

Extruded Feed in Poultry: A Bibliometric Analysis of Research Trends (1968-2025)

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Abstract | Feed extrusion technology can expand the digestibility of ingredients and improve the performance of chickens, and has thus gained significant attention in feed production research. Determining patterns and predicting trends in poultry feed extrusion research are important for obtaining dynamic information that can help identify research gaps for future studies. This study presents a comprehensive bibliometric analysis to explore the research landscape of extruded feed for poultry, identifying its development, key contributors, and the most influential research areas. Bibliometrics were conducted using Scopus, VOS Viewer, and the R software package Biblioshiny. A total of 346 articles were collected, including 311 research articles, 16 conference papers, and 19 reviews. These publications cover 1968–2025, with the USA, Brazil, Canada, Poland, and Germany being the most productive countries. A number of articles have been published in several reputable scientific journals such as Poultry Science (43 articles), Animal Feed Science and Technology (28 Articles), Journal of Applied Poultry Research (24), Revista Brasileira de Zootecnia (19 Articles), British Poultry Science (16 Articles) and Animals (11 articles). Moreover, over the past ten years, the keywords that correlated with extruded poultry feed were oleic and fatty acids, meat quality, egg production, egg quality, flaxseed, and amino acid digestibility. The results of this study can provide valuable insights for further investigations on extruded feed for poultry on behalf of cost-effective feed solutions.

Keywords | Extruded feed, Bibliometrics analysis, Poultry, Research

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INTRODUCTION

Feed costs account for up to 70 % of production costs in the poultry industry. The high price of feed ingredients has led the industry to find alternative ingredients that are cheaper but have almost the same nutrient content. For instance, faba bean meal and flaxseed can be used as substitutes for soybean meal (Hejdysz *et al.*, 2019; Avazkhanloo *et al.*, 2020). Another example is palm kernel cake, which is an unconventional ingredient in poultry feed formulations

(Faridah *et al.*, 2020). Nevertheless, the utilisation of these alternative feedstuffs in poultry feed should be restricted because of the high concentration of resistant starch and the presence of anti-nutritional components (Diaz *et al.*, 2006). These elements may negatively affect the performance and nutrient digestion of broiler chickens. To overcome the high concentration of resistant starch and anti-nutrients, it is imperative to use a persuasive feed technology, such as the extrusion process. The use of technology is key to sustaining and growing the poultry industry in the future (Sumiati

et al., 2025). Extrusion technology is characterised by the accumulation of material and the application of pressure, heat, shear forces, and water. The high-temperature and short-time (HTST) process refers to the extrusion process and is considered an effective way to hygienize feed from contaminated non-spore-forming bacteria. However, the production of feed through the extrusion process requires more energy and cost. Thus, it is critical to confirm that the extrusion technique significantly improves broiler chicken performance. Extensive research has been conducted on the effects of extruded feed on the performance, digestibility, and quality of poultry products. Spalding *et al.* (2018) highlighted the challenges associated with extruded feed, including high operational and investment costs. Conversely, Risyahadi *et al.* (2023) demonstrated that extruded feed improved chicken performance, as evidenced by a higher ADG and lower FCR than unextruded feed. Furthermore, it has been emphasized that extruded feed ameliorates rheological properties by gelatinization, collective hygiene, and reduction of anti-nutritive factors. This suggests a potentially beneficial effect on digestibility. In the case of protein sources, extrusion effectively decreases anti-nutritive factors and maintains protein levels, so that cost-effective alternatives to soybean and sunflower meals can be achieved for broiler chicken feed (Baib'atyrov *et al.*, 2024).

Understanding the effect of the extrusion method on cost-effectiveness, nutritional factors, and poultry performance is crucial for developing new feed production research strategies. Considerable scientific evidence has been published regarding extruded poultry feed. However, there is a lack of inclusive bibliometric studies that thoroughly examine the current literature, hampering further investigation of this topic. A scientific bibliometric method examines every published publication on a certain subject using computer-assisted review. This technique provides unique insights over traditional reviews. Bibliometrics is becoming increasingly crucial in managing the increasing quantity of manuscript publications collected from empirical contributions, as well as fragmented, clustered, and contrary research findings (Donthu *et al.*, 2021). This bibliometric analysis was conducted to investigate yearly publications, pertinent affiliations, document sources, and keyword outlines that have influenced scientific arguments regarding the use of extruded feed in poultry. This study serves as a reference for researchers seeking information on current research on extruded feed in poultry.

MATERIALS AND METHODS

DATABASE AND EXPLORATION STRATEGIES

This bibliometric analysis elaborated on regaining published manuscripts on extruded feed for poultry from

the Scopus record on 26 February 2025. The examination enquiry used was TITLE-ABS-KEY (extrusion OR extruded) AND (feed OR diet) AND (broiler OR poultry OR hen), resulting in 346 manuscripts available from 1968 to 2025.

Subsequently, books and chapters were excluded from the review. Manuscripts were partitioned for eligibility based on their title and abstract. The manuscript selection process is shown in Figure 1. The Scopus mining feature was applied to obtain raw bibliographic data in Excel format. The extraction procedure included topics related to authors, journals, keywords, affiliations, citations, titles, research areas, and abstracts.

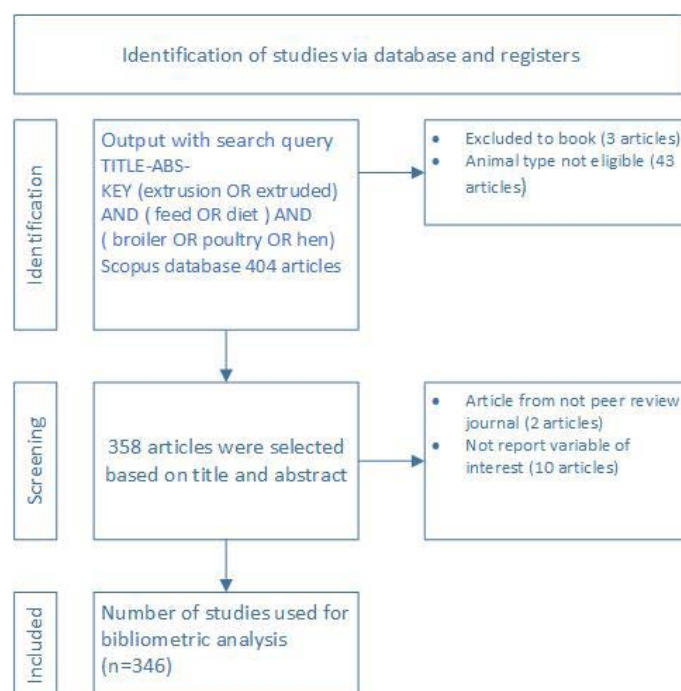


Figure 1: Screening charts of the article selection process utilized for the analysis of bibliometrics.

BIBLIOMETRIC PROCEDURES

A bibliometric evaluation was conducted to analytically assess the manuscripts on extruded poultry feed. The R programming language and RStudio version 2023.03.1, were used for this analysis. The software is an open-source instrument designed for bibliometric analyses. It is accessible using a permitted and inclusive R programming language (Fakruhayat and Rashid, 2023). This software was used to accumulate data regarding the detailed main publication, yearly citations and production, most-cited countries, related journal sources, related affiliations, analysis of Word Cloud, and the evolution of themes. To present the web interface of Biblioshiny, researchers type R Studio coding using the command prompt text. Scopus data were introduced into the Biblioshiny program for analysis. A bibliometric study was conducted to analyse the yearly publications and related affiliations associated with extruded feed in poultry

research. In addition, the study analysed the most relevant journals, manuscript sources, and keyword outlines on poultry extruded feed. Meanwhile, the involvement data of numerous research funding sources on extruded feed in poultry were obtained by searching the outcomes feature Scopus database records after the manuscripts that met the specifications were nominated.

RESULT AND DISCUSSION

ANNUAL MANUSCRIPTS PUBLICATIONS

In total, 346 manuscripts from 121 journals were published between 1968 and 2025. These manuscripts comprised 90.5% research articles, 4.3% review manuscripts, and 5.2% conference manuscripts. An average of 15.5 citations per article was observed, with a mean age of 12.8 years. The number of authors was 1306, with only 10 single-authored manuscripts and a mean of 5.09 co-authors per article. Table 1 shows the outcomes, indicating that 15.03% of the authors were involved in international collaborations. Figure 2 shows the changes in the number of publications and citations from 1968 to 2025. The number of publications on extruded feed in poultry has increased steadily from two document from to 1968-1977 to 143 documents from to 2018-2025. This shows that in the last seven years, there has been significant growth in publications, almost approaching 50% of the total number of articles published (Figure 2). As shown in Figure 3, the first publication from the USA continuously dominated the number of publications between 1978 and 2024. However, Canada, the country with the second-highest number of publications, experienced substantial growth, from 15 articles in 2005 to 52 in 2015. Poland began research in 1997, followed by Brazil in 1998 and Italy in 2000. Brazil and Poland show later but rapid growth, probably because of the growth and competitiveness advantages of the local poultry industry. Poland has a comparative advantage mainly in the EU market, which is confirmed by the increasing values of the export to import ratio and export stability indicators (Kowalska et al., 2023) (Figure 4).

JOURNAL OF SOURCES OF ARTICLES

As 346 document journal sources were recognised, Figure 5 presents the top ten sources that covered publications on extruded feed in poultry. The Journal Poultry Science had the highest number of manuscripts published, tracked by Animal Feed Science and Technology, Journal of Applied Poultry Research, Revista Brasileira de Zootecnia, British Poultry Science, Animals, and Italian Journall of Animal Science. Poultry Science recorded the uppermost H-index (162) and SJR (1.1).

ANALYSIS OF KEYWORDS AND TERMS

The Word Cloud analysis revealed that the terms broiler

(72), extrusion (70), digestibility (30), performance (23), Soybean Meal (20), poultry chicken (19), and laying hens (18) had the highest occurrence (Table 2). A total of 79 keywords were identified from 1968 to 2025.

Table 1: General research outputs.

Description	Result
Timespan	1968:2025
Sources	121
Documents	346
Annual growth rate%	4.19%
Document average age	12.8
Average citation per doc	15.55
References	121
Document contents	
Keyword plus (ID)	
Authors Keyword (DE)	862
Authors	
Authors	1296
Authors of single-authored docs	10
Author collaboration	
single-authored docs	0
Co-authors per doc	5.09
international co-authorship	15.03%
Document type	
Article	313
Conference paper	18
Review	15

Table 2: Top 15 keyword research outputs.

No	Keyword	Occur- rences	Total link strength
1	Broiler +Broilers + Broiler chicken + Broiler chickens	72	169
2	Extrusion + extrusion cooking	70	184
3	Digestibility + Nutrient Digestibility	30	70
4	Performance + growth performance + broiler performance	23	54
5	Soybean meal	20	57
6	Poultry + Chickens	19	50
7	Laying hen + laying hens	18	44
8	Flaxseed + extruded flaxseed	15	43
9	Feed processing + processing	15	39
10	Meat + Meat quality + broiler meat	15	36
11	Nutrition + Nutritional Value	12	31
12	Amino Acid + Amino Acids	12	31
13	Apparent Metabolizable Energy + Metabolizable Energy	10	26
14	Fatty acids	9	24
15	Egg quality	8	12

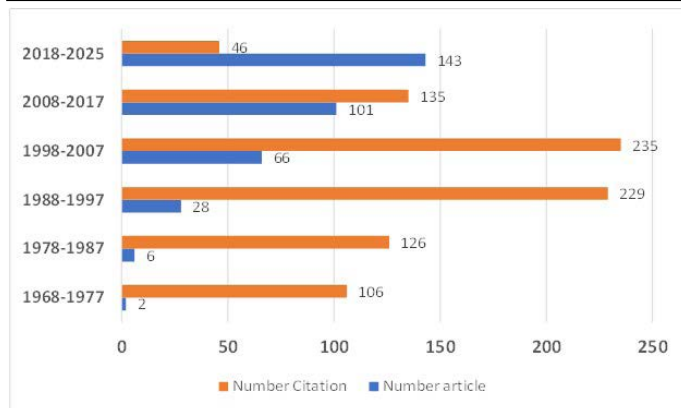


Figure 2: Publications and citations trends about on extruded feed in poultry.

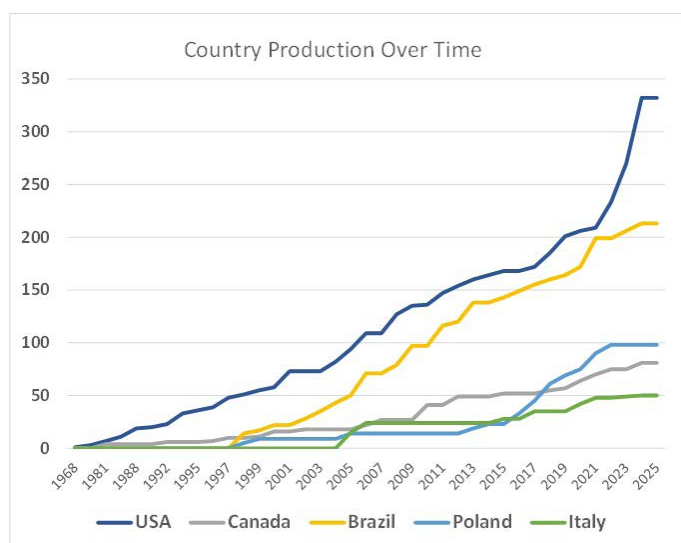


Figure 3: Trend of annual publication from the top 5 productive countries.

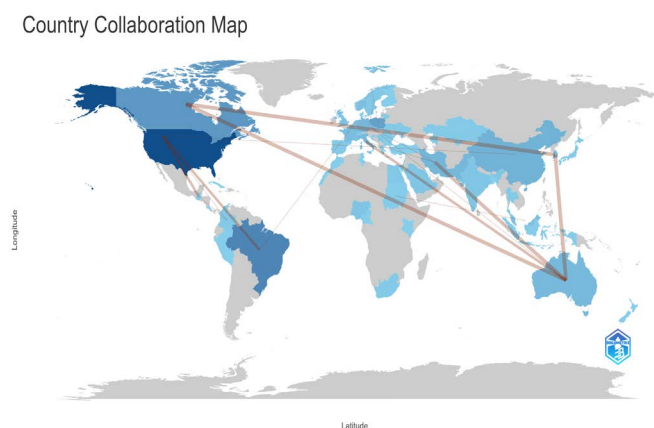


Figure 4: Country scientific production.

CLUSTERING AND KEYWORD RELATIONSHIPS

The VOS viewer network visualisation shown in the image represents a bibliometric analysis of the keyword relationships in the scientific literature. Figure 6 shows various coloured clusters, each representing a group of closely related terms in the literature. The node size specifies the frequency of occurrence of the terms,

whereas the thickness and proximity of the linking lines represent the strength of the co-occurrence relationships. At the centre of the visualisation, the terms “extrusion”, “broiler”, “poultry”, and “digestibility” were the most prominent keywords, suggesting their significant role in the literature analysed. The first red cluster shows research on the influence of extrusion on the digestibility of livestock with the main keywords being extrusion, digestibility and poultry. The second green cluster focused on egg production, fatty acids, flaxseeds, and laying hens, which may be related to the effect of extrusion on the performance and quality of eggs of laying hens. The third cluster in blue appears to be related to broilers, soybean meal, and performance, which may indicate the effect of extrusion on the performance of broilers. The yellow colour seems to be related to broiler meat quality, amino acids, and carcasses, which may indicate the need for research on the effect of extrusion on broiler meat products. The purple cluster indicates research on the effects of extruding alternative feed ingredients on nutritional value. The total link strength quantifies the intensity of connections within a keyword association network. This metric supports the understanding of the importance and relevance of specific entities within the context of network analysis. If two nodes are not connected by a line, there is potential for new research. Even if they are connected by a thin line, there is still little research linking the two nodes in the field of poultry feed extrusion. Nodes connected by multiple lines indicate that the concept has many relationships with other terms in the study.

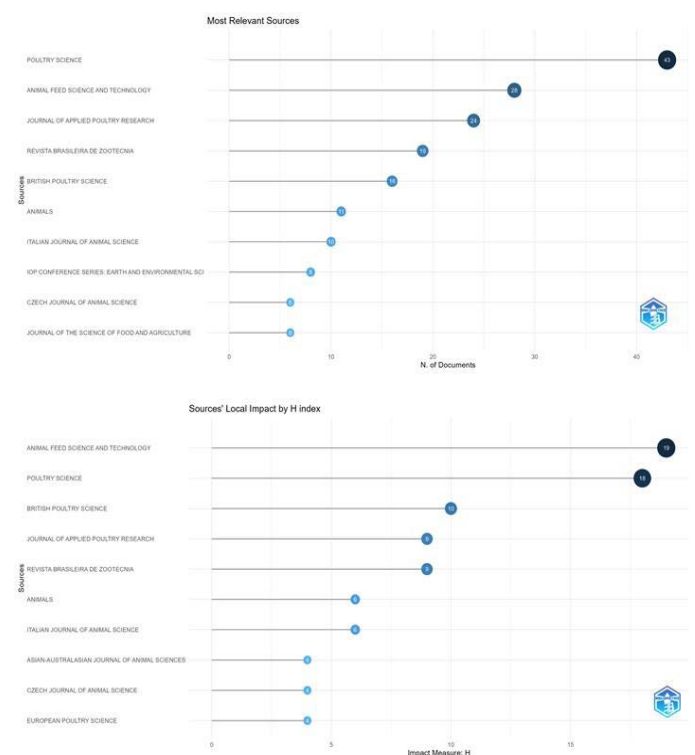


Figure 5: Most relevant Sources and their local impact of the extruded feed in poultry.

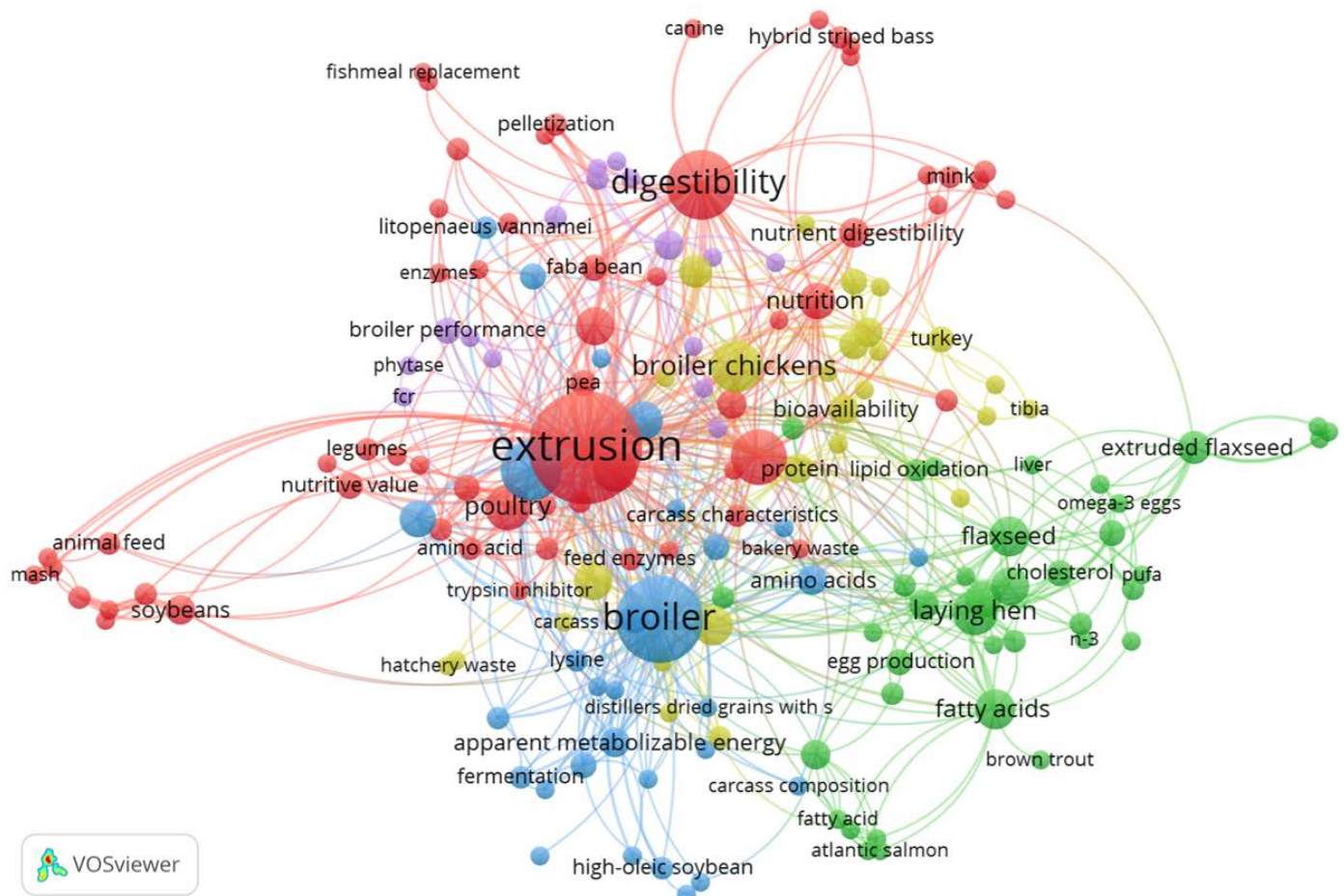


Figure 6: Keyword network visualisation of extruded feed in poultry.

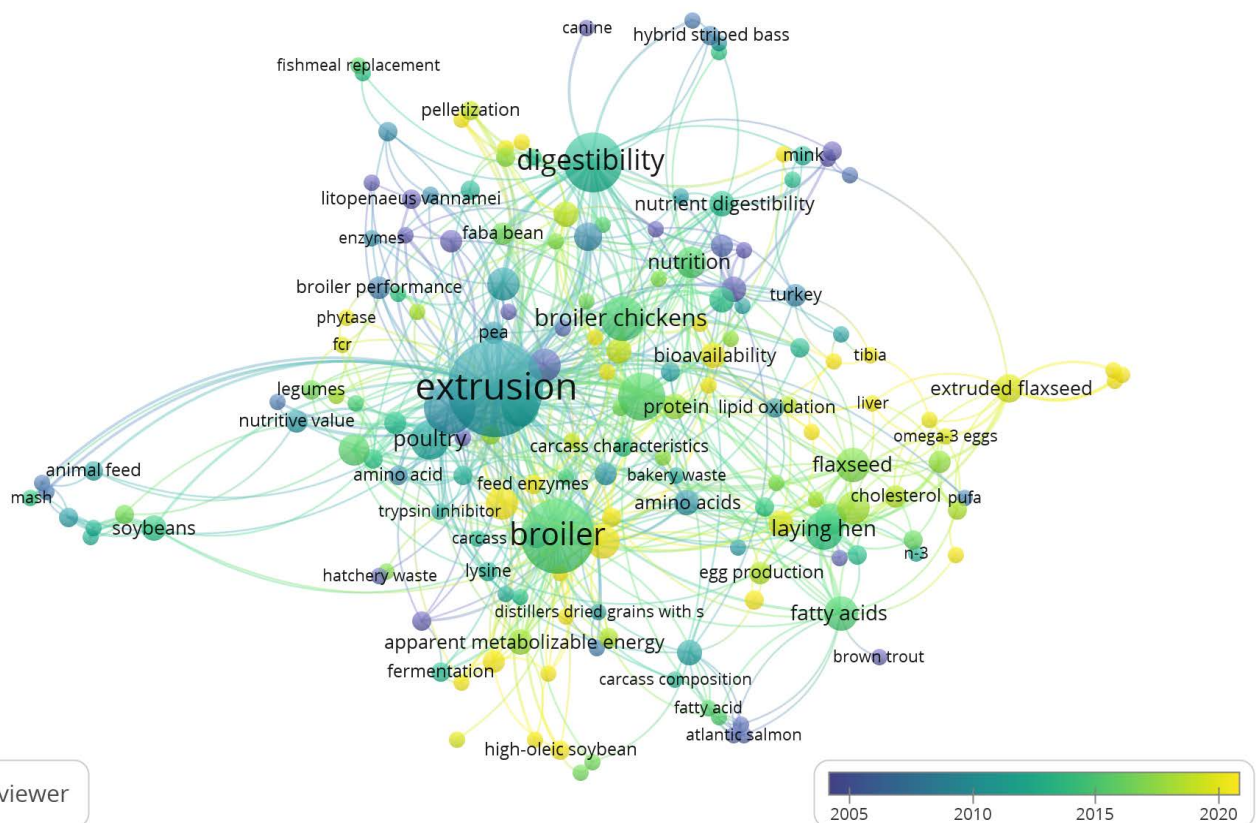


Figure 7: Keyword overlay visualisation of extruded feeds for poultry.

Figure 7 shows the trending topic visualisation of the extruded feed. Trending research keywords in the last ten years, represented by green to yellow, were analysed for oleic and fatty acids, meat quality, egg production, egg quality, flaxseed, and amino acid digestibility. The oldest keywords from 2005, represented by blue to violet, such as extrusion, digestibility, and broiler performance, represent well-established fields of research. The detailed trends and time durations of these topics are shown in Figure 8. Overall, the figure demonstrates the complex interplay between feed extrusion technology, nutrition, and poultry performance, providing insights into the main research

directions and evolving trends in this area.

This study explored and identified annual publications, article sources, and keyword tendencies that have formed a knowledgeable address on extruded feed for poultry. The results indicate an increase in the number of published manuscripts over the last ten years. Since the 1960s, extruded feed, which started with soybean meal and was followed by various local ingredients, has gained importance because extruded feed can increase the performance of poultry (de Vries *et al.*, 2012).

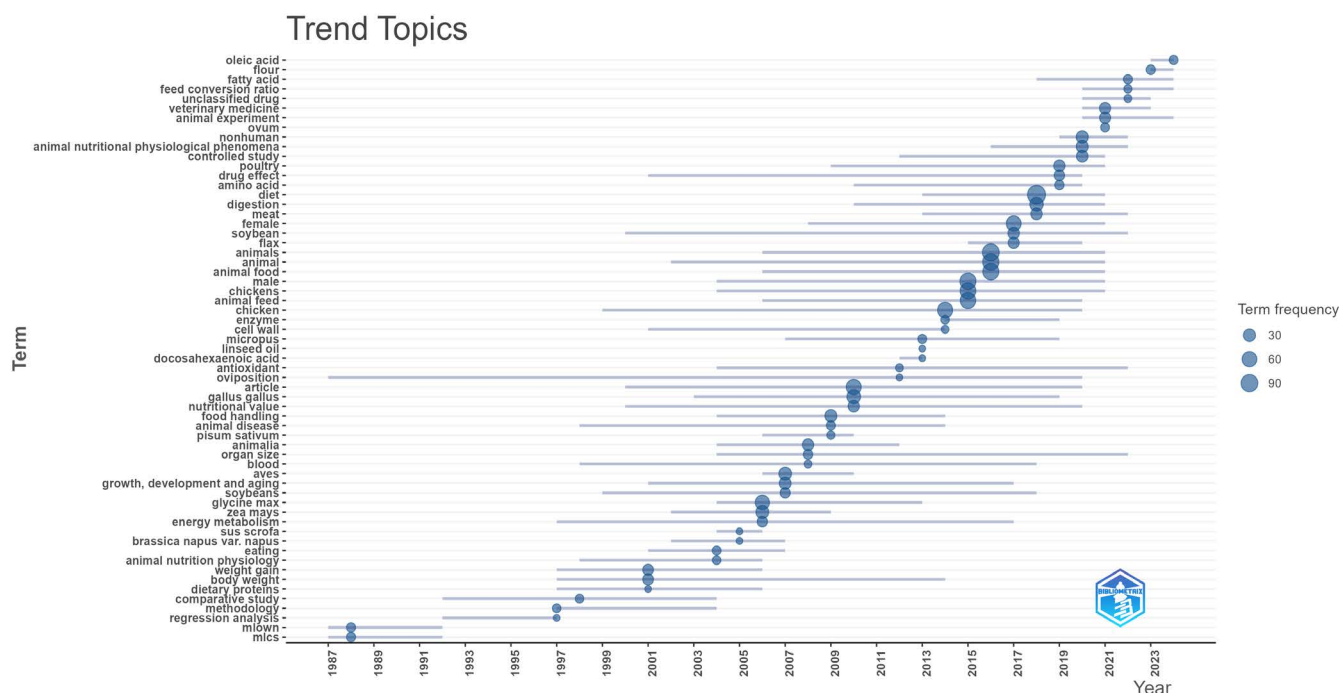


Figure 8: Trending topics of extruded feed for poultry.

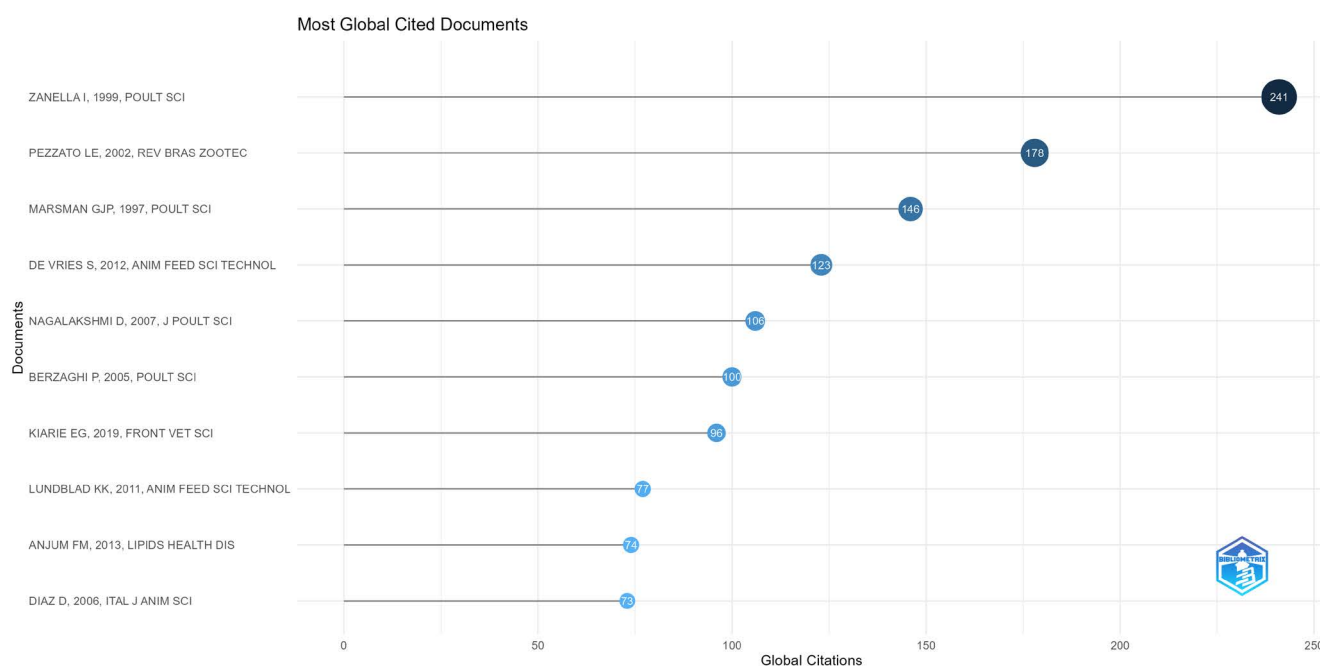


Figure 9: Most global cited document of extruded feed in poultry.

The three most frequently appearing keywords in this bibliometric analysis were extrusion, broilers, and digestibility, with strong links (Table 2). This shows that extruded feed is widely applied and studied in broilers in terms of its performance and digestibility. Broiler performance is largely determined by the availability of feed nutrients. Goodarzi-Boroojeni *et al.* (2016) stated that extrusion.

These methods are operative approaches to decrease feed contamination with bacteria, reduce anti-nutritional factors (ANF), and improve AA digestibility in broilers. Based on a meta-analysis approach using the Scope database, extruded feed ingredients improved the performance of broilers by increasing weight gain, reducing the feed conversion ratio, and increasing the digestibility of crude protein and several amino acids (Risayahadi *et al.*, 2023). The application of extruded feed to laying hens has not been widely studied; keywords specifically for laying hens had only 18 occurrences, much fewer than broilers, which had 70 occurrences. This shows that there is a fairly large opportunity for novelty in the study of the application of extruded feed in laying hens.

Keywords that have emerged relatively recently in the last five years include meat quality, egg production, egg quality, flaxseed, oleic and fatty acids, and amino acid digestibility. This shows that researchers have begun to be concerned about the effect of feed extrusion on poultry products, which was previously focused on performance alone. Risyahadi *et al.* (2025) conducted a meta-analysis on the effects of extruded feedstuff on broiler meat quality. The results revealed no negative effects on meat quality, such as unsaturated fatty acids, saturated fatty acids, thiobarbituric acid reactive substances, pH, Omega-3, freshness, drip loss, and yellowness. The extruded feed can also recover quality by reducing its water-holding capacity (WHC) and total lipid content. The shifting extrusion effect on meat and egg quality is likely due to changing consumer demand. Consumers want not only the quantity but also the quality of poultry products and ethical production. The rising demand for organic and ethically produced poultry products presents market opportunities. Maró *et al.* (2025) added that freshness, health impact and price are among the most significant considerations before buying poultry product.

Flaxseed is an alternative feed ingredient that has been extensively studied. Extruded flaxseed can be used effectively to increase the performance of laying hens at a profitable level of up to 90 g/kg (Sepehr *et al.*, 2021). Furthermore, Huang *et al.* (2020) concluded that supplementation with extruded flaxseed could significantly increase n-3 PUFA content, and feeding extruded flaxseed up to 9% of the diet had no adverse effects on the performance of laying hens

and improved the concentration of n-3 PUFA in the liver, blood plasma, and egg yolk. Regarding extruded flaxseed applied to broilers, Avazkhanloo *et al.* (2020) reported that flaxseed extrusion coupled with enzymes changed the lipid and protein molecular structures of flaxseed, enhancing the activity of digestive enzymes, breast muscle fatty acids, intestinal morphology, and broiler growth performance.

As the number of publications on extruded feed in poultry increases, the number of citations also increases. This may be due to the increase in research on extruded feed at numerous research centres and universities in Japan. The Journal of Poultry Science had the highest number of manuscripts, followed by Animal Feed Science and Technology and the Journal of Applied Poultry Research. Recent published manuscripts in the Journal of Poultry Science have reported

Evaluation of expeller-extruded soybeans with high oleic acid content on broiler growth performance, meat quality, and blood profile. Expeller-extruded soybeans with high oleic acid content enhanced the composition of fatty acids in meat with higher oleic acid content and increased broiler growth performance compared to conventional soybeans, suggesting their potential as a protein source for improving the quality of broiler meat (Atoó *et al.*, 2025). In a recent study published in Animal Feed Science and Technology (Sousa *et al.*, 2021), the effects of extrusion on growth performance, digestive organ morphometry, and enzyme activity, such as pancreatic amylase, lipase, and plasma glucose, were evaluated. Insulin concentration was also evaluated in broilers fed diets containing various carbohydrate sources during the post-hatching phase.

The Journal of Applied Poultry Research recently published a study on the use of thermal food waste by extrusion as a broiler feed to examine not only broiler growth performance but also nitrogen-corrected apparent metabolisable energy and amino acid digestibility (Beckman *et al.*, 2024). Based on the latest studies published in reputable journals, the development of extruded feed ingredients is aimed at improving the quality of poultry products, blood and digestibility profiles, and the use of food waste to increase their added value.

Some of the most cited articles related to extruded feed in Figure 9 include Marsman *et al.* (1997) who observed the effects of thermal processing of soybean meal on ileal nutrient digestibility and growth performance in broilers. Their results showed that extruded soybean meal significantly reduced the feed conversion ratio and improved the digestibility of non-starch polysaccharides and apparent ileal crude protein content. This study provides a reference for researchers because it is the first to comprehensively compare extruded and unextruded

soybean meal, which is the most extensively used feed ingredient in broiler diets (de Vries *et al.*, 2012) have also been cited by many researchers who have conducted extruded feed studies. This article systematically reviews the use of processing technologies to enhance the digestive utilisation of fibre-rich feedstuffs. High crude fibre content in broiler feed affects growth performance; therefore, many studies have focused on the use of extrusion technology to break down fibre in feed ingredients.

CONCLUSIONS

In conclusion, 346 publications on extruded feed in poultry were published between 1968 and 2025. The highest number of published manuscripts was published between 2018 and 2025 (143 articles). The United States has the highest and most dominant scientific manuscript production, followed by Canada and Poland. Trending topics related to extruded feed in publications in 2025 included meat and egg quality, amino acid digestibility, and alternative ingredients such as flaxseed. Future research on extrusion for poultry should focus on using food waste to increase added value, as well as the response to blood profile and stability of enzyme activities. More potential studies are extrusion's economic viability for small-scale farms.

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NOVELTY STATEMENT

No study has examined research trends regarding extruded feed in poultry using bibliometric analysis.

AUTHOR'S CONTRIBUTION

The authors approve contribution to the paper: study design and conception: Sazli Tutar Risyahadi; draft manuscript preparation: Heri Ahmad Sukria and Sumiati; revised manuscript: Anuraga Jayanegara; data collection: Yuli Retnani; interpretation and analysis of results: Anuraga Jayanegara; all authors studied the results and agreed with the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest

with any financial or organization related to the content discussed in this paper.

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