and practical challenges are important factors affecting the widespread adoption of this technology (Roque et al., 2021).

International collaboration analyses indicate that this research field has a global structure. It is well known that scientific collaboration accelerates knowledge production in fields where cooperation is strong (Secinaro et al., 2020).

Overall, the use of algae in ruminant nutrition has significant potential in terms of environmental sustainability (Altomonte et al., 2018). However, more comprehensive and long-term studies are needed to translate this potential into practical applications (Min et al., 2021).

Conclusion

This bibliometric analysis has demonstrated that research on the use of algae in ruminant nutrition is increasing and is particularly focused on methane mitigation. Future studies should focus on comparing different algal species, evaluating their long-term effects, and assessing their economic feasibility.

Declarations

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgments

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