

Review

Sustainability of Meat Value Chain: Bibliometric Review of Main Trends and Theoretical Connections

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Abstract: The sustainability of the meat value chain is a topic of global importance, with slaughtering close to farms emerging as a significant measure that not only enhances animal welfare, but also integrates economic, environmental, and social aspects into the meat production process. In this study, we conducted a thorough analysis of 99 academic articles focusing on the sustainability of the meat value chain, published between 1985 and 2024. Utilizing *VOSviewer* software version 1.6.20, we performed both bibliometric and thematic analyses to gain insights into the evolution of research in this field. Our findings reveal a substantial increase in studies on this subject since 2017, with 80% of publications emerging in the last seven years, indicating a growing interest in this area of research. Swedish universities and researchers were identified as key contributors to this body of work, demonstrating a significant commitment to exploring the sustainability of the meat value chain. Furthermore, we observed that studies related to sustainability and the circular economy are predominantly published in journals focused on environmental issues, highlighting the interconnectedness of these concepts. This review aims to provide valuable support to researchers and academics by elucidating the boundaries and potential of research on the sustainability of the meat value chain. By shedding light on current trends and areas of focus, we hope to inspire further exploration and innovation in improving the supply chain in the future.

Keywords: circular economy; meat value chains; mobile slaughterhouse; short marketing circuits; sustainability; bibliometric analysis



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1. Introduction

In the context of the 21st century, marked by economic globalization and ecological crises, sustainability has emerged as a central paradigm for addressing the complex interplay between economic growth, environmental challenges, and social equity. This concept, although broad, has been defined and operationalized in numerous ways, with scholars and practitioners converging on its three main pillars: economic, environmental, and social sustainability. The economic dimension seeks to ensure profitability and efficiency while minimizing waste; the environmental dimension prioritizes the preservation of ecosystems, the reduction of carbon emissions, and responsible use of resources; and the social dimension focuses on equity, community well-being, and fair labor practices [1–7]. Together, these principles provide a framework for industries, including the food sector,

to innovate and transform their practices to align with global sustainability goals, such as those outlined in the United Nations' Sustainable Development Goals [8]. Recent studies have highlighted that industries embracing sustainability are better positioned to navigate regulatory changes, consumer expectations, and competitive markets [9].

In the food sector, sustainability has been strongly linked to the promotion of short marketing circuits (SMCs), which aim to reduce the physical and logistical distance between producers and consumers. These circuits are characterized by their ability to bypass complex supply chains, resulting in multiple benefits, such as lower transportation costs, reduced greenhouse gas emissions, and improved access to fresh, locally produced food [10,11]. Furthermore, SMCs have been praised for fostering fairer value chains by reducing the power of intermediaries and ensuring better income distribution among stakeholders, particularly small-scale producers [10,12,13]. However, implementing SMCs on a broader scale remains a challenge, as it requires rethinking distribution networks, leveraging digital platforms for marketing, and addressing infrastructural and logistical bottlenecks [14,15]. Scholars have also pointed out the potential of SMCs to support rural development by revitalizing local economies and promoting traditional and sustainable farming practices [11,13,14]. Despite their benefits, the adoption of SMCs is often limited by regulatory frameworks, scalability issues, and consumer habits, which require targeted interventions to overcome [14].

In parallel, the circular economy proposes minimizing waste and optimizing resources through reuse and recycling, increasing efficiency and extending the life cycle of materials [7,13,16–18]. When combined, these approaches make it possible to create more sustainable and efficient systems [16].

These concepts are particularly relevant in meat value chains, where the centralization of large companies and criticism of the working conditions of small producers generate economic and social inequalities [2,12,19,20]. The implementation of circular economy practices and short marketing circuits could thus improve conditions for small producers and the sustainability of farms, while aligning meat production with consumer expectations regarding environmental responsibility and animal welfare [21–23].

Recent research into the circular economy and short food marketing circuits, economic, environmental, and social sustainability, and the meat value chain has seen significant advances, with growing interest in this topic prominently reflected in sustainability-focused journals, as highlighted by Melas et al. [24], Ziegler et al. [25], and Rahimi et al. [6]. However, in these publications, the researchers' approaches do not include connections with mobile slaughterhouses or animal welfare. Most of the studies lean heavily towards subjectivity and individual biases on each topic, resulting in a poor bibliometric ratio. In conclusion, the over-reliance on subjective approaches and individual biases diminishes the perceived quality and credibility of the research. Consequently, this leads to lower engagement and citation rates within the academic community, contributing to a poor bibliometric ratio. This weakens the studies' impact and hinders their integration into the wider research field. To corroborate this claim, this research study used *VOSviewer* to perform a bibliometric analysis and relational visualization of articles in the field of circular economy, sustainability and meat value chains, mobile slaughterhouses, and animal welfare published in the Scopus database from 1985 to 2023. Specifically, this analysis was guided by four main objectives: (1) to register publication trends in this field in recent years; (2) to identify the journals with the highest number of publications and the geographical origin of these articles; (3) to identify the institutions and academics who publish most frequently in this field; and (4) to analyze the main clusters of words and their interconnection.

This work aims to provide readers with a comprehensive, in-depth perspective on the intersection between the circular economy, short marketing circuits, sustainability

and meat value chains, mobile slaughterhouses, and animal welfare. At the same time, it highlights prevailing trends, key issues, and possible avenues of research in this field, offering valuable information for universities and professionals alike. This article has been structured as follows: Section 2 covers the literature review, Section 3, the materials and methods, Section 4 presents the results and analyses, and in Section 5, the conclusion is outlined.

2. Literature Review

The meat value chain has undergone profound transformations in recent decades, reflecting the transition from traditional approaches to modern practices with a focus on sustainability. Originally, livestock production was based on family methods, centered on subsistence and low-environmental-impact practices, where the use of local resources and integrated soil management were predominant [26,27]. However, population growth, globalization, and increased demand for meat have led to an intensification of production processes [27]. This transformation has brought with it large-scale production practices, where efficiency and profit have become priorities, often at the expense of environmental and social concerns [28].

In recent years, sustainability has become a priority in the sector, driven by ecological pressures and growing awareness of the environmental impacts of intensive livestock farming [26], such as greenhouse gas emissions, soil degradation, and animal welfare [29]. In this context, the circular economy and short marketing circuits have emerged as promising solutions. The circular economy promotes the reuse of resources and a reduction in waste [16], while short marketing circuits shorten the distance between producers and consumers, encouraging the local economy and reducing the carbon footprint associated with transport [11].

These approaches represent a new phase in the meat value chain, where the balance between environmental sustainability, economic viability, and social responsibility becomes essential to meet the sector's challenges.

2.1. Circular Economy in the Meat Value Chain

The circular economy, as a sustainable model, aims to extend the life cycle of products and minimize waste by promoting the reuse, recovery, and recycling of materials [16]. In the meat sector, the adoption of circular economy practices seeks to maximize resource efficiency, reducing environmental impact and adding value for both producers and consumers [13,30]. These practices generate social impacts by creating new local jobs, improving the profitability of small producers and promoting greater food security [31,32].

Recycling waste and valorizing by-products are fundamental practices in this sector. It is estimated that 50% to 60% of the live weight of animals is made up of by-products that can be transformed into feed additives, pharmaceuticals, cosmetics, or fertilizers, reducing waste and generating additional revenue for the industry [29,33]. These by-products, which were once considered waste, become part of the value chain, covering part of the production costs and increasing the sector's profitability [29]. In addition, this practice favors entry into new markets and the export of innovative products in response to the growing demand for sustainable solutions [16,29].

The application of circular economy principles therefore represents an effective solution for reducing waste and environmental impact in the meat sector. Practices such as recycling by-products and using renewable energy technologies, as well as recycling water and efficiently managing organic waste, are key to transforming this sector, making it more efficient and less dependent on non-renewable resources [30,31]. However, for these practices to be widely adopted, it is essential that there are public policies to incentivize

and financially support small and medium-sized businesses that wish to implement this model [32,33]. Finally, the integration of short marketing chains and the circular economy in creating more efficient and sustainable meat production and distribution systems, improving food safety and promoting more responsible management of natural resources [16], should also be emphasized.

2.2. Short Supply Chains and Local Sustainability

By bringing producers and consumers together directly, short marketing circuits have multiple benefits for the meat sector, with environmental and economic impacts that strengthen the sustainability and resilience of local economies [34]. Reducing the distances traveled by products results in a reduction in carbon emissions, as the need for long-distance transport is minimized [35]. This factor contributes significantly to mitigating the environmental impact associated with food logistics, especially in the sector of fresh and perishable products such as meat [14,36]. With fewer intermediaries, products reach the consumer more quickly, which cuts down on storage time and reduces food waste, promoting a more efficient and sustainable supply chain [19].

Another important benefit of short marketing circuits is the strengthening of the local economy. By eliminating intermediaries, small producers are able to capture a greater share of the economic value of their products, which increases their profit margin and reinforces the viability of small farms [12,13]. This model allows producers to set fairer and more competitive prices, promoting the retention of value in rural communities and encouraging economic development at a local level [12]. Direct marketing also fosters more robust support for local economies, as consumers opt for products from their regions, which contributes to the creation of a positive and sustainable economic cycle [34].

In addition to the economic and environmental benefits, short marketing circuits promote greater transparency and trust between producers and consumers [11]. By providing a direct link, consumers can learn more about production practices and have access to transparent information about the origin and quality of the products they consume [34]. This direct connection contributes to the valorization of local products and reinforces consumer confidence in the producer, facilitating more informed choices in line with the values of sustainability and social responsibility [15]. The direct relationship between the two also strengthens social and economic ties, promoting community cohesion and encouraging more ethical and responsible production [11].

This model not only reinforces environmental sustainability, but also allows for a fairer distribution of value and promotes transparency, consolidating itself as an effective strategy to face the contemporary challenges of food production and sustainability [34,37].

2.3. Animal Welfare and Its Impact on Sustainability

The implementation of short supply chains in the meat value chain, especially with regard to slaughter, plays a crucial role in improving meat quality and promoting animal welfare. A widely debated alternative today is proximity slaughter, either through the use of mobile slaughterhouses or slaughter directly on the farm [38,39].

These innovative solutions have been highlighted in the context of animal welfare and the sustainability of meat production, as they make it possible to reduce stress on animals by reducing the distances traveled and the waiting time associated with conventional slaughterhouses [39,40].

The literature indicates that prolonged transport raises cortisol levels, which can compromise meat quality [41]. With less transport and less waiting time, mobile units are able to reduce pre-slaughter stress and improve meat quality compared to conventional slaughterhouses, which contributes to more ethical and responsible production [40]. This

focus on animal welfare, combined with sustainability, generates a positive perception among consumers who value ethical and sustainable practices, thus promoting a value chain that responds to new consumption patterns [38,42].

2.4. Economic Challenges and Competitiveness for Small Producers

Proximity slaughterhouses or on-farm slaughter can represent a transformative opportunity for small-scale and organic producers [40]. Currently, they face significant challenges to compete with large corporations in the meat sector, namely the high costs of transport to centralized slaughterhouses and the complexity of strict regulations [28]. These new models can help reduce these barriers, promoting greater economic viability and sustainability in their operations [40,41,43]. The adoption of niche markets—such as sustainable and organic meat—is one of the strategies used to differentiate themselves and build loyalty among a specific group of consumers who value sustainability and environmental responsibility [12,19]. However, these niches also bring challenges, as they require certifications, constant improvements in quality, and a commitment to high production standards, which can represent a significant investment for small and organic producers [40]. Models such as mobile slaughterhouses, which facilitate slaughter close to the farm, can reduce transport costs and allow these producers to obtain a fairer financial return, strengthening their competitiveness in the market [39].

2.5. Mobile Slaughterhouses: Efficiency and Sustainability

Mobile slaughterhouses represent an innovation that integrates efficiency, sustainability, and a positive impact on rural communities. From an environmental point of view, they reduce the ecological footprint associated with transporting animals to large slaughterhouses, contributing to a more sustainable logistics chain [40]. This system offers flexibility and accessibility to small producers, allowing them to carry out slaughter on farms and, in some cases, close to farms in shared ‘support stations’ that increase efficiency [44]. The social and economic impact of mobile slaughterhouses is also significant, as they promote job creation and boost rural economies, offering a fairer and more sustainable solution to centralized options that can be economically unviable for small producers [42].

Similarly, slaughter in small units allows for the preservation of traditional techniques, such as the transfer of knowledge, and contributes to the resilience of communities which are less dependent on large meat-processing industries. Thus, mobile slaughterhouses and other proximity practices help to capture and retain value in production regions, strengthening environmental, economic, and social sustainability [40,42].

3. Materials and Methods

We conducted a search for relevant articles in the *Scopus* database, as it offers comprehensive coverage of the academic literature. This choice was further influenced by the limitations of *VOSviewer* software, which requires documents to be in csv format for analysis.

In order to gather articles related to the research domain of meat value chains and farm sustainability, a thorough search process was conducted. This involved consulting articles using specific keywords such as ‘meat’, ‘sustainability’, ‘agriculture’, ‘environmental’, ‘circular economy’, ‘transport’, ‘livestock’, ‘on-farm slaughter’, ‘mobile slaughter’, and ‘mobile abattoir’. Articles were then selected based on their thematic relevance.

Each article in the dataset contained essential details including authorship, affiliated institutions, keywords, abstracts, countries, publication dates, and more. Preference was given to articles published in scientific journals, and the bibliographic information was exported in csv format through the literature management platform *Scopus*.

Initially, a search for these keywords yielded over 500 articles published up to 2024, many of which were not directly related to the meat value chain. In the second phase, the literature was screened based on a combined keyword search and specific inclusion criteria to ensure the relevance of the selected articles. The search criteria, as well as the exclusion and inclusion of articles, are summarized in Table 1.

Table 1. Search criteria for articles in the Scopus database.

Key words	“meat sustainability” (7 articles)
	“meat” AND “circular economy” OR “supply chains” (6 articles); excluded if they did not include the word “meat”
	“meat” AND “circular economy” OR “transport” (5 articles); excluded if they did not include the word “meat”
	“meat” AND “circular economy” OR “sustainable agriculture” (5 articles); excluded if they did not include the word “meat”
	“livestock” AND “circular economy” OR “transport” (9 articles)
	“livestock sustainability” AND “environmental” (3 articles)
	“agriculture sustainability” AND “environmental × social” (17 articles)
	“agriculture sustainability” AND “circular economy” (10 articles)
	“on farm slaughter” (18 articles)
	“mobile slaughter” (16 articles)
	“mobile abattoir” (10 articles)
Filters	All fields
	All document types
	Any year (any time)
	All languages
	Survey carried out on 5 January 2024

Given the broad scope of the topic, which involved multiple keywords, eleven Excel™ files were exported—each corresponding to the eleven themes listed in Table 1—resulting in a total of 106 articles. These files were subsequently merged into a single Excel™ table using the online tool “merge CSV files online”.

VOSviewer 1.6.20 software, developed by Jan van Eck and Waltman from the Centre for Science and Technology Studies at Leiden University in the Netherlands, is a tool for visualizing maps of bibliographically linked documents, that helps to identify articles with similar themes [45]. The more commonly cited articles in a bibliographic coupling, the more likely they are to share a common research theme [46]. The proximity of the items on the maps generated indicates the degree of thematic relationship between these items.

In this way, data collected from the Scopus database were imported into VOSviewer software for information processing, and some co-occurrence analyses were carried out on the keywords, authors, journals, institutions, year, and country of publication. As shown in Table 2, a total of 106 articles were obtained from 1985 to 2024, with 7 duplicates, involving 128 journals, 266 authors, 114 institutions, and 40 countries.

Table 2. Survey summary with the type of research output and their numbers.

Output	Number
Articles	99
Journals	128
Institutions	114
Authors	266
Countries	40

4. Results and Discussion

This section summarizes the results of the bibliographic analysis and thematic analysis, carried out using *VOSviewer* software, which combined articles guided by sustainability concepts and focusing on meat value chains as the predominant research area.

4.1. Publication Trends

Of the scientific journals selected, ten published more than 60 articles on the subject, and these were identified as the most relevant. The distribution of the number of articles published in the ten main journals is shown in Figure 1.

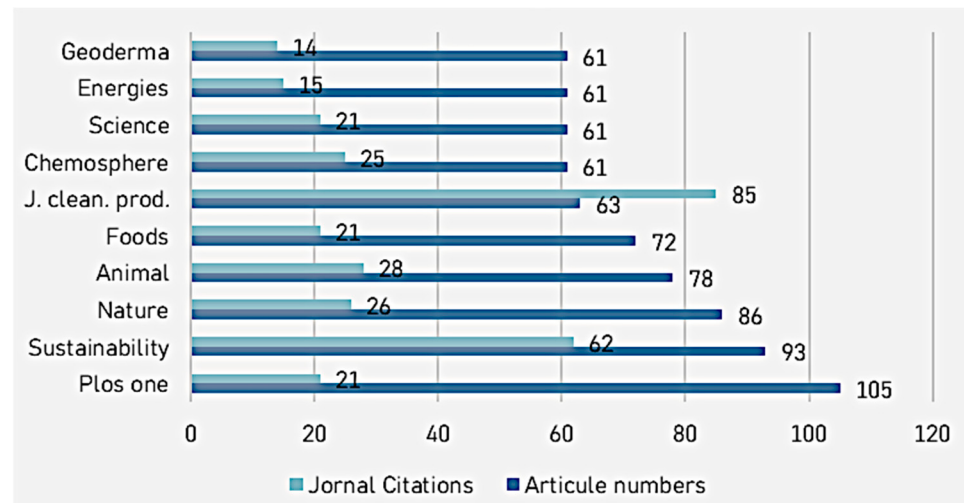


Figure 1. Most cited journals with the highest number of publications.

As can be seen, the *Plos One* journal, which mainly covers primary research in various areas of science and medicine, leads the way with 105 publications, followed by the *Sustainability* journal with 93 publications, the *Nature* journal with 86, the *Animal* journal with 78, and the *Food* journal with 72 publications.

A simple way of measuring the influence and impact of an article is the number of citations it has. In general, it is common for older articles to accumulate more citations; however, the research carried out showed that the most cited articles mainly dealt with sustainability and environmental issues. The journal *Cleaner Production* stood out as the most cited, as it is a scientific journal that covers transdisciplinary research related to cleaner production and environmental issues. For example, Lehmann J., despite having no direct articles in this bibliometric analysis, is among several key authors whose work significantly impacts the field. Lehmann is frequently cited in articles on environmental sustainability, including one by Hamilton et al. [47], which addresses water use in industrial agriculture. Similarly, Wang et al. [48], another highly cited author, explores the environmental and economic impacts of pig production. These topics are highly relevant and closely connected to environmental issues, forming a central focus of research on sustainability of farming.

All of these key research themes were subsequently identified and will be discussed in detail later in this article. The number of articles published per year has been increasing steadily over time, as shown in Figure 2, with a particularly pronounced upward trend since 2019. Around 80% of the articles were published in the last seven years, with 50% of them concentrated between 2022 and 2023. However, no publications related to the topic were recorded in the years 2006, 2008, or 2010, or in 2012 or 2015. Until 2013, publications were scarce and irregular, highlighting the contemporaneity of the topic. The number of articles in this field of study is expected to increase annually. The trend highlights the growing relevance of the topics investigated. The significant increase in the number of

publications highlights the importance of this review and the need to identify keywords related to this topic.

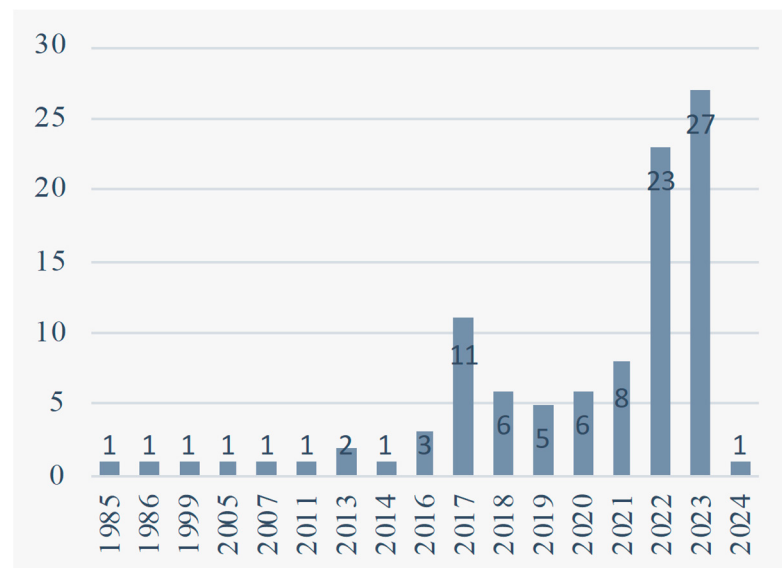


Figure 2. Number of publications per year.

Among the 40 countries identified in the research, the United States, Italy, Spain, Sweden, and Canada make up the top five of those that published the most on the topic under study (Table 3). The United States leads with 12 articles and 64 citations, while Italy and Spain stand out with nine articles each, accumulating 227 and 110 citations, respectively, followed by Sweden, Canada, and India with eight articles. Only 19 of the 40 identified countries published two or more articles, and the remaining 21 contributed only one article each.

Table 3. Number of articles published by country.

Country	Number of Articles	Citations
United States	12	64
Italy	9	227
Spain	9	110
Sweden	8	214
Canada	8	99
India	8	38
England	7	84
China	6	71
France	5	95
Germany	4	75
Australia	4	73
Netherlands	4	64
Ireland	3	86
Norway	3	38
Brazil	2	24
Mexico	2	20
Portugal	2	10
Belgium	2	3
Argentina	2	2
Remaining 21 countries	1	-

4.2. Authors and Institutions Most Cited in the Literature

Firstly, it was explored which institutions obtained the greatest number of articles on the topic under study. From Table 4, it can be seen that only one institution had two articles published, while the other institutions identified had only one article. The institutions with the highest number of citations were then identified. The results reveal that, despite having published a small number of articles, Swedish universities were the most cited. Examples of this are the Swedish University of Agricultural Sciences and the School of Business, Economics and Law at the University of Sweden, which stood out as the institution with the largest number of publications in this area.

Table 4. Top 5 institutions with the most articles and citations.

Institution	Number of Articles	Citations
Swedish University of Agricultural Sciences, Department of Animal Environment and Health, Sweden	2	20
University of Gothenburg, Sweden School of Business, Economics and Law, Department of Economics	1	159
Swedish University of Agricultural Sciences, Department of Economics, Sweden	1	159
Agroscope, Institute for Livestock Sciences, Switzerland	1	62
University of Milan, Coordinated Research Center: Innovation for Welfare and Environment, Italy.	1	62

However, none of the institutions present specific consolidation on this topic, which implies that none of them can be considered experts on the topic under study.

Network analysis and co-occurrence maps can provide valuable information about authors and the topic areas they cover most. To this end, *VOSviewer* was used to analyze the most cited authors and the main areas of study, the results of which are presented in Figure 3 and Table 5.



Figure 3. Grouping of authors by themes.

As shown in Table 5, the author Grandin [49] was cited 37 times in the articles analyzed. The article “Perspectives on transportation issues: the importance of having physically fit cattle and pigs”, published in 2001, in the *Animal Science* journal, was cited in 14 of the selected articles, accumulating a total of 37 citations. This author provided a comprehensive analysis of issues related to animal transport, highlighting the importance of ensuring adequate physical condition of animals during transport [49].

Table 5. Authors with the highest number of citations.

Authors	Thematic Area	Number of Citations
Grandin T.	Animal welfare	37
Lehmann J.	Environmental sustainability	30
De Boer I.J.M.	Meat value chain and sustainability	25
Faucitano L.	Animal welfare	22
Li Y.	Environmental sustainability	21
Wang Y.	Environmental sustainability	21
Murphy J.D.	Circular economy and agriculture	19
Laso J.	Agriculture and sustainability	19
Margallo M.	Agriculture and sustainability	19
Algers B.	Animal welfare	19

Among the articles that cite this author, the following stand out: (1) “Relationships between transport conditions and welfare outcomes during commercial long-haul transport of cattle in North America”, whose objective was to document the relationship between transport conditions and welfare outcomes in the long-distance commercial transport of cattle; (2) “Trailer temperature and humidity during winter transport of cattle in Canada and evaluation of indicators used to assess the welfare of cull beef cows before and after transport”, which concluded that problems in transporting cows for slaughter in Canada could be related to the animals’ pre-transport conditions and handling during transport unloading; and (3) “Risk factors for deterioration of the clinical condition of cull dairy cows during transport to slaughter” which aimed to investigate whether the clinical condition of dairy cows for slaughter would deteriorate during transport [50]. All articles by this author are clearly related to animal welfare during transport to the slaughterhouse.

Although none of his articles were identified, the second most cited author, Lehmann, was cited thirty times in eight articles related to agricultural sustainability and soil and water preservation practices. For example, these were mentioned in a systematic literature review article titled “Contribution of biochar application to the promotion of circular economy in agriculture”, which investigated the most recent research on the application of biochar in agriculture and its contribution to the promotion of the circular economy [51], relating the concepts of “sustainability”, “agriculture”, and “circular economy”.

In contrast, they were also cited in articles on farm slaughter and issues of food safety, herd uniformity, and animal welfare. The article “Exploring Consumer Preference towards the On-Farm Slaughtering of Beef in Germany: A Discrete Choice Experiment” by Lauterbach et al. [52] explores consumer preferences and willingness to pay for farm-slaughtered beef compared to conventional slaughter methods. Lauterbach et al. [52] cites Lehmann in the context of a study on the opinion of German consumers regarding the slaughter of animals from organic and conventional production. This study addresses the question of whether animals in organic production should be slaughtered differently to animals in conventional production. No references were found to the issues of circular economy, soil sustainability, and water waste that led other authors to cite Lehmann. The article “Artificial intelligence, sensors, robots, and transportation systems drive an innovative future for poultry broiler and breeder management” by Park et al. [53] proposes a highly automated system, managed by an artificial intelligence structure, with autonomous robots, advanced sensors, virtual reality, and innovative transport systems. The association with this author is due to the fact that the article mentions a comparative study on the application of poultry litter and poultry litter biochar, which explores the effects of these materials on soil and their potential to promote plant growth [53]. Furthermore, improvements in the transportation and slaughter of birds are discussed, with the aim of reducing stress and manual handling.

The third most cited author, De Boer, was identified in 25 articles related to environmental sustainability practices in animal production and food waste, as exemplified in the article by Noya et al. [54], “Environmental assessment of the entire pork value chain in Catalonia—A strategy to work towards Circular Economy” from *Science of the Total Environment*.

Also of note are the following articles in which De Boer was cited: (1) “Sustainability indicators for improved assessment of the effects of agricultural policy across the EU: Is FADN the answer?” by Kelly et al. [55]; (2) “Assessing sustainability in agricultural landscapes: A review of approaches” by Eichler Inwood et al. [56]; and (3) “Signs of agricultural sustainability: A global assessment of sustainability governance initiatives and their indicators in crop farming” by Konefal et al. [3]. All articles address sustainability, discussing different aspects related to the topic, with an emphasis on indicators for assessing sustainability in agriculture.

De Boer has also been cited in articles that share a common approach to assessing sustainability in animal production and that explore diverse aspects such as resource efficiency, biodiversity, and supply chain practices. Examples include the following: (1) “Assessing multiple goods and services derived from livestock farming on a nation-wide gradient”, by Ryschawy et al. [57]; (2) “Quantifying biodiversity impacts of livestock using life cycle perspectives”, by McClelland et al. [58]; (3) “Circular Bioeconomy Practices in the Greek Pig Sector: The Environmental Performance of Bakery Meal as Pig Feed Ingredient”, by Melas et al. [24]; and (4) “Local seal or imported meat? Sustainability evaluation of food choices in Greenland, based on life cycle assessment”, by Ziegler et al. [25].

In general, the articles in which De Boer is mentioned address a variety of aspects related to sustainability in agriculture, the assessment of agricultural landscapes, global sustainability governance, the assessment of livestock products, biodiversity impacts, circular economy practices in swine feeding, and the assessment of sustainable food choices.

Regarding the thematic analysis, the concept of sustainability in agriculture is widely debated and comprises three interconnected dimensions: environmental, social, and economic, as previously mentioned [3,6,16]. However, when deepening the analysis of the articles associated with these authors, the literature on agricultural or livestock sustainability is often limited to environmental issues. Konefal et al. [3], in their study, concluded that although the tripartite approach to sustainability is common, there is considerable variation in the operationalization of each dimension and the relationship between them, and the environmental dimension receives more attention, a fact that is confirmed by analyzing Table 5.

The study conducted by Noya et al. [54], “Environmental assessment of the entire pork value chain in Catalonia—A strategy to work towards Circular Economy”, is a good example of environmental concerns, identifying pig feed production and transport activities as the main critical points in terms of environmental impact, and proposing alternative strategies based on circular economy principles to reduce these impacts.

The analysis of Figure 3 provides similar conclusions; the map facilitated the analysis between the main themes identified and the most cited authors. The proximity or distance between the lines indicates the strength of the association between the elements represented on the map. Closer lines indicate a stronger association between connected elements, suggesting a closer relationship or more robust connection. More distant lines suggest a weaker association, and elements separated by greater distances are not as strongly connected or related in the analyzed context.

There is clearly a significant departure from the authors whose main topics are related to animal welfare and challenges in transport during slaughter compared to the other authors whose analyzed themes were “agricultural sustainability”, “environmental and

social sustainability”, “circular economy”, and “short supply chains”. The connections exist, but they are not very expressive.

This gap was equally noticeable during the bibliographic research, where the attempt to integrate keywords such as “meat value chain”, “animal welfare”, “animal production”, “transport and slaughter”, and “slaughterhouses” resulted in an abrupt transition from a significant number of articles, over hundreds, to a dozen articles, when related to “sustainability” and “circular economy”. With regard to the theme of “short marketing chains” or “local marketing chains”, the attempt to associate them with terms such as “meat chain”, “animal welfare”, “animal production”, “transport and slaughters”, and “slaughterhouses” did not produce any results, which explains the absence of this theme in the bibliometric analysis.

Still, as mentioned by Stillitano et al. [13], the circular economy is related to short marketing circuits, as both aim to reduce waste and maximize the efficient use of resources. Therefore, the circular economy and short marketing circuits are interconnected in the search for a more sustainable production and consumption model.

4.3. Authors Keywords

A cluster analysis of the keywords was also carried out, which revealed the associations and network structure between them, facilitating the identification of the main research topics and subtopics within a vast amount of literature. Keywords such as “agriculture”, “sustainability”, “circular economy”, and “animal welfare” stood out, reflecting the focus of the research.

For example, if a node in the keyword cluster diagram appears highlighted with the label “animal welfare”, this indicates that this cluster may contain keywords associated with animal welfare issues and related topics, as “Life Cycle Assessment” indicates that the vast majority of the existing literature used empirical and quantitative methodologies to analyze the relationship between sustainability and other themes.

It was observed that the four keywords that stood out the most included “agriculture”, “sustainability”, “circular economy”, and “animal welfare”, as observed in Figure 4. Among them, “circular economy” was the most prominent theme, cited eighteen times and with a stronger and more frequent association with the word “sustainability” than with the remaining two themes (Table 6).

Table 6. Most cited keywords.

Keywords	Number of Occurrences
Circular economy	18
Sustainability	10
Life cycle assessment	8
Animal welfare	6
Agricultural sustainability	5
Livestock sustainability	5
Agriculture	4
Indicators	4
Mobile abattoir	4
On-farm slaughter	4
Slaughter	4
Biochar	3
Greenhouse gas emissions	3
Meat quality	3
Meat sustainability	3

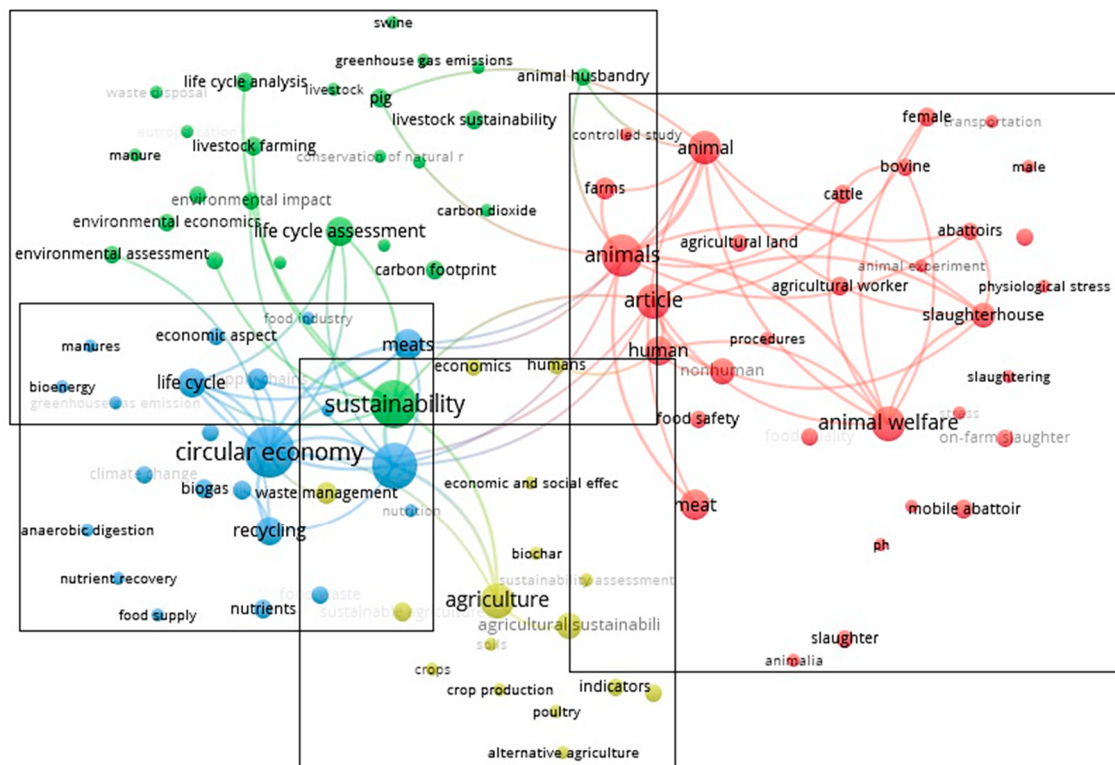


Figure 4. Literary clusters based on bibliographic coupling.

For example, Cooney et al. [16] address the implementation of a circular economy model for the recovery of seafood waste, aiming to meet the challenges and opportunities of intensive production and sustainability and discuss the growing concern about food safety and the sustainability of food production [16]. Noya et al. [54] highlights the importance of implementing the circular economy in the pork production chain, with both environmental and economic benefits. The same study identified that pig feed production and transport activities are the main critical points in terms of environmental impact. Based on these results, strategies were proposed that include the use of local ingredients in the production of food for pigs, the application of pig waste as organic fertilizer, and the economic valorization of the main co-products (blood and lard). The results demonstrated that the implementation of these strategies could make the pork production chain more sustainable and competitive.

Sustainability was the group's second most highlighted theme, occurring ten times, with a stronger association with the theme of "circular economy". The explanation for coming in second place may lie in the fact that some articles that address sustainable practices use the word "sustainable" and not "sustainability", and the latter was not included in the searches carried out in the *Scopus* database.

The frequently mentioned "Life Cycle Assessment" methodology assesses the environmental impacts associated with all phases of the life cycle of a product, process, or service, from the extraction of raw materials to final disposal [13,17,58]. This approach, which was mentioned eight times and came in third place, aims to quantify environmental impacts to guide decisions towards more sustainable practices [13]. This theme emphasizes the conclusions of Konefal et al. [3], which indicate that the environmental dimension receives considerable attention.

Animal welfare was the fourth most significant keyword, with six occurrences, although it had limited associations with other themes. Connections were strongest in the

context of animal welfare, transport, and slaughter, but were less robust with terms such as “agriculture”, “sustainability”, and “circular economy”.

When analyzing twenty-three articles on mobile slaughter and on-farm slaughter, it was observed that nineteen addressed animal welfare issues, often including in the themes the expressions “mobile slaughter” and “animal welfare”, which reflects the close interconnection between these areas (Figure 4).

Examples include the articles “Consumer willingness to pay for farm animal welfare: mobile slaughterhouses versus transportation to slaughter”, by Carlsson et al. [59], and “Transport versus on-farm slaughter of bison: Physiological stress, animal welfare, and avoidable trim losses” by McCorkell et al. [60].

Further analysis of the articles demonstrates that authors who discuss transport and slaughter prioritize animal welfare issues, with little attention to environmental and economic aspects, and especially social ones, which make up the concept of sustainability. The study by Carlsson et al. [59] is an exception, as it investigates the preferences and willingness to pay of Swedish consumers for the mobile slaughter of poultry, cattle, and pigs, also considering economic aspects. The results indicated that consumers would be willing to pay more for the mobile slaughter of cattle, but not chickens, and that the non-purchase option significantly influenced the heterogeneity of the results.

In general terms, the articles focus on the issue of animal stress and how it can affect the quality of meat, while animal welfare is a key factor in the quality of the meat production process. Studies by Eriksen et al. [41] and Lauterbach et al. [52] concluded that animals slaughtered on the farm or in local slaughterhouses have lower stress levels than animals slaughtered in conventional systems. The use of mobile and on-farm slaughter methods, by avoiding transporting animals over long distances, increases animal welfare and contributes to economic and social improvements due to better meat quality [52,60].

Themes such as “mobile abattoir” and “on-farm slaughter” were themes with little relevance compared to the other topics covered, and from the analysis of Figure 4, it is evident that the interconnections between these and the other themes of the study are not very robust.

No articles were found that investigated in more depth the impact of proximity slaughter on farms in terms of (i) short meat marketing circuits; (ii) final costs for small producers who need this service; (iii) the expansion of products with organic certification; (iv) at a regulatory level, how they could contribute to the reduction, if not even extinction, of clandestine slaughter; (v) the development of the small-scale agriculture sector, favoring decentralized food systems adjusted to geographic specificities, with shorter value chains and fair remuneration for producers; and (vi) combating rural depopulation, promoting new job opportunities and the socioeconomic development of the region.

4.4. Limitations and Further Research

It is important to highlight that the articles identified in the Scopus database do not comprehensively cover the entire field of this topic. An informal investigation in the ScienceDirect and Google Scholar databases revealed the existence of more than 200 articles, in different languages, originating from countries in the European Union, Asia, and Latin America, which are not present in the Scopus or Web of Science databases, which were largely limited to identifying articles written in English and published in renowned scientific journals.

Additionally, the detailed identification of many keywords requires a thorough analysis of the articles and a qualitative assessment of the topics covered, steps that were not included in this study. For future studies and for a more detailed and robust bibliometric analysis, it would be advantageous to use qualitative data analysis software, which facil-

itates content analysis and qualitative data exploration. These programs are not limited to being restricted only to articles from the Scopus database, allowing for the analysis of a wider variety of articles, from different sources and databases. This makes it possible to capture nuances and contexts that an isolated quantitative analysis may not reveal, enriching the interpretation of the data.

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The analysis included articles that did not address sustainability issues in the whole meat value chain, or either at certain stages of the meat value chain or in the meat production sector in general. Many of the articles analyzed address the sustainability of perishable foods like fruits, which are not part of the meat value chain, but it is important to note that these foods share common characteristics with meat, such as shelf life from production to processing and distribution. This aspect reinforces the idea that the meat value chain has relatively few studies focusing on sustainability, primarily because existing studies tend to address issues related to animal welfare rather than the sustainability of the entire chain.

5. Conclusions

This study has identified four key research themes within meat marketing chains: “sustainability”, “agriculture”, “circular economy”, and “animal welfare”. These themes indicate a growing interest in sustainable practices and the environmentally conscious management of meat production and supply chains. Through bibliometric analysis, we have observed a significant increase in the relevance of the relationship between agricultural sustainability, circular economy, and short marketing circuits since 2017. This highlights a progressive response to environmental concerns and a shift towards more sustainable and efficient business models.

The frequent utilization of the Life Cycle Assessment methodology in the analyzed studies underscores the importance of quantifying environmental impacts throughout the agricultural product life cycle. This approach has proven to be particularly valuable in examining value chains within the agricultural sector, providing an integrated and detailed view of the environmental impacts and sustainability of these activities. However, this study has revealed that the connections between slaughter and sustainability, circular economy, and short marketing circuits are not yet well established, indicating the need for further research to solidify these interrelated areas.

This study reveals that existing research on slaughtering largely centers on animal welfare and meat quality, leaving economic, environmental, and social dimensions underexplored. Addressing this oversight could pave the way for a more holistic understanding of sustainability in slaughtering practices. By considering factors such as short marketing circuits and the circular economy, future research could better align slaughtering with principles of sustainability, fostering localized and decentralized food systems”.

Overall, the findings underscore the need to expand the scope of slaughtering research. A more inclusive framework would integrate animal welfare with economic and social considerations, promoting practices that support regional adaptability and sustainable development. This broader approach could unlock significant benefits for the food industry and local communities alike.

However, we acknowledge the limited availability of the literature on this subject, particularly comprehensive reviews that integrate different links within the meat value chain. One possible limitation of this study is the scope of the keywords used in the literature search, which may have restricted the range of sources included. To address this limitation, we adopted an approach that combined primary and secondary sources, analyzing existing studies and identifying gaps in current knowledge.

Given this limitation, we recommend that future research explores underexamined aspects, such as the digitalization of the production chain, traceability, and the impacts of environmental and health regulations on different markets. Additionally, comparative studies on various production systems and supply chains could offer valuable insights for enhancing the sector's efficiency and sustainability.

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