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# GLOBAL RESEARCH STUDIES ON ALTERNATIVE FEEDSTUFFS FOR IMPROVING LIVESTOCK PRODUCTION: A FIVE-DECADE BIBLIOMETRIC ASSESSMENT

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ABSTRACT:

The current study presents investigations on research studies on alternative feedstuff and livestock farming globally. An aggregate of 1634 publications were retrieved into a BibTex template for assessment by way of bibliometric assemblage in R studio software. The result obtained from the study included relevant authors in the field, number of citations, affiliations, journals, and important key words associated with the research field. Publications on the use of alternative feedstuff and livestock production had increase scholarly outputs of a yearly growth of 11.49 % during the studied span line. The USA lead in the first position with output of n = 258, and worldwide scientific impact of highest article citations (n = 6265). The result also showed that thedocuments/author (n = 0.273), single-authored documents (n = 156),co-authors/ documents (n = 4.22), authors/document (n = 3.67), and collaboration index (n = 3.96), respectively. Nations in Africa however, had only Egypt in the top 20 countries with high outputs. For multiple country publications (MCPs), the USA, Turkey and Germany have 25 %, 14 %, and 10 %, respectively. Lastly, the findings indicated vividly that the USA (n = 258), Turkey (n = 152) and Brazil (n = 102) are taking the lead (in terms of total article publications) in supplementing and/or substituting conventional feedstuffs with alternative feedstuffs for improving livestock farming.

Keywords: Non-conventional feedstuffs, bibliometric assessment, livestock, sustainable farming

## INTRODUCTION

Livestock fodder is the key driver of animal husbandry while animal breeding, animal welfare, and health are among few other factors that play secondary, but vital roles too. Feed makes up for about 70 % of the aggregate cost of livestock production (Makkar, 2018). The topic of feed/fodder in livestock production displays perhaps a challenging situation confronting planners, nutritionists and scientists of most nations globally. The situation is predominantly serious now considering the issue of global climate change resulting to drought and occasional chronic yearly feed scarcities of conventional feedstuffs, thus causing the problem of animal feed a persistent saga to the livestock industry.

Several nations of the world and especially countries from the Mediterranean and African continents are plagued with unfavourable climatic conditions, making pasture to be available at times for a short time. Conversely, cereal utilization as livestock feed generates some sort of conflicting interest with human beings, while considering the utilization of another important feed ingredient like soybean is mostly unaffordable by most livestock farmers (Herrero et al., 2013; Makkar et al., 2014; Tran et al., 2015). A fascinating challenge for researchers and feed nutritionists is the inclusion of non-conventional feed materials to mitigate the difficulties of harsh climate and weather and the cost of animal production. The proficient use of naturally abundant feed wastes/bio-materials is a really convincing mission and the quest for pressing alternative solution/intervention is sacrosanct.

In virtually all societies of the world, livestock husbandry is fast depending on substitutional and supplemental diets, particularly during certain stages in animal development such as reproductive and production (animal products such as milk, egg etc.) periods. The financial implication of most conventional feeds limits their utilization in most part of the world, and livestock farmers are now seeking the option of alternative feed materials to boost the feeding question of their animals for better performance. These alternative feedstuffs/materials have

been shown to supply several needed nutritive benefits needed for both reproduction and production purposes (Morales et al., 2000; Blache et al., 2008; Vasta et al., 2008; Tran et al., 2014; Gowda et al., 2021). According to some authors, alternative feedstuffs can be classified into the following categories namely: crop residues (bagasse,maize stubble, stovers, and rice straw), agro-industrial by-products (rice bran, molasses, palm oil mill effluent, pineapple waste, seed-cake or waste) and non-conventional feed resources (wastes fro citrus, vegetables andcereal grains)(Devendra 1988; Meffeja et al., 2000; Belewu and Ademilola, 2002). Another category of alternative feedstuffs, with a prospect to advance livestock performance, is called food-not feed bio-materials and it includes protein isolates, single cell proteins, insects, seaweeds, protein hydrolysates,and animal wastes from slaughterhouse among others (Makkar, 2018).

Chiefly producers who may lack access to conventional feedstuffs or who are financially constrained to afford the price of conventional feedstuffs utilize alternative feedstuffs / materials/resources. A peculiar problem in livestock farming most times is the 'feed gap' which may coincide with drought seasons where natural feeds (forage) is scare or not available. The utilization of alternative feedstuffs or materials to complement conventional fodders/ forage is reasonable vital in livestock husbandry. In most nations of the world, it forms an important management instrument to sustainable animal production (Meffeja et al., 2000; Malau-Aduli et al., 2003; Morand-Fehr, 2005; Idamokoro et al., 2016).

Several authors have reported the use of some plants (e.g. Atriplexnummularia; Acacia karroo; Acacia cyanophylla), legume pods and seeds (such as Pisumsativum, peas, chickpeas, faba beans), or agro-industrial wastes (such as, citrus pulp, sugar beet pulp, extruded linseed cake), could be effectively utilized as complementary ingredients in livestock nutrition, without negatively affecting animal productivity (Blache et al., 2008; Vasta et al., 2008; Idamokoro et al., 2022a).

Despite several reports on the investigations on the use of non-conventional feed/ alternative feedstuffs/bio-agro food resource to improve livestock production in the literatures, till date it seems that, publications documenting the amount of outputs in the research domain is rare and hence, the current investigation becomes essential. The approach of using bibliometrics for analyzing research findings, is now an exceptional instrument for schematic representation and characterization of investigations in a certain research niche, and it combines statistical computations and mathematical methods to reveal the knowledge pool that has the ability for the projection of the scientific research direction in a given research subject matter (Wang et al., 2016; Zou et al., 2019). It thus facilitates scientists, researchers, academics, and policymakers to come up with strategies and propose a way forward in advancing projects or researches in line with research happenings in that field of research (Olisah and Adams, 2020).Bibliometric evaluation is an essential aspect of scholarly investigation that help to evaluate the extent of maturity of a particular research domain (Khatun and Ahmed 2011; Zhang et al., 2019).

For this reason, the current study, adopted a bibliometric research to advance the term "alternative feedstuffs" in the context of "livestock farming/production". The trends of records and research publications with respect to the subject matter, using Scopus and the Web of Science databanks (from 1969 - 2020). Although a lot of publications attempts to address alternative feedstuffs (also known as non-conventional feedstuffs, naturally available feedstuffs etc.), bibliometric analysis data on alternative feedstuffs with regards to livestock production is scarce. Thus, this current work aimed to present findings on the development of scientific publications on alternative feedstuffs and their importance in boosting livestock production and food availability for humans arising in this niche area within the stated time (1969 - 2020) of study.

## MATERIALS AND METHOD

### Data search, retrieval, and evaluation

Several data banks exist including PubMed,Thomson ISI, Scopus and WoS among others that could be utilized to retrieve bibliometric data. Of these several data banks, the two data banks adopted for this work (WoS and Scopus) are the two (2) bibliographic data banks widely approved data banks that permit the building of an extended and combined search questions (Zhu and Liu, 2020; Pranckute, 2021;Zhang et al., 2023).The data banks used for the present study were fromsearch methods of Scopus (http://www.scopus.com) and WoS (http://www.webofknowledge.com). In addition, WoS and Scopus are databases for efficient and reliable top-impact scholarly research publications (Mansoori, 2018; Repiso et al., 2018). For our study, the title search was employed to retrieve data on both the WoS and the Scopus data banks on 20 April 2021. The utilization of title search enhance important recovery of documents and lessens the loss of sensitivity of the research subject matter to the lowest minimum. It also helps to eradicate several pseudo-documents that could affect the result of search subject matter (Sharma et al., 2018). After the data were retrieved from Scopus and WoS, they were further cleaned-up before validation. This was achieved by means of an exhaustive literature review search of vital keywords related to the subject matter. The technique of data gathering employed in our investigation have also been employed by other authors (King et al., 2018; Fesseha et al., 2020). Furthermore, all the retrieved data copied into R Studio and a customized mathematical command was employed to remove article duplications from the WoS and Scopus data bases. A diagrammatic presentation of how the data retrieval, exclusion and analysis is described in figure 1. Meanwhile, the yielded data (result) were originally downloaded in Bibtex file template before they were uploaded into Rstudio for bibliometric data processing (Olisah et al., 2018a; Olisah et al., 2018b; Okaiyeto et al., 2020; Idamokoro and Hosu, 2022b).

**Data processing**

Data gather from WoS and Scopus were transferred into the bibliometrix R-package software (under the biblioshiny tab) software before they were analysed statistically for descriptive bibliometric information. The analysed descriptions include global publications of articles per annum, yearly outputs and citation by various nations, article sources of outputs and their scholarly impacts, collaboration/ allied networks around the globe, and trend of relevant subjects, amongst other useful scientific features about the subject matter (RStudio v. 127.0.0.1: 5645) as described by Aria and Cuccurullo (2017). Furthermore, the RStudio was utilized to visualize, tabulate, and present several other bibliometric features, including article keywords plus; author's keywords; authors; relevance; author impact; organizations, nations, and authors' networking; frequency of citations; co-citation networks; co-word network assessment among others. A particular collaboration network (e.g. authors, institutions, nations) proposes some partnerships in a trend as a collection of nodes (Zhang et al., 2012). Authors' influences in a particular research niche is assessed via the Lotka's law (Lotka, 1926).

**Results and discussion**

**Major research information trend**

Publication of the trends on the subject of "alternative feedstuffs" in the context of "livestock production" from 1969 to 2020 were presented in this current study. The 1634 research articles gathered from both Scopus and WoS archives as shown (table 1) were published in English language and available in 954 archives from 5989 authors. From this investigation, single-authored outputs were published by a total of 143 authors, while the multi-authored outputs were published by 5846 researchers, respectively. All the published articles altogether had 43377 references with average of publication being 9.66. The mean citations per article/document were 18.09. The mean citations per year per article/document were 1.866. Results from keyword plus (ID) and author's keywords (DE) from our findings were 9614 and

4812. Furthermore, from the authors' networking index, single authored publications were 156 with articles per author accounting for 0.273. Likewise, the authors per articles stood at 3.67, co-authors per documents was 4.22. The CI (collaboration index) was 3.96. The collaboration index gotten in the current study was lower compared to that of Okaiyeto and Oguntibeju (2021) and Idamokoro and Hosu (2022c) and Tywabi-Ngeva et al. (2022), but higher compared to that of Ekundayo and Okoh (2020), and Olisah and Adams (2020). On aggregate, multiple authors produced 1478 of the 1634 retrieved publications in the present investigation, and this amounted to the 90.45 %. Thus, this finding, resulted in the value of the CI (collaboration index) as compared to 156 documents (9. 55 %) published by single authors.

**Yearly growth of article publication and citations**

Bibliometric evaluation is a research tool that assists to define the rate of increase in the number of articles published in a particular domain of research. An annual decrease in the sum of articles in a research niche depicts a decreasing interest among authors/ researchers in the scientific niche area (Okaiyeto and Oguntibeju, 2021). With regards to the annual growth in the article publications on alternative feedstuffs, in the context of boosting livestock production, there was a slow growth (1969 to 1975), followed by fluctuations in article publications between the year 1977 and 1998, however, a substantial increase was observed from 1999 to 2020 (see figure 2). The highest amount of publications was in 2020, with over 180 (figure 2). Conversely, research studies in this niche area recorded a yearly growth rate of 11.49 %. This result was lower compared to the one reported by Idamokoro and Hosu (2022d), however, it was higher than the one reported in another bibliometric study by Okaiyeto and Oguntibeju (2021). Again, the yearly growth rate observed from our investigation was comparable to the findings of Smith et al. (2021), thus giving credence to the fact that research in this niche area is growing globally.

**Most influential researchers in the research niche**

The result gotten from Scopus and WoS on alternative feedstuffs between 1969 and 2020 showed that 5989 authors published 1634 documents for this assessment. Likewise, the authors per article in the investigation was 3.67, hence, displaying the power of partnership and network by different authors in this research domain. Table 2 shows the 20 most relevant researchers in this research niche, with an h-index of between 2 to 7 and citations extending from 7 to 601. The spread of citations among the authors in the present study is expected. This is due to the fact that there are high numbers of researchers/authors who have reported findings along the line of thought (alternative feedstuffs for livestock production) as compare to other bibliometric studies (e.g. Tywabi-Ngeva et al., 2022) with fewer authors having higher individual/group citations on a particular subject matter. Generally, the h-index is often utilized to evaluate worth/value of findings (Huang et al., 2019). Likewise, it is employed to appraise how impactful (through number of citations) and prolific a researcher or assemblage of researchers are within an organization or a nation (Hirsch, 2005). Researchers, nations, organizations and journals are often rated from their h-index score, which tallies with the number of scholarly publications arraigned based on the counts of times they are cited by other authors, and they are calculated by means of the logic that h publications were cited h times at the minimum (Hirsch, 2005). Notwithstanding, the comparison of using h-index among authors should fall within certain research domain since it is unfit for such reason across lines of expertise. Conversely, the h-index measurement is an essential instrument in this type of assessment, as it often correctly replicates the level of scholarly attainment to the pool of scientific knowledge of individual researcher (Guilak, and Jacobs, 2007).

From our current investigation, the impact of institutions, influence of authors, and various nations with regards to their impact to the pool of scientific knowledge as it relates to the use of alternative feedstuffs in the context of livestock production were evaluated. The relevance

of any article is based mostly by the amount of instances the article is referenced by other authors. Meanwhile, the use of citations does not indicate a perfect yardstick of impact of an article, it however, gives some vital indexes that would assist to attain a logical inference on the issue (Su et al., 2018). As observed in Table 2, which reported the information of the 20 relevant publishers, Li M and Kim J contributed 10 (0.61 %) and 9 (0.55 %) articles from the total of 1634 articles retrieved from Scopus and WoS databank, accordingly, and they had a h-index of 5 and 4, accordingly. Conversely, Kimber, I (h-index = 4), positioned in 8$^{th}$ ranking, had the most sum of citations (n = 601) when compared to the topmost two (2) researchers, with 110 and 101 citations, despite having lesser amount of publications in the niche area. This indicates that the use of citations is not only affected by the amount of outputs published by an author and rating of the h-index, but also by the year of publication (Okaiyeto and Oguntibeju, 2021).

**Most impactful institutions**

From table 3, the information for the top twenty-five (25) institutions with the highest amount of publications in this niche area were tabulated. It was observed that, SO Illinois Univ published the highest amount (n = 25) of articles while Egerton Univ, Iowa State University, and KocaeliUniv produced the least number (n = 8 each) of articles, accordingly. Furthermore, 8 of the 25 most relevant institutions are in the United States of America. Previous studies have also reported similar observation of institutions from the USA having significant contributions to the body of knowledge in particular research areas (Okaiyeto and Oguntibeju, 2021; Idamokoro and Hosu, 2022d).

**Most impactful journal sources**

Concerning bibliometric evaluation, research areas and journals are considered as vital aspects required to describe the opportunity of research spread in a certain research field (Leydesdorff and Rafols, 2009). From our investigation, the document sources where authors who published

articles on the subject matter about alternative feedstuffs in line with livestock production were assessed. The information obtained from these sources included the amount in numbers of articles published in each journal. The 20 most relevant/impactful journals in the discussed niche area is presented in figure 3. The first ten (10) journals ranked in order of position are Aquaculture (n = 29), Aquaculture Research (n = 21), Journal of Cleaner Production (n= 21), Poultry Science (n = 18), Journal of Animal Science (n = 16), Journal of the Science of Food and Agriculture (n = 14), Fresenius Environmental Bulletin (n = 13), Journal of Applied Poultry Research (n = 13), North American Journal of Aquaculture (n = 13), and Animal Feed Science and Technology (n = 11), respectively, which are articles published within the specified period of 1969 to 2020. These afore-mentioned journal out-lets are known to disseminate scholarly information that are related to anything animal feed and feed materials for improving livestock farming.

**Most globally cited articles**

Generally, the world indices of citation of a particular article points to the amount of citation that document have received on scholarly data archives for the time-span the said data were downloaded online. Likewise, the global citation depends on the academic weight of the citing document (i.e. how relevant to the pool of knowledge) rather than their popularity. For instance, a manuscript cited by a very important and impactful paper draws the attention of authors and researchers that are more relevant, while the amount of citations a publication attracts pinpoints its global impact, not caring about the value of the citing manuscript(s).

The top 15 globally cited documents that was evaluated based on their total citations per year (TC/Year) andtotal citations (TCs) in alternative feedstuff research from 1969 – 2020 are presented in table 4. Yang et al. (2009), Allan et al. (2000), Lunger et al. (2007), Lock et al. (2016), and Richter et al. (2003) published the five (5) topmost documents among the globally cited articles, accordingly. These articles were published in World's Poultry Science Journal

(TC: 278; TC/Year: 21.38), Aquaculture (TC: 186; TC/Year: 8.45), Aquaculture (TC: 139; TC/Year: 8.17), Aquaculture Nutrition (TC: 124; TC/Year: 15.5), and Aquaculture (TC: 118; TC/Year: 5.61), respectively. The coverage of the afore-mentioned top rated articles covers different subject matters on the utilization of alternative feedstuff for improving livestock farming, including "Evaluation of nutritional quality of moringa (*Moringaoleifera Lam.*) leaves as an alternative protein source for Nile tilapia (*Oreochromisniloticus* L.) – Richter et al. (2003)". Similarly, another author described the effects of using "mealworm larvae as a potential substitute to soybean diet for broilers to improve its production and product quality such as meat – Bovera et al. (2015)". Again, another researcher reported an investigation regarding the modulation of diets in the gut microflora of broilers: which is a review of the effect of six (6) different types of alternatives to in-feed antibiotics in poultry (Yang et al., 2009). Among the five (5) top cited articles, Yang et al. (2009), recorded exceptional TC and TC/Year, which comprised of multiple citations observed by other authors in the same field (table 4). The total citation (TC) and total citation per year (TC/Year) as shown in table 4 ranged from 69 to 278 and from 2.7 to 21.3. Furthermore, six (6) of the top 15 globally cited publications were published in "Aquaculture" while two (2) in "World's Poultry Science Journal".

It is noteworthy that the impact or relevance of a research publication in the scientific journal community is mostly evaluated by the number/amount of citations (Tahim et al., 2016). This impact/influence however, grows as the citation number surges (Faggion et al., 2017). Likewise, it should be noted that citations increase might however come with high increase of negative criticism of the article's content (Cheek et al., 2006). Thus, the growth of an article in a journal becomes visible with time, and this is apparent in our observation (table 4). Thus, 20 topmost cited research publications were produced between 1990 and 2015. As the years goes by, recently published papers will also accumulate citations (Feijoo et al., 2014).

**Most impactful nations**

The top 20 most impactful nations by corresponding researchers in this field are tabulated in in table 5. Of these top 20 nations presented, three (3) of them were from North America (i.e. USA, Mexico and Canada), one was from South America, Oceania and Africa (i.e. Brazil, Australia and Egypt), Six were from Asia (i.e. China, Indonesia, Korea, Japan, Malaysia and India), eight were from Europe (i.e. Turkey, Spain, Italy, Germany, UK, France, Netherlands and Switzerland), respectively. This result further indicates that European nations were more intentional and important in the research niche area, although they had fewer number of articles as compared to the United State of America that is having a number of single country publications (SCPs) and multiple country publications (MCPs), which were 233 and 25, accordingly. The article contributions from the USA as a nation portray them as a relevant nation in the research domain of understudied field. Furthermore, scholarly contributions from other nations including Turkey (Articles: 152; SCP: 138; MCP: 14), Brazil (Articles: 102; SCP: 97; MCP: 5), China (Articles: 61; SCP: 58; MCP: 3), and India (Articles: 54; SCP: 52; MCP: 2), were likewise significant. The MCP ratio for Egypt (0.25), Australia (0.23), France (0.22), and Germany (0.21) was high as compared to other nations. Conversely, Indonesia had no MCP.

Worthy of note is the fact that, there were positions switch in the ratings among the 20 topmost nations who were ranked to be the most active nations in researches done on alternative feedstuffs and livestock farming when research outputs were evaluated based on total citation (TC) per nation (between tables 5 and 6). This glaring observation is similar to the findings of other studies in bibliometric analysis by other researchers (Orimoloye and Ololade, 2021). The possible reason that was given for this position switch in article ratings when using the sum aggregate of citations to evaluate author's outputs may describe its unpredictability as a reliable instrument to evaluate the productivity of authors. In the findings of Fricke et al. (2013), it was

reported that, the frequency of citation of a particular nation does not automatically portray the article publications of that author. The explanation for this, is because, the fewer the amount of research publications utilized for evaluation in bibliometric researches, the more relevant a few regularly cited articles (Fricke et al., 2013). For example, in some circumstances, several authors engaged in self-citations, and other authors give wrong citations when presenting their findings and this in away may give pseudo-qualitative and quantitative metrics of the total number of citations of that particular author or nation (Ekundayo and Okoh, 2018).

**Researchers, organization, and nations networking**

Research networking is a vital index that is used to move the relevance of scientific findings forward and intensifies outputs, as it boosts collaboration among authors that do related research globally and locally. Collaboration also allows for intra and inter-disciplinary knowledge exchange and assist to improve networking at various cadres among researchers who do research in similar field (Wenwen et al., 2019). Interestingly, global and local networking is presently pulling interest, recognition, support and endorsement from financial organizations, non-governmental agencies, policy makers and the governments globally. Scientific partnerships and networking again enhance the quality of findings of such research work (Bukvuva, 2010). Several other advantages of scientific networking among researchers, organizations, and nations as linked to scholarly publications comprises of human capacity, funds availability, efficient facilities, and significantly the ease of resolving complex scientific questions resulting from bringing across board expertise with different skills and research experience (Jeong et al., 2011; Bozeman et al., 2013). The details of nation's collaborations and networking is presented in figure 4 using varieties of colours to depict their groups of cooperation. In all, six (6) groups were represented in the diagram. Conversely, the node depicting each nation and the strokes that link the nations together have different thicknesses and sizes, which is indicative of their significance and the prowess of partnership that occur

among the nations. The names of the nations depicted in figure 4 should originally be presented in the correct lettering, but by default (Rstudio software), they were written in small letters. Liu et al. (2019) have also reported similar result. The USA was shown to be the most influential nation with the largest node, with the highest amount of networks with allies from various nations around the globe such as Turkey, Australia, Mexico, UK, China, Canada, and Belgium among others. It is clear from figure 4 in our investigation, the most relevant nations in this research niche area show robust collaboration with each other and majority of these nations are developed economically. This further show the relevance of the topic under discourse.

In the same vein, the global networking among the leading researchers in this research niche area is presented in figure 5. Authors like Zhang, Wang, Chen, and Liu showed strong collaboration and networking with each other (figure 5). This is portrayed in the level of thickness of the strokes/lines that link them together. There are different clusters in the depicted diagram, as revealed by the different colours representing each cluster of network. Researchers having similar colour are known to be in the same group/cluster (Sweileh et al., 2016).

**Source growth assessment**

The source growth of the 11 topmost relevant and productive journals is presented in figure 6. The result of journals leading in reporting research subject matters on alternative feedstuff and livestock research started in a slow manner from 1969 – 1987 (figure 6). However, this trend took an astronomic growth afterwards from 1988 - 2020. The journals "Animal Feed Science and Technology", "Aquaculture", "Aquaculture Research" and "Journal of Animal Science" among others have grown exponentially over the years in the studied subject matter. Importantly between the year 1969 to 1988, very little or negligible amount of articles was published on alternative feedstuff and livestock farming. However, in recent years, there are more published articles on alternative feedstuff as linked to livestock farming which is indicative that the research niche area is gaining popularity. In another bibliometric study,

similar finding was also observed showing an increase in the research investigations on a particular research topic which is important for animal improvement (Smith et al., 2021). Our result is not out of place, reason being that, the utilization of alternative feedstuffs to as complementary feed ingredients for essential animal nutrients (protein, energy, minerals and vitamins) is particularly important to improve livestock production due to seasonal feed shortage and drought experienced by several nations over the years. In most nations of the world and including developing countries, non-conventional feedstuff forms a vital management instrument to sustainable livestock farming (Blache et al., 2008).

**Most relevant words, co-occurrence author's keywords and word cloud**

Cutting edges in scholarly publications for a given time are simply projected via the author's keywords (Synnestvedt et al., 2005). Interestingly, editors of most journal often require authors to list their keywords when they are about to submit their manuscript before journal review process and prospective acceptance of such paper by the journal. The number of keywords varies by individual journals. However, author's keywords are vital to help readers to understand the main areas captured by any study, which is often a mandatorily requirement before a manuscript can be submitted successfully for journal consideration (Okaiyeto and Oguntibeju, 2021). Figures 7 and 8 were used to cover the author keywords in this research niche area between 1969 and 2020. The result observed from this study revealed the top keywords utilized by most of the authors are growth (n = 46), performance (n = 44), digestibility (n = 34), broiler (n = 28), nutrition (n = 28), and growth performance (n = 23) among others. Likewise, it is apparent that the keywords from authors with the peak amount of occurrences (n > 15) were growth, performance, digestibility, broiler, nutrition, "growth performance", "aquaculture", "feed", "sustainability", soybean meal and pig (figure 7).

Furthermore, the result in figures 7 and 8 shows the findings of author's keywords and the word cloud for alternative feedstuffs and livestock farming studies. Importantly, the different

keyword sizes and clusters (with different colours), as shown in the word cloud and collaboration network diagram (i.e. figures 7 and 8) depicts their strong point and occurrence in the research studies associated with alternative feedstuffs and livestock farming. From figure 8, the nearer the keywords are to each other, the closer they are related in literatures. The word cloud simply depicts the most common words used in studies of alternative feedstuffs in the context of livestock production research, which in turn easily pinpoints areas of consecration in this niche research. In summary, it is vital to state that, keywords are used to capture the main subjects of a scholarly niche area, and it helps readers to focus and understand the key concepts of the studied subject matter (Chen et al., 2014).

From the result in figures 7 and 8, it can be deduced that different types of alternative feedstuffs such as natural plant or animal-base materials, domestic and/or industrial waste and by-products have been used to meet the nutritional demands of livestock for better performance and productivity. For instance, studies by two authors whose articles were ranked among the most globally cited articles (table 4), it was observed that naturally available sources (moringa leaf meal and yeast-based proteins) were employed as an alternative protein source to improve the growth and productivity of fish (Lunger et al., 2007;Richter et al., 2003). Likewise, from another most globally cited article (table 4), it was observed that the use of yellow mealworm larvae (YML) improved the feed conversion ratio (FCR) of broilers than that of the soybean meal (SBM) group (Bovera et al., 2015). Furthermore, the study discovered a lower albumin-to-globulin ratio in broilers fed on YML compared to those fed on SBM which suggests a higher immune in the birds fed YML compared to those fed with SBM. Very importantly, it should be noted that livestock farmers and producers must know the dynamics involved in substituting and supplementing alternative feedstuffs in animal ration so as to meet the energy, protein and key mineral levels of the new feed in order to formulate balanced, least-cost diets for livestock. The reason for this is because; many of the animal/plant based alternative

feedstuff vary extensively in terms of nutrient content, making an analysis or some assessment of the feed value very important.

**Study limitations**

Regardless of the several benefits of this particular analysis (bibliometric), it is essential to acknowledge limitations which are related with the current investigation. Published articles associated to alternative feedstuffs and livestock production were evaluated using both the Scopus and WoS archive, to accommodate an enormous coverage of the required articles. Howbeit, it is not unlikely that some other articles published in journals that are not indexed in the two data archives were excluded. Therefore, the results of the present findings may not have represented the whole articles accessible on the studied topic. Additionally, the publications assessed in our investigation were constrained to the ones communicated solely in English, without considering others written in other internationally recognized languages. Hence, it is suggested that future studies in this niche area (alternative feedstuff and livestock farming) should consider all the enumerated limitations to allow for a more accurate inclusiveness.

**CONCLUSION**

The current study deliberated on bibliometric research findings on "alternative feedstuffs in the context of livestock farming" from 1969 to 2020. An aggregate of 1634 research publications collected from both Scopus and WoS archives, focusing on research articles, reviews, books, and notes among others. The documents had 5989 authors while the amount of authors per documents gave a figure of 3.67; co-authors per documents were 4.22 while the collaboration index was 3.96. Nations were ranked base on their level of scholarly and scientific performance, amount of citations, and global networking among scientist within the studied period. The USA, Turkey, Italy and Germany were the nations with topmost collaboration in the research domain among others. This suggests that the USA and Europe leads in the

continents with high impact in this research niche area. These nations also displayed a remarkable allied globally among their research associates. However, only Egypt represented Africa as a continent among the top 20 most relevant nations in this research domain. Hence, there is a high optimism that the understanding of this result will assist new and emerging scientists to discover where and with which senior researchers or colleagues in this research field they can pursue a mutual collaboration/network in the near future. Scientists doing research in economically disadvantaged (developing) countries such as Africa should therefore be challenged to get more involved in doing research in this research domain and where necessary, they should sort for assistance from well-known and established researchers globally who have immensely contributed to the advancement of this kind of research in the past. This will in the long run open more doors to do research that will support the use of alternative feedstuffs which are abundantly available for use to boost livestock farming in the region (Africa).

**Future perspectives and recommendations**

Scientist, researchers, and especially feed nutritionist can continue to search and work on innovative feeding schemes with the use of more discovered nutritionally rich alternative feedstuffs/materials/resources that may have proven records to demonstrate and boost more economic animal performance and productivity when used (e.g. proteinaceous forages, insects, and agro-allied materials) for livestock farming and production. Furthermore, advance strategies that reported on the usage of these alternative feed materials are needed to encourage comprehensive on-farm testing of principal feedstuffs, supported by robust institutional provision and broader resource utilization. The significance of extensive and comprehensive on-farm feed adoption deserves utmost consideration, and it far surpasses the requisite for additional reports on pre-treatments of roughages and the positive advantage of supplementation. These innovations can meaningfully impact higher points of productivity

from livestock, and lessen the quest for productivity in the intensive use of the entire feed resources globally. Meanwhile, the issue of plant secondary compounds in some alternative feedstuffs (e.g. shrubs, proteinaceous forages etc.) should also be considered when formulating livestock feed for production purposes. For instance, in ruminant production, careful and intentional management and treatment measures of alternative feed materials will help to limit the negative effect of the toxicity of unwanted/desirable impact of secondary metabolites which will permit the exploitation of some exceptional properties of the secondary metabolites to guard protein from rumen digestion.To effectively use alternative feedstuffs successfully, the impact of those feed materials on animal performance also requires attention .

## DECLARATIONS

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**Authors' contribution**

E.M.I conceptualize the study.

E.M.I did data collection and analysis.

E.M.I wrote the manuscript.

A.N.S logistic and support.

The manuscript was reviewed by all authors.

**Conflict of interests**

No conflicting interest.

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Table 1. Summary findings of retrieved published documents on alternative feedstuffs as a tool for improving livestock production from Scopus and WOS data bases.

| Information Description | Results |
|---|---|
| MAIN INFORMATION ABOUT DATA | |
| Timespan | 1969:2020 |
| Sources (Journals, Books, etc) | 954 |
| Documents | 1634 |
| Average years from publication | 9.66 |
| Average citations per documents | 18.09 |
| Average citations per year per doc | 1.866 |
| References | 43377 |
| DOCUMENT TYPES | |
| Article | 1440 |
| Article; book chapter | 12 |
| Article; proceedings paper | 32 |
| Book | 6 |
| Book chapter | 46 |
| Conference paper | 77 |
| Editorial | 5 |
| Erratum | 3 |
| Letter | 6 |
| Note | 2 |
| Short survey | 5 |
| DOCUMENT CONTENTS | |
| Keywords Plus (ID) | 9614 |
| Author's Keywords (DE) | 4812 |
| AUTHORS | |
| Authors | 5989 |
| Author Appearances | 6893 |
| Authors of single-authored documents | 143 |
| Authors of multi-authored documents | 5846 |
| AUTHORS COLLABORATION | |
| Single-authored documents | 156 |
| Documents per Author | 0.273 |
| Authors per Document | 3.67 |
| Co-Authors per Documents | 4.22 |
| Collaboration Index | 3.96 |

Table 2. Top 20 relevant/productive authors on alternative feedstuffs research for livestock production.

| S/N | Author | Rank | H_index | G_index | M_index | TC | Articles | Articles Fractionalized | PY_start |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Li M | 1 | 5 | 10 | 0.192 | 110 | 10 | 2.85 | 1998 |
| 2 | Kim J | 2 | 4 | 9 | 0.222 | 101 | 9 | 3.35 | 2006 |
| 3 | Trushenski J | 2 | 7 | 9 | 0.538 | 165 | 9 | 2.74 | 2011 |
| 4 | Kim S | 3 | 3 | 7 | 0.231 | 92 | 8 | 1.98 | 2011 |
| 5 | Wang H | 3 | 6 | 7 | 0.462 | 101 | 8 | 1.67 | 2011 |
| 6 | Zhang Y | 3 | 5 | 8 | 0.208 | 169 | 8 | 1.67 | 2000 |
| 7 | Kimber I | 4 | 4 | 7 | 0.129 | 601 | 7 | 1.67 | 1993 |
| 8 | Lucas P | 4 | 4 | 6 | 0.364 | 45 | 7 | 1.67 | 2013 |
| 9 | Bracher A | 5 | 2 | 2 | 0.400 | 7 | 6 | 1.52 | 2019 |
| 10 | Khan M | 5 | 5 | 5 | 0.333 | 164 | 6 | 1.37 | 2009 |
| 11 | Lee S | 5 | 2 | 2 | 0.333 | 15 | 6 | 1.37 | 2018 |
| 12 | Liu H | 5 | 4 | 5 | 0.286 | 91 | 6 | 1.37 | 2010 |
| 13 | Awawdeh M | 6 | 3 | 4 | 0.250 | 18 | 5 | 1.21 | 2012 |
| 14 | Bosworth B | 6 | 3 | 5 | 0.250 | 33 | 5 | 1.21 | 2012 |
| 15 | Davis D | 6 | 5 | 5 | 0.333 | 122 | 5 | 1.21 | 2009 |
| 16 | Dearman R | 6 | 2 | 5 | 0.065 | 358 | 5 | 1.21 | 1993 |
| 17 | Dursun M | 6 | 3 | 5 | 0.214 | 133 | 5 | 1.21 | 2010 |
| 18 | Fisher R | 6 | 5 | 5 | 0.139 | 196 | 5 | 1.06 | 1988 |
| 19 | Hardy R | 6 | 2 | 3 | 0.074 | 20 | 5 | 1.06 | 1997 |
| 20 | Lee K | 6 | 3 | 5 | 0.375 | 70 | 5 | 1.06 | 2016 |

NB = PY_start: Publication year start; TC: Total citation.

Table 3. The topmost productive institutes on alternative feedstuffs research with over 7 publications.

| S/N | Affiliations | Articles | Country | Institution type |
|---|---|---|---|---|
| 1 | SO Illinois Univ | 25 | USA | University |
| 2 | Istanbul Tech Univ | 22 | Turkey | University |
| 3 | Univ Sao Paulo | 20 | Brazil | University |
| 4 | University of California | 20 | USA | University |
| 5 | Jordan UnivSci and Technol | 16 | Jordan | University |
| 6 | Univ Guelph | 15 | Canada | University |
| 7 | Auburn Univ | 13 | USA | University |
| 8 | Mississippi State Univ | 13 | USA | University |
| 9 | Swedish UnivAgrSci | 13 | Sweden | University |
| 10 | UnivHohenheim | 13 | Germany | University |
| 11 | Seoul Natl Univ | 12 | South Korea | University |
| 12 | DokuzEylulUniv | 11 | Turkey | University |
| 13 | EgeUniv | 11 | Turkey | University |
| 14 | Kangwon Natl Univ | 10 | South Korea | University |
| 15 | King Saud Univ | 10 | Saudi Arabia | University |
| 16 | Near East Univ | 10 | Cyprus | University |
| 17 | Univ Fed Santa Catarina | 10 | Brazil | University |
| 18 | Univ Idaho | 10 | USA | University |
| 19 | KahramanmarasSutcu Imam Univ | 9 | Turkey | University |
| 20 | Texas AandmUniv | 9 | USA | University |
| 21 | Univ Georgia | 9 | Georgia | University |
| 22 | Univ Maryland | 9 | USA | University |
| 23 | Egerton Univ | 8 | Kenya | University |
| 24 | Iowa State University | 8 | USA | University |
| 25 | KocaeliUniv | 8 | Turkey | University |

Table 4. Top 20 most global cited articles on alternative feedstuffs and livestock production research from 1969 - 2020

| S/N | Lead author & year | Name of Journal | DOI | Total Citations | TC per Year | Normalized TC |
|---|---|---|---|---|---|---|
| 1 | Yang Y, 2009 | World's Poultry Science Journal | 10.1017/S0043933909000087 | 278 | 21.3846 | 9.2238 |
| 2 | Allan GL, 2000 | Aquaculture | 10.1016/S0044-8486(99)00380-4 | 186 | 8.4545 | 2.2346 |
| 3 | Lunger AN, 2007 | Aquaculture | 10.1016/j.aquaculture.2007.07.006 | 139 | 8.1765 | 4.5463 |
| 4 | Lock E R, 2016 | Aquaculture Nutrition | 10.1111/anu.12343 | 124 | 15.5 | 10.2439 |
| 5 | Richter N, 2003 | Aquaculture | 10.1016/S0044-8486(02)00497-0 | 118 | 5.619 | 3.6581 |
| 6 | Woyengo TA, 2014 | Journal of Animal Science | 10.2527/jas.2013-7169 | 111 | 11.1 | 5.5175 |
| 7 | Ng WK, 2001 | Aquaculture Research | 10.1046/j.1355-557x.2001.00024.x | 106 | 4.6087 | 1.9361 |
| 8 | Bovera F, 2015 | British Poultry Science | 10.1080/00071668.2015.1080815 | 96 | 10.6667 | 7.2366 |
| 9 | Tibbetts SM, 2006 | Aquaculture | 10.1016/j.aquaculture.2006.08.052 | 96 | 5.3333 | 2.7871 |
| 10 | Davies SJ, 1990 | Aquaculture | 10.1016/0044-8486(90)90271-N | 94 | 2.7647 | 3.9316 |
| 11 | Montero D, 2010 | Fish Oil Replacement and Alternative Lipid Sources in Aquaculture Feeds | 10.1201/9781439808634 | 79 | 5.6429 | 2.571 |
| 12 | Elizabeth Cruz-Suarez L, 2010 | Aquaculture | 10.1016/j.aquaculture.2010.01.021 | 78 | 5.5714 | 2.5385 |
| 13 | Demir E, 2003 | British Poultry Science | 10.1080/00071660301944 | 78 | 3.7143 | 2.4181 |
| 14 | Gong J, 2014 | Canadian Journal of Animal Science | 10.4141/CJAS2013-144 | 78 | 7.8 | 3.8772 |
| 15 | Khan RU, 2012 | World’s Poultry Science Journal | 10.1017/S0043933912000517 | 69 | 5.75 | 4.2593 |

Table 5. The top 20 publications by countries in the field of alternative feedstuffs and livestock production research from 1969 - 2020.

| S/N | Country | Articles | Frequency | SCP | MCP | MCP_Ratio |
|---|---|---|---|---|---|---|
| 1 | USA | 258 | 0.177808 | 233 | 25 | 0.0969 |
| 2 | Turkey | 152 | 0.104755 | 138 | 14 | 0.0921 |
| 3 | Brazil | 102 | 0.070296 | 97 | 5 | 0.049 |
| 4 | China | 61 | 0.04204 | 58 | 3 | 0.0492 |
| 5 | India | 54 | 0.037216 | 52 | 2 | 0.037 |
| 6 | Spain | 54 | 0.037216 | 47 | 7 | 0.1296 |
| 7 | Canada | 52 | 0.035837 | 44 | 8 | 0.1538 |
| 8 | Italy | 50 | 0.034459 | 41 | 9 | 0.18 |
| 9 | Germany | 47 | 0.032391 | 37 | 10 | 0.2128 |
| 10 | United Kingdom | 44 | 0.030324 | 39 | 5 | 0.1136 |
| 11 | Australia | 38 | 0.026189 | 29 | 9 | 0.2368 |
| 12 | Indonesia | 36 | 0.02481 | 36 | 0 | 0 |
| 13 | Korea | 32 | 0.022054 | 28 | 4 | 0.125 |
| 14 | Japan | 31 | 0.021365 | 25 | 6 | 0.1935 |
| 15 | Malaysia | 23 | 0.015851 | 20 | 3 | 0.1304 |
| 16 | France | 22 | 0.015162 | 17 | 5 | 0.2273 |
| 17 | Egypt | 20 | 0.013784 | 15 | 5 | 0.25 |
| 18 | Mexico | 18 | 0.012405 | 16 | 2 | 0.1111 |
| 19 | Netherlands | 18 | 0.012405 | 17 | 1 | 0.0556 |
| 20 | Switzerland | 18 | 0.012405 | 16 | 2 | 0.1111 |

**SCP:** Single Country Publications; **MCP:** Multiple Country Publications.

Table 6. The top 20 most cited regions in terms of average article citations (AAC) in researches on alternative feedstuffs for livestock production from 1969 to 2020.

| S/N | Country | Total Citations | Average Article Citations |
|---|---|---|---|
| 1 | USA | 6265 | 24.28 |
| 2 | Spain | 2042 | 37.81 |
| 3 | Turkey | 1900 | 12.50 |
| 4 | Italy | 1764 | 35.28 |
| 5 | Australia | 1548 | 40.74 |
| 6 | Canada | 1214 | 23.35 |
| 7 | China | 1143 | 18.74 |
| 8 | United Kingdom | 1127 | 25.61 |
| 9 | Japan | 1026 | 33.10 |
| 10 | Brazil | 952 | 9.33 |
| 11 | Germany | 844 | 17.96 |
| 12 | India | 685 | 12.69 |
| 13 | France | 653 | 29.68 |
| 14 | Norway | 554 | 32.59 |
| 15 | Malaysia | 537 | 23.35 |
| 16 | Netherlands | 525 | 29.17 |
| 17 | Korea | 440 | 13.75 |
| 18 | Switzerland | 435 | 24.17 |
| 19 | Greece | 363 | 24.20 |
| 20 | Finland | 330 | 47.14 |

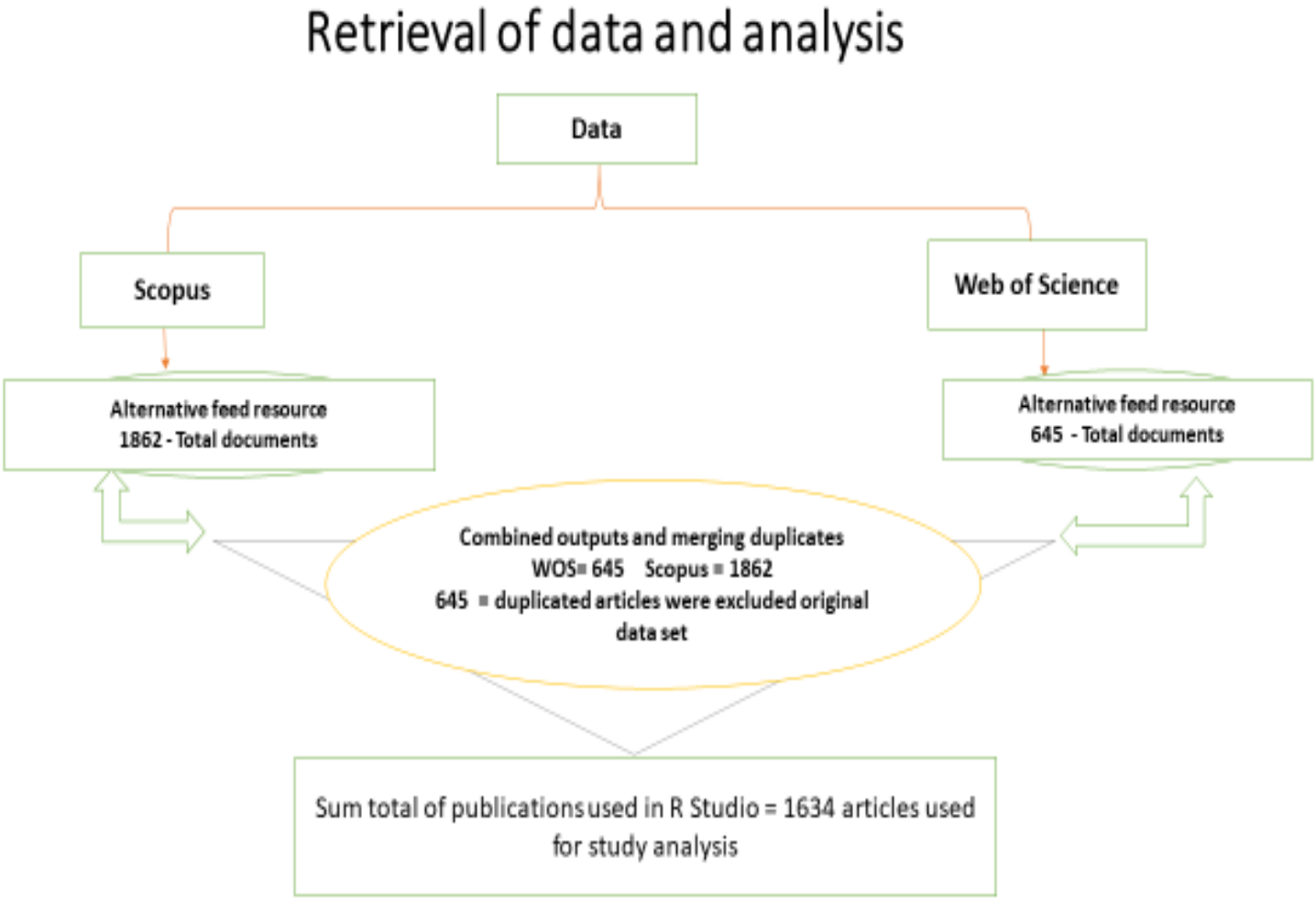


Figure 1: Diagram depicting data inclusion and exclusion of articles for selection

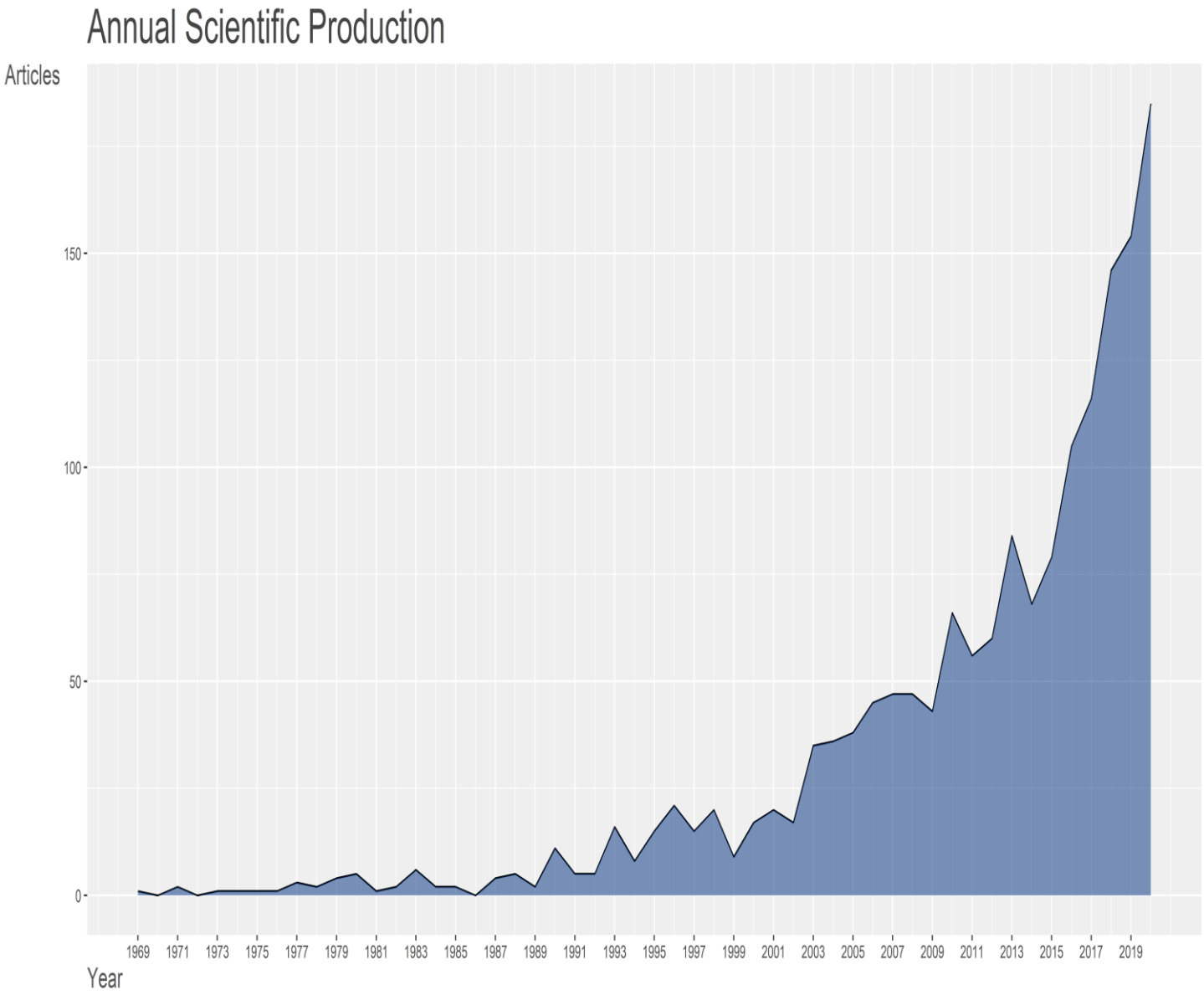


Figure 2. Annual scientific research publications (from 1969 to 2020) on alternative feedstuffs research studies for livestock production with an annual growth rate of 11.49 %. Alternative feedstuffs research studies showed a fluctuating trend in growth in the research field from 1969 to 1999. However, there was a steady upward rise in research publications from 1999 to 2020.

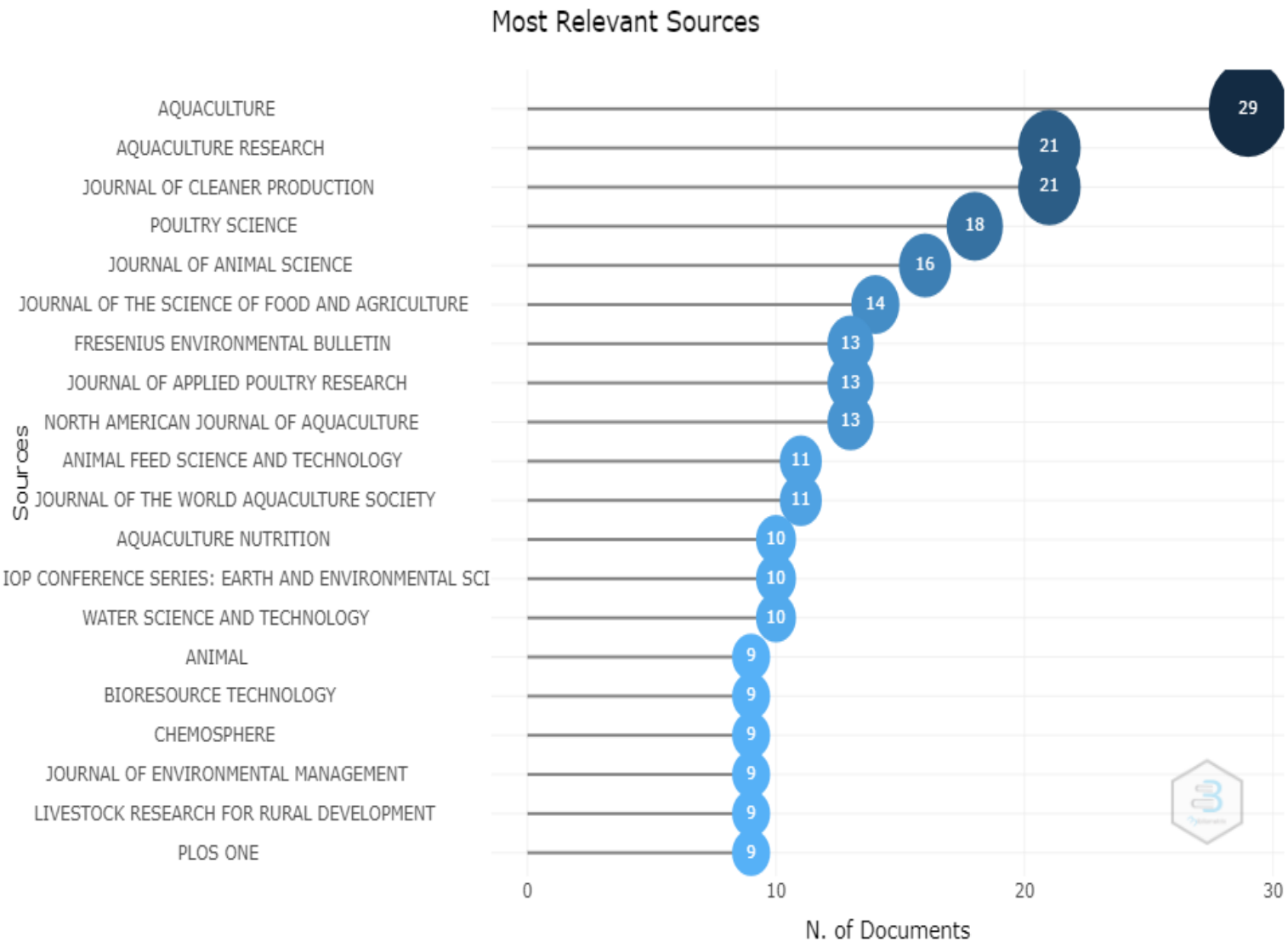


Figure 3. The topmost 20 journals that have reported relevant research in the field of alternative feedstuffs as a tool for improving livestock production from 1969 to 2020.

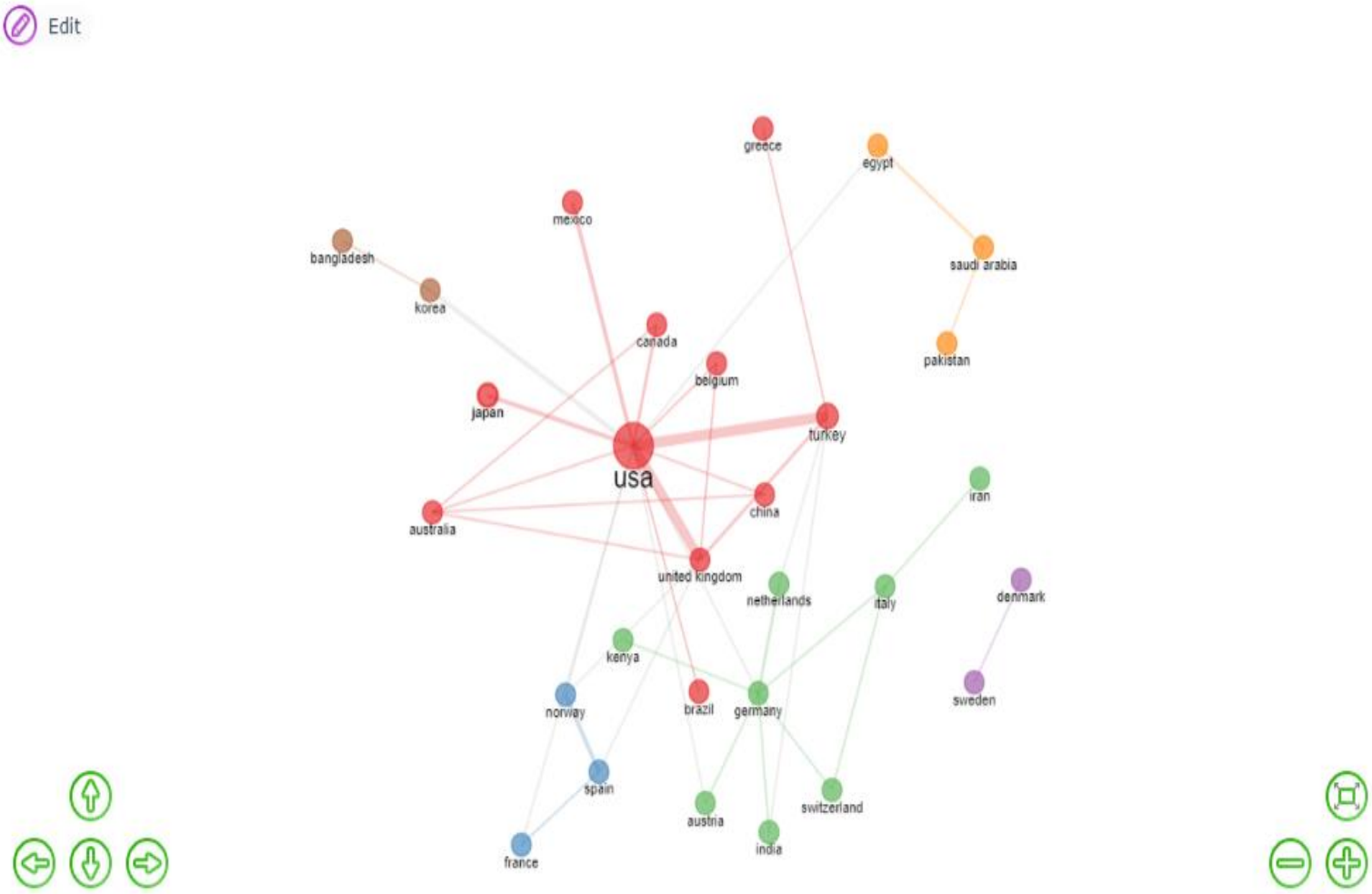


Figure 4. Collaboration among countries from 1969 to 2020.

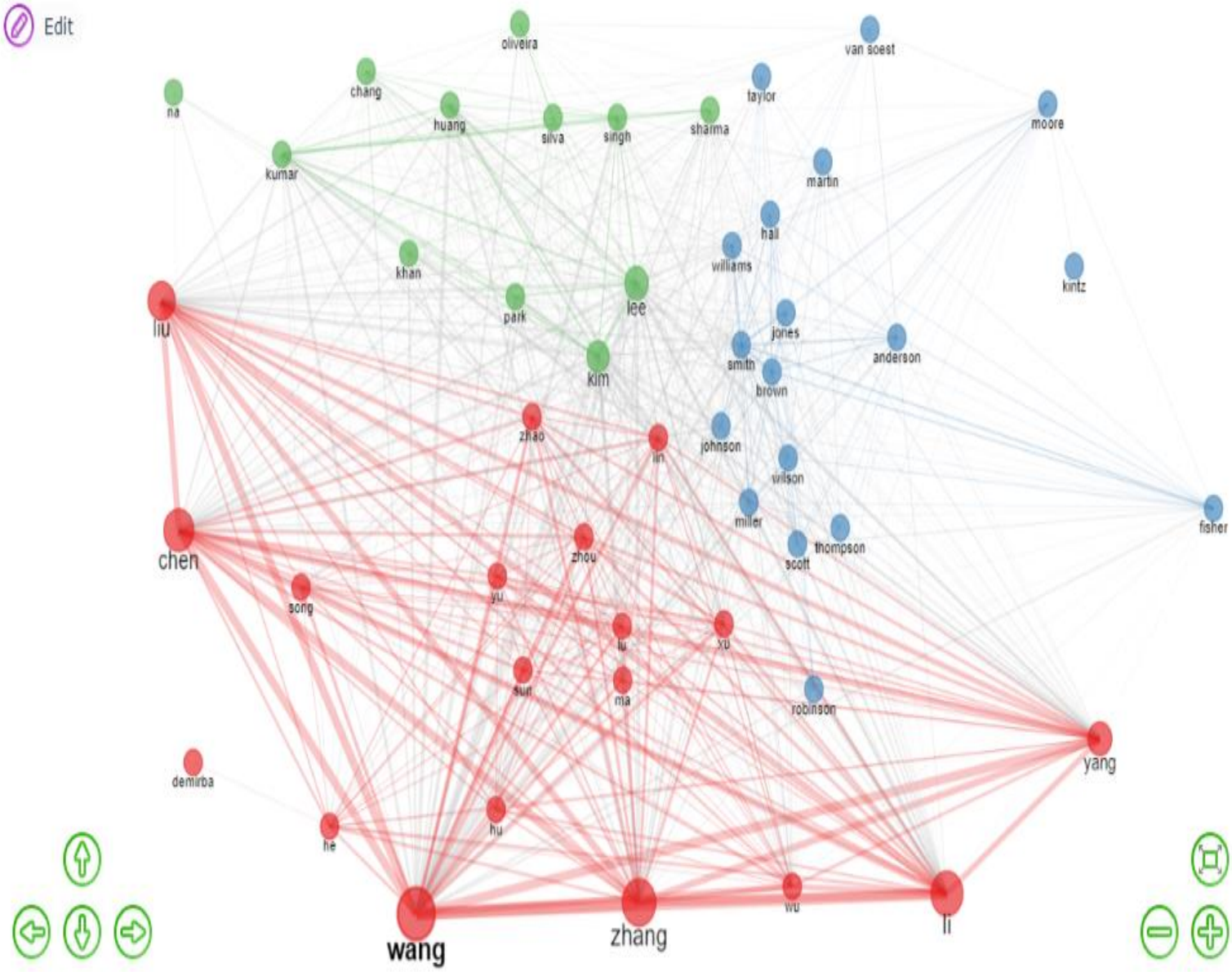


Figure 5. Authors' network/collaboration among several institutions between 1969 and 2020.

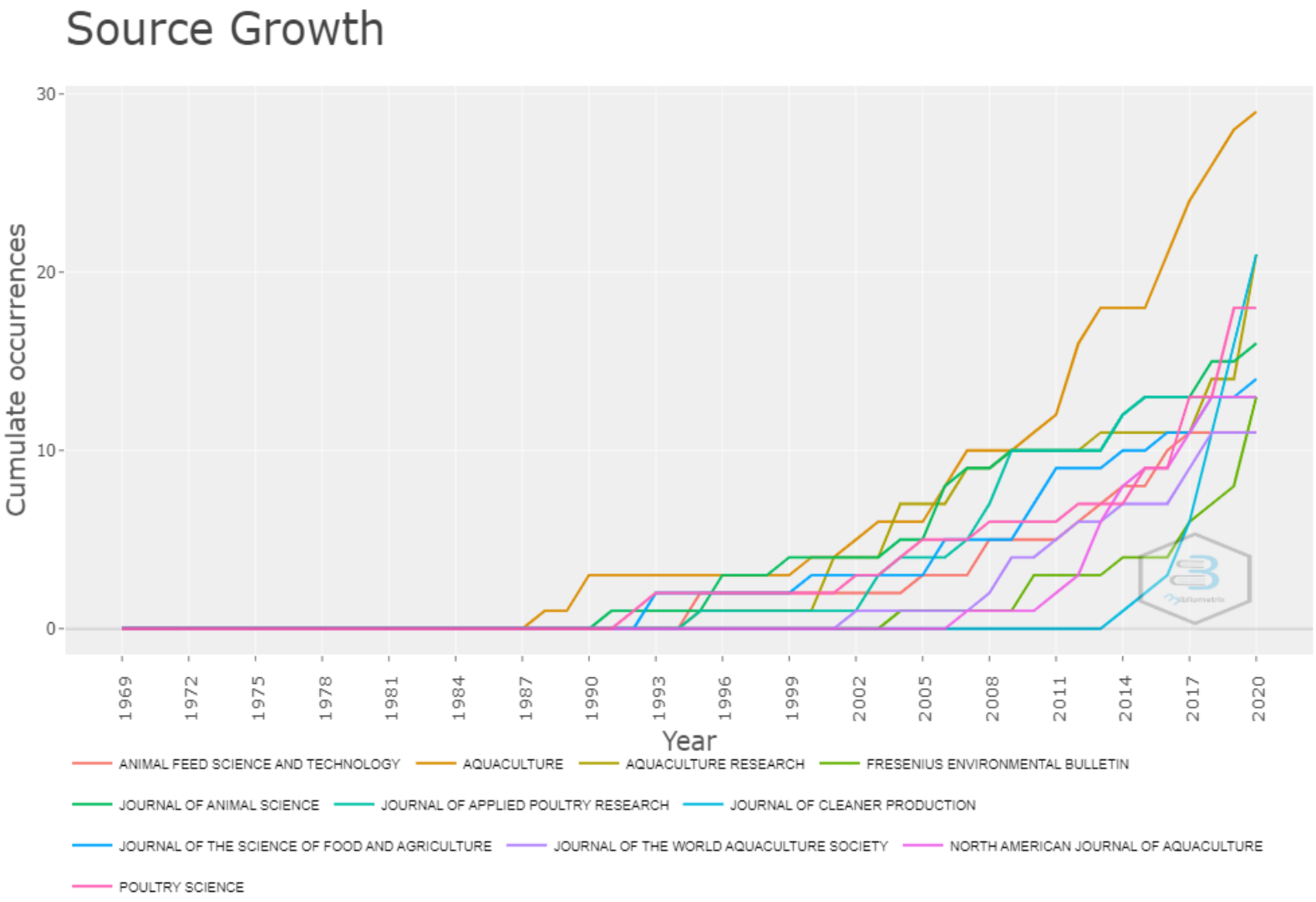


Figure 6: Source growth of the incremental trend of the 11 topmost productive journals in alternative feedstuffs research from 1969 to 2020.


Figure 7. Word cloud on alternative feedstuffs and livestock production studies.

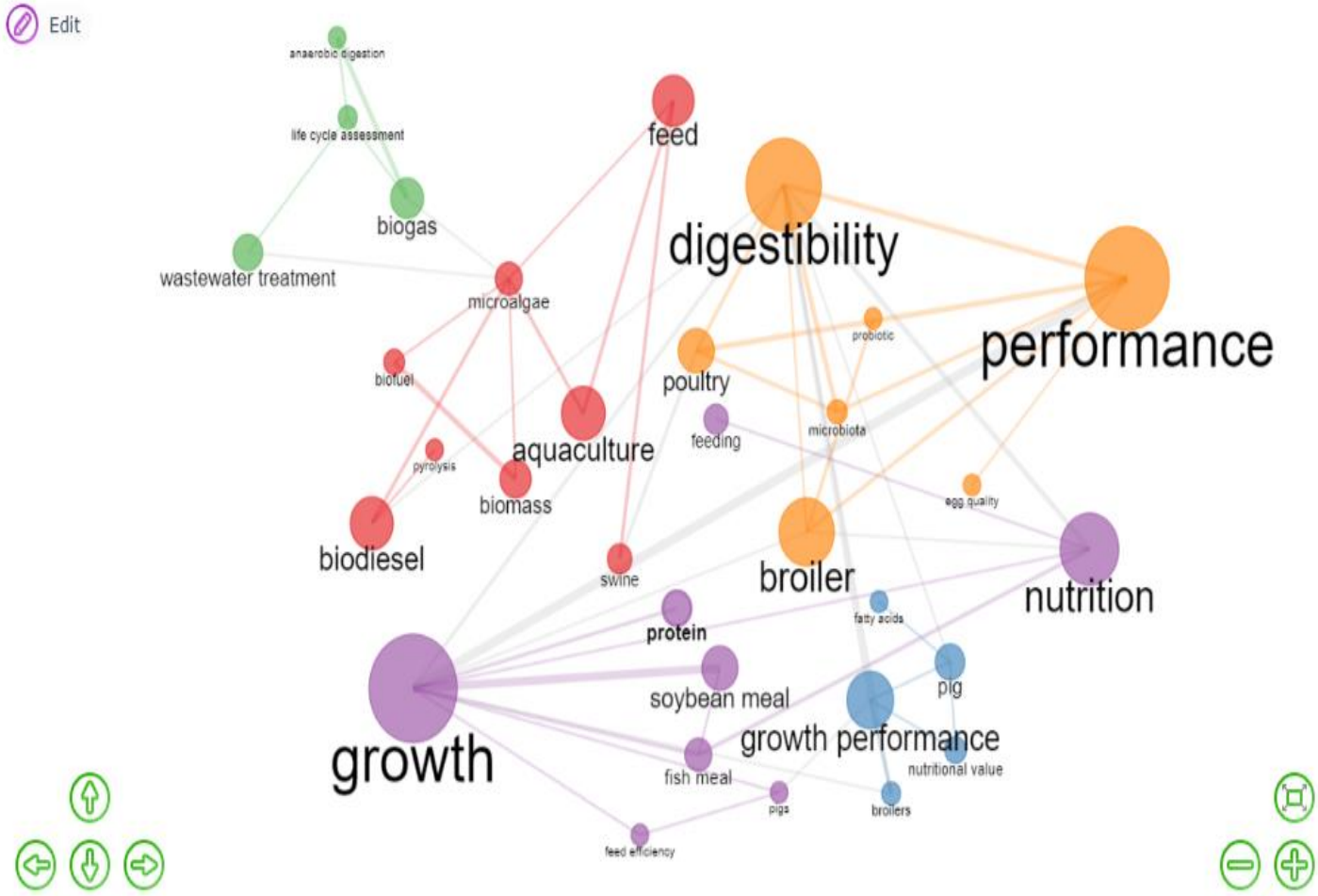


Figure 8. Top author's keywords from 1969 to 2020.