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MAIN TRENDS IN THE DEVELOPMENT OF BIOECONOMIC STRATEGIES IN AGROINDUSTRY: A SYSTEMATIC LITERATURE REVIEW

Muflihah Ramadhia[1], Imam Santoso[2]
[1]Teknologi Industri Pertanian, Universitas Brawijaya and Pengolahan Hasil Perkebunan Terpadu, Politeknik Negeri Pontianak
[2]Teknologi Industri Pertanian, Universitas Brawijaya

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ABSTRACT

Bioeconomics is an emerging concept and has not been given a generally accepted definition. Bioeconomic strategy tries to consider every aspect of this emerging concept from different perspectives depending on the country, region, or organization that publishes it. Therefore, each strategy has its advantages depending on the economic, geomorphological, social, environmental, and technological conditions of each country. In this review, attempts are made to address key trend areas of bioeconomic strategies through a systematic literature review. PRISMA analysis is used to review the literature on key trend areas of bioeconomic strategies. Review articles address this topic in two major scientific literature databases, namely Scopus and AgEcon. Using a repeatable search process to identify relevant studies in the literature, only 68 publications that met the eligibility criteria were included in the review. The results showed that the movement of the main trends of the Bioeconomic Strategy in agro-industry 2013-2022 was observed as well as the economic and technological development of each country to show its superiority. The transition to a successful bioeconomy model requires the participation of the whole society because a sustainable society as a whole requires sustainable and environmentally responsible solutions. The study concludes that management with global coordination and training for stakeholders is necessary for the successful implementation of bioeconomic strategies in agro-industry.

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1. INTRODUCTION

The term bioeconomics seems to have been used in the early 2000s[1]. Policy discussions on bioeconomics began in the middle of the decade on the agenda of the European Commission (EC). However, the foundations for the bioeconomy came from previous EC strategic agendas, including a 1993 white paper that emphasized the need for knowledge-based investment and the role of biotechnology in innovation and growth, and the Lisbon agenda in 2000, which called for global leadership to focus on the knowledge economy to ensure competitiveness and economic growth. In addition, in 2002, the EC stated that life sciences and biotechnology may be the most promising cutting-edge technologies, with high potential to contribute to the achievement of the Lisbon agenda Goals. In 2005, at an international conference of the European Union, the knowledge-based economic framework (KBBE) was presented, followed by another conference in 2007, which outlined the prospects for the European bioeconomy over the next 20 years. Both of these events contributed to the emergence of a knowledge-based bioeconomy in European political circles [2].

Bioeconomy has high attractiveness as a potential solution for green growth and competitiveness [3]. The European Bioeconomy Strategy supports the production of renewable biological resources and their transformation into essential products or bioenergy to achieve the 2030 Agenda and the Sustainable Development Goals[4]. Biomass resources represent opportunities for sustainability in the biomass industry [5], including sectors as diverse as agriculture, food, biochemistry, bioenergy, biocides, and forests [6,7]. In addition, the development of the bioeconomic sector is an opportunity to promote innovation and job creation in rural and industrial areas [8]. It is also an opportunity to revitalize productivity and growth by increasing the competitiveness of domestic industries through new technologies[9] and reduce dependence on imported raw materials by rehabilitating marginalized areas [10].

In the context of climate change, production processes and consumption patterns are becoming more sustainable, due to the increasing pressure on non-renewable resources. A shift towards more sustainable production and more efficient use and management of biological resources can help reduce waste, pollution, climate change, and the use of fossil resources[11]. This transformation implies a number of changes in both primary and industrial production processes, which are referred to as bioeconomy. Bioeconomics describes a concept that recognizes the full potential of biotechnological research and innovation for the economy and society. In the past twenty years, it has mainly been promoted by leading biotechnology countries such as Belanda, Germany and Finland [12].

In 2006, the OECD presented the main report "*The Bioeconomy 2030: Shaping the Policy Agenda*" [13]. In 2012, the European Commission presented its first bioeconomy strategy [14]. Within this framework, bioeconomics is defined as follows: "Bioeconomy involves the production of renewable resources and their transformation into food, feed, bioproducts, and bioenergy. These include agriculture, forestry, fishing, food, and paper production as well as chemical and energy parts. Bioeconomic sectors are innovative because they use a wide range of sciences (life sciences, earth sciences, ecology, food sciences, social sciences) and technology (biotechnology, nanotechnology, ICT), engineering and local traditional knowledge". As stated in the latest 2018 strategy, the EU's bioeconomic objectives are: (a) ensuring food security and nutrition, (b) ensuring the sustainability of natural resources, (c) to reduce dependence on non-renewable and unsustainable resources whether domestically sourced or from abroad, (d) to mitigate and adapt to climate change, and (e) to strengthen Europe's competitiveness and create jobs [4]. The goal was revised to recognize the contribution of the bioeconomy strategy to both the circular economy and the *Energy Union*. The scale must be adapted and adaptedto the main European trends [4].

Based on this, it can be concluded that the bioeconomic strategy is a set of expectations. All bioeconomic strategies aim to contribute to economic development and international economic competitiveness [15]. In addition, some strategies clearly envision job creation as a result of economic growth. Furthermore, the strategy that defines bioeconomy in a broad sense extends the promise of economic development to traditional sectors of the bioeconomy [16]. Economic expectations are closely related to the goals of the bioeconomy, which plays an important role in the development of technology. What all strategic documents have in common is that new scientific discoveries and technological developments make upthe bioe economy and must be supported [17].

Almost all strategies expect the bioeconomy to make a significant contribution to society or global challenges. Food security, resource conservation, climate and environmental protection, and health issues are cited as examples. Depletion of mineral resources and climate change are the business case for transitioning from a fossil fuel-based economy to a bio-based economy [17]. Strategies differ in the extent to which they consider replacing fossil resources with biological ones. This means a transition from a biological economy with little dependence on mineral resources to a renewable resource-based economy [14]. At the same time, bioeconomic disorganization is described as a comprehensive and integrated process of societal transformation that must be supported by social, economic, political, and environmental research. From transformational approaches, some strategies face conflicting goals, side effects, and management challenges [18].

About half of strategists predict that the bioeconomy will become global in two different ways: First, it is seen as part of a global strategy for sustainable resource management and focuses on solving global problems. The second argument considers bioeconomics a global phenomenon. The focus is on global networks of biomass resources, value chains and technologies, with an international division of labor in research, production, and markets[19]. Both arguments predict important health developments in the context of bioeconomics. The objectives of developing a bioeconomic strategy at the national or international level are general because they concern sustainability and survival. Despite obstacles and conflicts of interest [20], it is a one-way street to implement bioeconomic strategies by all.

From the many literatures, although bioeconomic strategies are analyzed in detail, it is clear that each focuses on the main trends and specific needs of each country or region. There is no research that addresses all major trends, and this is the gap this review is trying to fill. The main objective of the study is to review the relevant international scientific literature on existing bioeconomic strategies and its main trend areas using a systematic literature review. In addition to the results of research on bioeconomic strategies, the evolution of these topics, the relationship between them, and the policy measures taken are also examined. The importance of this research is that some countries have not adopted bioeconomic strategies, and they have contributed directly by contributing to global efforts to save the planet. The next section presents the methodology used, the results of the analysis and finally the conclusions, limitations and suggestions for further research.

2. METHODS

A systematic review performs an important role, as it can provide a synthesis of knowledge in a particular area. The resulting knowledge guides the main trends of future research and helps answer questions that individual studies cannot answer. However, systematic reviews contribute to mainstream research by identifying problems that need to be fixed in future research, and evaluating theories about how or why certain phenomena occur [21]. Systematic reviews can be used by a wide range of users such as citizens, researchers, and policy makers, so they must be transparent, comprehensive, and accurate [22]. PRISMA analysis can be used to achieve these goals and is designed to address the shortcomings of systematic review reporting [23]. In particular, PRISMA's analysis includes a list of 27 items [21] that are widely adopted, and adopted as evidenced by citations of over 31,000 documents in Scopus alone (December 2022). Although many studies report that PRISMA analysis is associated with more complete systematic review reporting [24]–[27], there is a counterargument that corrective action can be taken to improve it[28].

In this study, PRISMA analysis was used to review the literature on key trend areas of bioeconomic strategies. Although research on individual key trend areas (climate change, economic development, pollution reduction, energy, employment, etc.) is systematic and standardized, not all of them are related to bioeconomic strategies implemented by countries. In addition, VOSviewer is used for bibliometric analysis. The software has great advantages such as reliability and wide adoption, has been used in similar research, and is *open source* and available.

The research data was obtained from *Scopus* and *Agecon databases*. There is a systematic review of broader bioeconomic concepts in the literature, especially in the *databases Scopus*, *Web of Science*, and *AgEcon* [29]–[34]. Due to limited access, *the Web of Science* contained in this literature review. The database in this literature also retrieves information including journal articles, reviews, book chapters, conferences, books, short surveys, notes, and informational articles. References to key trend areas in bioeconomic strategies made nationally or regionally whose source is not clear, were not included in the study because the documents are not clear the database from which the information was obtained. In addition, much of the source literature is often not written in English [35].

The search for publications related to the main trends of the bioeconomic strategy is obtained from the match search "title, abstract, keyword" of the database.

In the first stage, a collection of publications from both databases (*Scopus, AgEcon*) was selected without specifying a time, and then publications relevant to the study were selected manually after eliminating duplication and non-English publications (Figure 1).

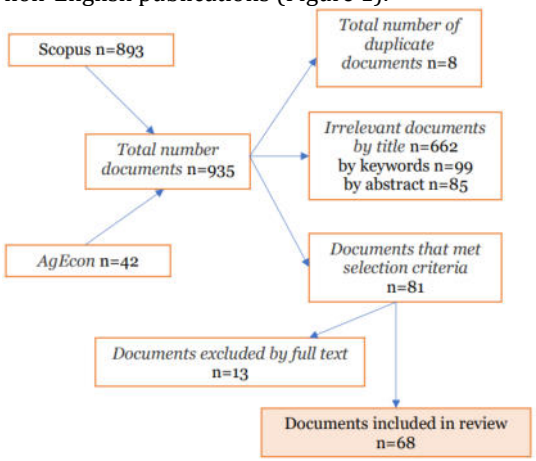

Figure 1.Flowchart illustrating the selection of pulication articles

Several search tests with different terms were conducted to determine the most relevant search terms [36]. Look for articles starting with the terms (bio*OR bio-*OR bio-based* OR biobased* OR biobased*) AND (economy) AND (strategies)) in the TITLE ABS KEY column and leave 5835 Results (5731 *Scopus*), 104 *AgEcon*) December 2022. However, it has been noted that the term *bio-based* or *biobased* is not directly related to bioeconomic strategies, but to products or sectors, and was issued [37]–[40]. The search is designed iteratively, ie. Searches that do not meet certain criteria are excluded [41]. To minimize the risk of relevant loss, the search for additional tests is carried out using a combination of alternative conditions. It was found and known that the bio-economy was largely associated with the pure economy

was also eliminated [42]–[45]. In the last search used in this review, the terms "bioeconomy" AND "strategies" returned 935 results (893 *Scopus*, 42 *AgEcon*). Next, irrelevant publications are manually deleted after reading the title, keywords, abstract and, if necessary, the full text. Finally, there are 68 publications based on this review. When reviewing publications that meet the selection criteria, a number of problems arise. First, in some publications, strategies are not defined by clear names, but by terms such as *policy* [46]–[48], *programme* [49]or *pathway* [50], [51]. Another problem is that some strategies refer to key trend areas that are already implemented, while others refer to the implementation of key trend areas in the future and what impact they will have [52]–[56]. Only studies that explicitly refer to strategies that have been implemented are included in this literature study.

3. RESULT AND DISCUSSION

The order of selection of publications included in the overview is shown in Figure 1. An initial search of the two databases yielded 935 results, and the publication title was used as the criterion for removing duplicates. As a result, 893 publications were identified as unique, and 81 of them met the notability criteria (i.e., title, keywords, irrelevant abstract) based on manual searches and were written in English. For 19 issues it was deemed necessary to read the article in its entirety to consider whether or not it was included, therefore 6 issues were included, and 13 issues related to future work were rejected. A total of 68 publications were considered in this review.

Bibliometric Analysis

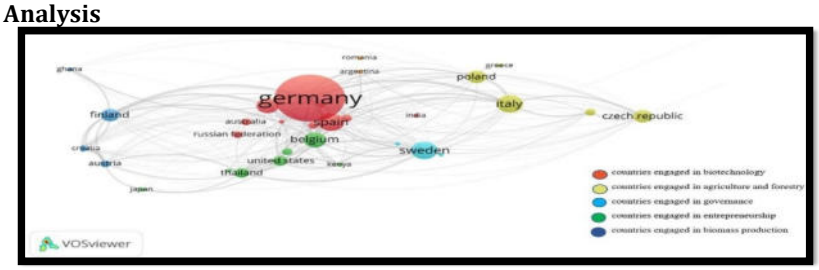

Figure 2. Co-Authorship Analysis/State Network Visualization

Source: VOSviewer

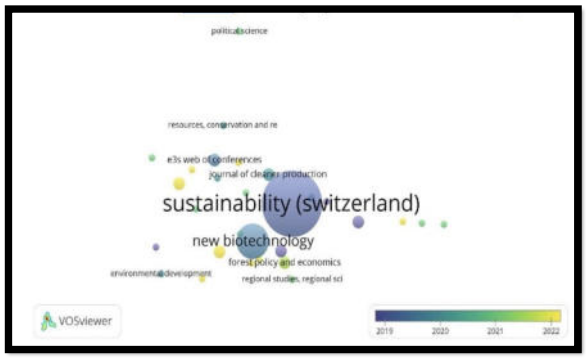

Figure 3. Bibliographic Coupling Mapping analysis/sourcing

Source: VOSviewer

The colors in Figure 2 show countries' priorities in terms of their bioeconomic strategies. The bioeconomic strategies of the red cluster countries promote biotechnology, technological development and innovation in renewable raw materials as priority axes[57]–[61]. These countries invest in biomass and bioenergy value chains through biofuels [19], [62], [63]. The yellow cluster countries promote bioeconomic development through agriculture [64], [65] and forestry [48], [66] and believe that economic development comes from proper resource management and total added value from biomass production [67], [68]. Competitiveness and employment are also major trends for these countries [69]. Light blue cluster countries consider knowledge management and transfer essential for a successful bioeconomic strategy [46], [70]. Since they also have a more ecological vision, their main trend focus is climate protection and sustainability [71], [72]. Entrepreneurship and business models are becoming a major trend for green cluster countries [73]–[75]. This leads to economic development, pollution reduction and proper resource

management [47], [76]. Lastly, blue cluster countries have tremendous advantages in biomass production. Countries such as Finland, Serbia, Croatia, and Austria base most of their economies and trade on biomass production [77]–[79].

In figure 3, journal publications included in the dark cluster have published bioeconomic strategy articles since 2019. In contrast, journal publications with green or yellow clusters have only published articles on bioeconomic strategies in the last two years.

Coverage of an overview of key trending areas by year, author, and geographic area

These priorities are considered according to the frequency of their appearance in publications per year (Figure 4). For orange, the main trending field appears once a year; yellow, twice; with a blue tint, three times; in purple, four times; brown, five times; and is green, six times. There is a trend reversal in the name of biotechnology into the development of more environmentally friendly technology. According to Spies et.al. [58], technology has a central role in bioeconomic policy, but there are barriers to integration of approaches due to lack of environmental considerations, proper management of natural resources and maximization of positive interactions between decision makers, local communities and nature. Biomass production is a major trend over time. Biomass refers to plants, animals, their derivatives and organic waste [80]. The conversion of this biomass into biomaterials is an innovation that contributes to resource adequacy and waste management [81]. In addition, the economic use of biomass is at the forefront of bioeconomic development [48].

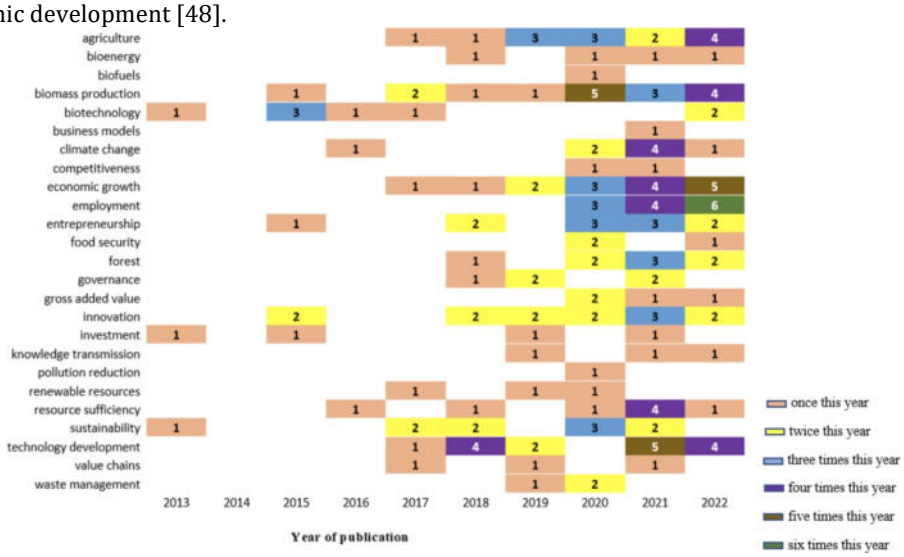

Figure 4. Number of publications of documents of key trend areas per year

The three main trend areas that are considered highly relevant for the three-year period 2020–2022 are economic growth, employment, and entrepreneurship. Economic growth from the implementation of bioeconomic strategies comes from value addition (among others) in agriculture, forestry, and the food industry [82]. In the European Union, two-thirds of people working in the bioeconomy come from the agricultural sector, despite a decline due to the restructuring of the agricultural sector in 2015–2017, and 2 million employees leaving the sector [83]. Agriculture, forestry, and the food industry account for about 24–26% of the total labor productivity in the bioeconomy (excluding services), and play an important role in its development [82]. However, critical problems such as urbanization and migration of the population to urban centers or abroad, leading to desertification of rural areas, can be controlled through employment in the bioeconomy [84]. Regarding the role of entrepreneurship in the bioeconomy and sustainable development, it is shown to create opportunities for the production of goods and services that provide economic and non-economic benefits, while preserving the natural and social environment. Entrepreneurship, in addition to increasing employment [85], has the potential to address market failures in terms of environmental issues and respond to sustainability challenges with different strategies. Obviously, based on the above, the market idea that economic growth reduces inequality is rejected [86]. Economic development through bioeconomy in agro-industry contributes to social cohesion and focuses on equality for marginalized people as they may belong to certain income, regional, or labor groups.

Notice in Figure 4 that the document was published after 2013. This is because it is just a document entered in the *Scopus* and *Agecon databases*. This explains the rejection of the European Bioeconomy

Strategy 2012 [14]. The main trends of bioeconomic strategies are assigned to each publication as described by the authors. Some authors focus on resource efficiency, but also on the added value of agricultural, livestock, forestry and organic biomass use [46], [48], [50], [58], [61], [64]–[66], [74]–[77], [79], [80], [84], [86]–[92]. Basically, a country or region that has an advanced primary sector and the ability to invest in biomass value chains that achieve environmental and social benefits. Another group of authors focuses on technological development and innovation, for the use of renewable resources or waste management [30], [31], [68], [93]–[102]. Their goal is the sustainability and isolation of mined resources. In addition, a large number of articles discuss management as a bioeconomic priority [51], [78], [103]–[105]. These authors truly understand that while adopting bioeconomic strategies, the most important thing is that society can adapt to new rules and challenges. They concluded that coordination of global governance is necessary [105]. Finally, employment and entrepreneurship have been identified by many authors as factors of economic development and competitiveness [60], [63], [69], [73], [82], [83], [106]. The authors argue that policymakers should consider the nature of entrepreneurial transformations taking place in universities and research centers [63]. The knowledge generated in these centers constitutes the starting point of the country's bioeconomy and competitiveness strategy [69].

The advantages of bioeconomic strategies are mostly studied at the national level (29 publications) and are mostly assigned to European countries, mainly from Central Europe and the Northern Hemisphere. At the same time, 14 publications presented bioeconomic strategies throughout the European Union, 13 publications at the global level, 11 publications presented priority areas of implementation at the regional level, and 1 publication presented how bioeconomic strategies can be implemented in enterprises and their priorities. It can be concluded that its geographical coverage is very wide.

Table 1. Overview of Publications by unit of analysis and affiliated countries

Unit Analisis	Nomor Publikasi Dalam Daftar Referensi	Negara Afiliasi
Nation	[66]	Czech Republic
	[84]	Norway, Denmark, Canada, Nepal
	[59]	Germany
	[87]	Argentina, Germany
	[95]	Poland
	[88]	Germany, Finland, Ghana
	[107]	Canada
	[71]	Sweden
	[69]	Brazil
	[108]	Germany
	[69]	Italy
	[94]	Czech Republic
	[73]	Latvia
	[105]	New Zealand
	[75]	Thailand, China
	[81]	Bulgaria
	[48]	Czech Republic
	[109]	Czech Republic, Brazil, Italy
	[91]	India
	[103]	New Zealand
	[92]	Greece, Poland
	[64]	Poland
	[100]	Spain
	[110]	Australia
	[102]	Germany, Italy
	[111]	Netherlands
	[49]	Australia
	[112]	Sweden
	[72]	Sweden
EU	[81]	Spain
	[83]	Spain
	[86]	Germany

	[60]	Germany
	[47]	Germany, Belgium, Netherlands, Finland
	[62]	Germany
	[89]	United Kingdom
	[96]	Italy, Spain, Belgium
	[113]	Germany
	[97]	Germany
	[106]	Poland
	[99]	Germany
	[101]	Germany, Belgium
	[19]	Germany
International	[46]	France
	[58]	Germany
	[51]	Sweden, Belgium, Kenya, Thailand, USA
	[31]	Italy
	[93]	Ukraine
	[67]	Italy
	[74]	USA
	[51]	Sweden
	[80]	Spain
	[70]	Netherlands
	[63]	Germany
	[61]	Germany
	[104]	Germany
Region	[77]	Finland, Croatia, Serbia, Austria
	[114]	Colombia
	[95]	Sweden, Costa Rica
	[90]	Russia
	[47]	Poland
	[98]	Russia
	[30]	Spain
	[78]	Finland
	[115]	Romania
	[79]	Austria, USA
	[116]	Australia
Company	[76]	Latvia

Source: 68 review publications in this literature review

Discussion

The aim of this systematic review is to identify key trend areas for agro-industry bioeconomy strategies in order to contribute to a more evidence-based dialogue on actions and policies to be implemented in the future. The global economy, where it is highly dependent on fossil resources, including oil, as an energy source, is vulnerable to declining supplies and unstable markets for those resources [117]. Therefore, to secure the economy, countries aspire to a low-carbon and resource-saving society based on bio-based products. The development of bioeconomy affects many sectors and branches of the economy, so the state adopts strategies and takes action. Bioeconomy in agro-industry contributes to food security, sustainable natural resource management, improved waste management, reduced dependence on non-renewable resources, climate change mitigation, job creation, and maintaining competitiveness [109]. Bioeconomic strategies in agro-industry address changes, among others, by developing knowledge in the field of primary production and food production [114]. By implementing bioeconomic strategies and related initiatives, it is more manageable to reduce waste and improve the efficiency of food chains with change, particularly in developed countries [91].

Sustainable production includes the use of biotechnology and other modern technologies that enable increased productivity and efficiency, reduction of environmental impact, development of sectors such as biofuels, and production of biomaterials from agriculture, forestry, and domestic sectors [62]. In the context of climate change, agriculture can be seen as an ally. Bioeconomic development in this sector can help reduce CO2 emissions by reducing energy consumption [4]. The implementation of bioeconomic

strategies also contributes to sustainable management of natural resources. The development of agriculture, forestry, and animal husbandry is related to the resources needed for biomass production [89]. These resources are limited and depleting, so it is necessary to adopt a production approach that can be described as 'more biomass from fewer resources'. In this context, bioeconomic development should lead to better use of nature-utilization regulatory functions that enable a better understanding of ecosystem functions. Significant growth also comes from the continued primary production and development of biotechnology, leading to the transformation of existing ones, and the opening of new markets for bioproducts [118]. Such developments increase the demand for labor in the primary and industrial sectors.

At the same time, mitigating the effects of climate change while ensuring energy security and economic growth and prosperity is a major challenge. Turning vision into reality requires innovation and knowledge-based research [47]. Supporting innovation is a driving force and this belief stems from the challenges facing the world today, such as sustainable natural resource management, sustainable production, improved public health, climate change mitigation, inclusive social development, and global sustainability. Despite the dominant focus on sustainability, primary sectors, technology development, and biomass production, this literature review shows that bioeconomic strategies in agro-industry are influenced by government policies, existing regulations, and human resources, as well as social acceptance and market structure. If there is no coordination of governance, no strategy can be implemented [93],[105].

These factors interact with each other, modifying the influence of each separately. A successful transition to a bioeconomic model requires the participation of society as a whole, as a sustainable society as a whole requires sustainable and environmentally friendly solutions. The search for opportunities to accelerate regional and state development requires the linkage of the concept of sustainable development with more flexible use of resources through better application of knowledge and innovation, and more efficient development of technology. The implementation of bioeconomic strategies in the development policy of a region should be the result of conscious decisions by state and local authorities, and their ability to coordinate and create effective networks of cooperation between scientific, agro-industrial, economic, business, and local stakeholders [78], [119].

4. CONCLUSION

There is no mention of stakeholders (farmers, entrepreneurs, etc.) in bioeconomics education papers. Knowledge generated from research needs to be channeled into communities to facilitate acceptance and adoption; Bioeconomy business models and• clusters have been successfully developed in China [120] contributing to the exclusion and marginalization of small and regionally isolated producers; The current energy crisis shows the country's dependence on carbon and the weakness of the bioeconomic strategy on agro-industry in solving these key problems.

Since the main trend areas of the bioeconomic strategy "lost" their ecological focus and acquired a social vision, and at the same time capitalist, priorities now focus on economic growth, gross value added, entrepreneurship, competitiveness, employment, and technological development, and future research is advised to avoid some previous trends such as focusing on biodiversity, development of remote areas, and agro-ecological systems. It is also important to conduct future research on training bioeconomy participants, and include education as central to the strategy.

In conclusion, a limitation identified in this review is the omission of relevant publications (e.g., bioeconomic strategies) that are excluded because they are not included in the databases used. Also, gray literature and studies not written in English are not included. As a measure of quality, *peer-reviewed* studies are distinguished from other studies, and this aspect is taken into account when summarizing conflicting study results.

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