

Evolution of publications in Brazil and in the world on efficiency and risk in dairy farming from 1979 to 2031

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ABSTRACT

Dairy farming is an important sector of global agribusiness, and it is essential for the economic development of Brazil. The objective of this study was to identify the main topics addressed by national and international literature on the efficiency and risk in dairy farming, as well as to propose a framework and an agenda for future research from the perspective of the theory of the firm. For this purpose, a bibliometric analysis was performed on the efficiency and risk in dairy farming, in scientific articles indexed in the *Web of Science* from 1979 to 2021, with a forecast for 2031. The national and international literatures are based mainly on studies related to efficiency and costs. Brazilian research seems to be supported by economic and cost issues, while in the international research, efficiency is advocated. Within the context of the theory of the firm, there seems to be a predominance of studies anchored on the assumptions of the theories of costs and income in Brazil, and production, in the world. Both in Brazil and worldwide, there are more articles on efficiency than on risk. It is possible that, if the international mainstream is followed, Brazilian research may increase its specificities in areas such as efficiency, production systems, and other more up-to-date topics.

Index terms: bibliometric analysis, dairy cattle, milk production, forecast.

Evolução das publicações no Brasil e no mundo sobre eficiência e risco na agricultura leiteira de 1979 a 2031

RESUMO

A pecuária leiteira é um importante setor do agronegócio mundial e é fundamental para o desenvolvimento econômico do Brasil. O objetivo deste estudo foi identificar os principais temas abordados pelas literaturas nacional e internacional sobre eficiência e risco na pecuária leiteira, bem como propor um *framework* e uma agenda para futuras pesquisas na ótica da teoria da firma. Para tanto, realizou-se uma análise bibliométrica sobre eficiência e risco na pecuária leiteira, em artigos científicos indexados na *Web of Science* de 1979 a 2021, com uma projeção para 2031. As literaturas nacional e internacional baseiam-se principalmente em estudos relacionados à eficiência e custos. A pesquisa brasileira parece apoiar-se em questões econômicas e de custo, enquanto na pesquisa internacional a eficiência é preconizada. No contexto da teoria da firma, parece haver predominância de estudos ancorados nos pressupostos das teorias de custos

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Ideias centrais

- Os principais temas abordados pela literatura sobre eficiência e risco na pecuária leiteira baseiam-se principalmente em estudos relacionados à eficiência e custos.
- A pesquisa brasileira sobre eficiência e risco parece apoiar questões econômicas e de custo, enquanto a pesquisa internacional preconiza a eficiência.
- No contexto da Teoria da Firma, parece haver predominância de estudos ancorados nos pressupostos das teorias de Custos e Receitas, no Brasil, e da Produção, no mundo.
- Uma análise bibliométrica sobre eficiência e risco na pecuária leiteira, com prospecção para 2031, é proposta como quadro analítico para vislumbrar a agenda futura de pesquisa no tópico.
- É possível que a pesquisa brasileira aumente suas especificidades em áreas como eficiência, sistemas de produção e em outros temas atuais.

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e receitas no Brasil, e nas de produção, no mundo. Tanto no Brasil quanto no mundo, há mais artigos sobre eficiência do que sobre risco. É possível que, seguindo o *mainstream* internacional, a pesquisa brasileira aumente suas especificidades em áreas como eficiência, sistemas de produção e outros temas mais atuais.

Termos para indexação: análise bibliométrica, rebanho leiteiro, produção de leite, projeção.

INTRODUCTION

Dairy farming is an important sector of global agribusiness and, according to Fassio et al. (2005), it is essential for the economic development of agribusiness. Two relevant topics for dairy farming are efficiency and risk. According to Guo et al. (2021), through the theory of the firm, the productive efficiency of production processes can be analyzed by the (best) use of the necessary resources. However, in the internal context of organizations, this theory is limited to the analysis of the production process (production theory), costs, and economic performance (cost and income theories) (Artuzo et al., 2018), for which the issue of risks in dairy farming has been neglected (Gebreegziabher & Tadesse, 2014).

The international literature may be very different from the national ones about dairy farming (Cardoso et al., 2019). This difference can be found in several studies that address issues related to efficiency and/or risk in dairy farming, in countries such as the United States (Evink & Endres, 2017), Norway (Lien et al., 2017), Australia (Bell et al., 2021), and Ethiopia (Gebreegziabher & Tadesse, 2014). These studies demonstrate that dairy farms are very heterogeneous among themselves, in terms of efficiency and risk. When comparing publications in Brazil with the international literature, some authors observed that publications in Brazil report a great heterogeneity in the national dairy farming. Those which lacks weaknesses such as nutritional problems, genetic, and technological improvement; while in the international literature, efficiency, investment viability and sustainability are highlighted (Lopes et al., 2004, 2021; Cardoso et al., 2019; Ferrazza et al., 2020).

In fact, it is possible that distinctions, such as efficiency, risks and costs, greatly differentiate national and international literature, since each country usually has a specific reality studied by researchers. Examples include international studies on efficiency and, in Brazil, on costs. Therefore, since no studies were found that analyze such distinctions, this study is important as it will allow us to better understand these topics in the national and international literature. In addition, this study allow us to understand how the theory of the firm, through the theories of costs and returns, can be inserted into dairy farming, since there is little evidence of studies that relate it to milk production.

There are several factors justifying this research. As the literature points out, national and international publications can be very different. Assis et al. (2016) highlight that regionalization is a factor that makes the national and international dairy production chain be very different. However, several studies report that the international milk production chain is similar to the national one in several factors, such as the difficulties identified by family farmers and productive efficiency, according to Gebreegziabher & Tadesse (2014), and Lopes et al. (2016).

Therefore, it is worth investigating which kind of research have been published in scientific publications regarding studies and scientific advances on the milk production chain in Brazil and around the world. Given the importance of studies on the efficiency and risk in dairy farming, studies contributing to the mapping of publications on this topic may indicate whether there is alignment between studies conducted in Brazil and those conducted in other countries.

Thus, the following question arises: Are studies on efficiency and risk in Brazil aligned with international publications about dairy farming? The objective of this study is to identify the main themes addressed by national and international literature on efficiency and risk in dairy farming, as well as to propose a framework and an agenda for future research that will allow identifying the main themes that make up national and international research on efficiency and risk in dairy farming.

THEORETICAL FRAMEWORK

Based on the concepts of Alfred Marshall, one of the most influential economists of the twentieth century, who sought to develop a management model to understand the behavioral logic of both companies and markets (Artuzo et al., 2018), Ronald H. Coase proposed the theory of firms, defining firms as highly complex organizations that are dependent on both the internal and external environment. With his article entitled *The Nature of the Firm*, published in 1937, he addressed new conceptions related to the firm, causing a rupture with the concepts that until then were considered mainstream of the time on business economics (Tigre, 2005).

It is possible to find in the literature a vast collection of publications dealing with the theory of the firm. However, Tigre (2005) warns that this theory focuses too much on prices and resource allocation in companies, leaving aside relevant issues, such as the operational performance of the production process. Likewise, most publications value more issues related to the external environment. Jensen & Meckling (2008) add that much of the literature related to the theory of the firm is actually inserted within the context of market theory, so that the firm is seen only as a participant in this process, which is responsible for transforming inputs into products, commercializing them in the market. Such views allow of the (erroneous) understanding that the firm is a simple and low-complexity organization.

In the literature, only two articles referring to the theory of the firm in dairy farming were identified. The first one, by Zylbersztajn (2005), was dedicated to study the relationship between the market and transaction costs, which occur through contracts signed in the sector. This work relates the concepts of the theory of the firm in dairy farming from the perspective of the external environment. In the second study, by Mondaini et al. (1997), the total cost and operating costs methodologies are applied as important components linked to the theory of the firm that contributes to the analysis of the economic performance of dairy farms. However, this work superficially analyzed the theory of the firm itself, dedicating itself to deepening the concepts of the aforementioned methodologies.

Several publications can be found that apply the concepts of total cost and operating costs methodologies in dairy farming. Based on the studies by Lopes et al. (2004), it is possible to observe that, although not explicit, other studies conducted in recent decades used these methodologies as mechanisms to analyze the profitability of dairy farms (Lopes et al., 2019; Pelegrini et al., 2019; Ferrazza et al., 2020).

The existing concern about the difficulty of managing organizations rescues central concepts of the theory of the firm that aim to analyze the production, costs, and income of organizations in the internal environment. Thus, the theory of the firm is subdivided into: production theory, which addresses concepts related to production and productivity; cost theory, which covers economic costs; and theory of profitability, which aims to minimize costs to maximize results (Vasconcellos & Garcia, 2009; Artuzo et al., 2018).

Risk can be understood as the possibility that the results achieved are different from the planned ones, due to the interference of noncontrollable factors (Buainain & Silveira, 2017). In dairy farming, farms are exposed to the most varied factors and ways of risk. There are several types of risks that can plague the sector, such as environmental, social, and technological ones, besides those related to management, infrastructure, logistics, and regulations (Buainain & Silveira, 2017), as well as commercialization and human capital (Gebreegziabher & Tadesse, 2014), production, operation and management (Bassotto & Machado, 2020), among others.

Guo et al. (2021) point out that high risks can decrease the stability of production processes, exposing organizations to higher levels of uncertainty. Therefore, it is essential to understand how risks can influence dairy farms. Although there is a limited number of studies that apply the concepts of the theory of the firm in dairy farming, and that relate efficiency and risks of the sector, several studies can be identified which were dedicated to studying production, costs and yields, elements of production theories, elements of costs and yields, as well as their risks for dairy farming, as presented in the next section.

Efficiency in dairy farming is essential for the development of the dairy business and for strengthening the sector. However, this theme seems to differ among countries. In Brazil, many properties have low attractiveness, due to poor technical and management performance. Lopes et al. (2016) emphasize that low economic, zootechnical, and productive efficiency is a problem that affects many properties. Lemos et al. (2003) add that, in addition to cultural issues, there is a great heterogeneity among Brazilian dairy farms, since the more specialized ones tend to be more productive and efficient, contributing to the increase of the average milk production in the country.

In Brazil, publications seem to be mainly concerned with the efficiency of the production process (internal environment) of dairy farms. There are several studies in the literature that point to issues such as the system of rearing calves and heifers (Conceição et al., 2018), management processes (Lopes et al., 2016), efficiency (Cardoso et al., 2019), analysis of production costs and/or profitability (Fassio et al., 2005; Lopes et al., 2011, 2015; Bassotto & Machado, 2020; Ferrazza et al., 2020), and investment feasibility (Bassotto & Angelocci, 2017; Demeu et al., 2021), which is one of the most recurrent themes in the country. Rezende & Domingues (2020), when conducting a bibliometric research into national publications on dairy farming, found that topics such as accounting, productivity, administration, strategy, and contracts are more commonly identified. All these studies suggest that the internal environment may be more recommended than the external environment in Brazil.

Conversely, the international literature indicates that there is a great technological development (Evink & Endres, 2017), which is a factor that provides a greater productive efficiency, which helps dairy farms to become more attractive economically (Lien et al., 2017).

Gebreegziabher & Tadesse (2014) studied efficiency in dairy farms and found that, in Ethiopia, smaller farms are usually less efficient and, consequently, more exposed to risks.

Bell et al. (2021) analyzed the efficiency of Australian dairy farms with regard to the mitigation of activity risks. They found that properties agricultural activities coexisting with dairy farming (crop-livestock integration), when running efficiently, had lower risks than those specialized in a single agricultural product. The authors emphasize that income diversification is a viable alternative, in the attempt to mitigate risks linked to the high climate variation and the high variation of the product's commercialization prices.

Gebreegziabher & Tadesse (2014) classified the main risks that can plague dairy farms into six categories: productive, technological, financial, institutional, market, and human factors.

For Evink & Endres (2017), milk producers should be concerned with issues such as public policies, milk marketing policies, and the absence of research that could help with the development of dairy farming. For these authors, these risks tend to overlap with the internal ones, and the main identified risk is linked to process automation, despite such risks contribute to the increase of productive efficiency, as well as to the increase of the fixed (operational) costs and the capital invested in the activity.

The international literature also reports several risk management tools efficiently used on dairy farms in other countries. The price of milk is considered by Wolf (2010) as the main factor that exposes dairy properties to risks, as it is directly related to the activity revenues. Furthermore, practices such as milk futures contracts and trading on stock exchanges are practices adopted by large dairy companies in several countries, such as the United States (Wolf, 2012). The main advantage of these practices is to mitigate the risks of fluctuations that the market exerts on dairy activity (Evink & Endres, 2017).

However, such risk management tools in Brazil do not appear to be viable, due to internal factors such as, for instance, the predominance of small farms, usually family farming (Bassotto et al., 2022), low efficiency, and low livestock productivity of the national dairy (Lopes et al., 2016).

There are still other strategies that can be adopted in Brazil. Wolf (2012) highlights the importance of participating in cooperatives and joint purchases and/or futures contracts, with fixed prices. The author explains that these actions can help to stabilize input and milk prices, allowing of a better financial planning of production activities. Spanevello et al. (2020) add that, in Brazil, cooperative practices still do not have much participation from producers.

Through these studies, it is possible to identify that in international studies there is concern for the efficiency of the production process and for the risks that may expose dairy farms to economic, technological and attractiveness vulnerabilities, among others. However, in Brazil, there seems to be a greater concern for the productive efficiency and less emphasis on the risks of dairy businesses.

Bassotto et al. (2022) emphasize that few Brazilian publications analyze issues related to efficiency and risk in dairy farming.

MATERIALS AND METHODS

The present study is classified as descriptive with a quantitative approach (Bryman, 2003). It has longitudinal temporality (Zangirolami-Raimundo et al., 2018) as it analyzes scientific articles from 1979 to 2021, which address issues related to efficiency and risk in dairy farming. The data collection and analysis techniques were bibliographic (Marconi & Lakatos, 2003) and bibliometric ones (Aria & Cuccurullo, 2017), respectively.

Bibliometric research is very important in descriptive and exploratory analyses, as it allows of the possibility of mapping networks of relationships between authors on contemporary themes linked to a given research topic (Chain et al., 2018). Bibliometric analysis techniques are anchored in the network theory that emphasizes the analyses of relationships, collaboration, and flow of information between different researchers, institutions, and countries represented by nodes, thus allowing to map areas of scientific knowledge, as well as to identify areas of concentration of studies and relationships between authors (Chain et al., 2018), with focus on dairy farming (Rezende & Domingues, 2020).

The themes of the present research were defined through preliminary analyses of the literature with the aim to identify different perspectives. We chose to follow the recommendations of studies by Bassotto et al. (2022), based on the understandings about the regionalization of the milk production chain in Brazil and around the world discussed by Assis et al. (2016). To meet the proposed objectives, two searches were performed in the same database and with the same search terms. This procedure allowed us to separately analyze the literature published in Brazil and in the world, to verify whether the national and international literature are aligned for the efficiency and risk in dairy farming.

A summary of the methodological procedures adopted in this study is presented as follows (Table 1). The first step was the definition of the Boolean operators (AND, OR, and NOT), and the search terms were defined according to the scope of this article (efficiency and risk in dairy farming). These operators were chosen to reach the largest possible number of scientific publications on the topic. Initially, the words firm theory; cost theory; income theory; and production theory were used. However, the reduced number of publications precluded the use of these terms. These descriptors were defined after a prior consultation in the literature, when keywords used in other research were identified. Subsequently, a search was performed in the *Web of Science* (WoS), *Scopus*, *Scielo* and *Spell* databases, to identify which one has the largest number of indexed articles on efficiency and risk in dairy farming. WoS was chosen because it has the largest number of articles published worldwide (2,754) and in Brazil (145).

Table 1. Summary of the methodological procedures adopted for this study (2021)

Stage	Procedure	Discrimination
1. Define	Database	Web of Science
	Search Terms	Delimitation of the terms that best represent the field: efficiency, risk, operational, management, technical, milk production, and dairy farms, researched in English.
2. Search strings	In Brazil	(TS = (operational OR management OR technical) AND TS = (efficiency OR risk) AND TS = (milk_production OR dairy_farm*)) AND CU = (Brazil)
	Worldwide	(TS = (operational OR management OR technical) AND TS = (efficiency OR risk) AND TS = (milk_production OR dairy_farm*)) NOT CU = (Brazil)
3. Formation of the database	Filters	Every year, areas and languages; file type: articles and review.
	Reference download	Formats: BibTex, for reference manager; plain text (txt), for bibliometric software; and xls, for spreadsheets.
4. Preparation of the database	Elimination of articles	In duplicate; by analysis of the polysemy of the terms; and because it is outside the scope of the article, identified through floating reading.
5. Data processing	Software	bibliometrix, CitNet Explorer, and Excel Spreadsheet.
	Parameters	Definition of the analysis parameters for each software.
	Data	Statistical analysis of data and export of results (to Word).
6. Data analysis	Only in Brazil	General analysis of publications. Analysis of the research field.
	World (without Brazil)	Analysis of citations. Most cited authors.
	In the world (with Brazil)	Most relevant scientific articles. Main research topics.
7. Analysis of projections	Brazil	Countries that have published the most on the subject.
	World	Most relevant scientific journals in Brazil and worldwide.
8. Thematic framework	Brazil	Identification of the most relevant topics and possible scenarios for research in Brazil, starting in 2022.
	World	

Subsequently, only scientific articles and *reviews* from all years, languages and areas were selected. This definition was made so as not to run the risk of eliminating from the analysis articles that might eventually fall into a different category in the *Web of Science*. There was a fluctuating reading in the titles of the selected articles, excluding those that were not aligned with the research and were in duplicate. A polysemic analysis was also performed to exclude articles that were selected and, eventually, did not adhere to the scope of this research. Van Eck & Waltman (2014) emphasize that such practices are fundamental to the reliability of the research. Thus, the world sample (excluding Brazil) and the Brazil sample were reduced to 2,478 and 140 articles, respectively.

Two other searches were performed, following the same above mentioned criteria, but searching for the terms “efficiency” “and” “risk” “separately.” The purpose of researching these terms separately was to better map, in the literature that deals with dairy farming, topics that are more handled in depth. This new analysis allowed the data to be stratified in the WoS according to the aforementioned themes (efficiency and risk) without changing the total number of articles dealing with the subject in Brazil and worldwide. All these procedures occurred in mid-June 2021.

To calculate the projections made for the years 2022 to 2031, the “FORECAST. ETS” function of *Excel* was used, which is responsible for making forecasts with exponential smoothing (Microsoft, 2021), taking into account trend, seasonality and error. *Excel* can be an important tool for projections due to the greater accessibility of users compared to specialized statistical software packages. Exponential smoothing modeling allows you to calculate weighted averages from a historical series, whose weights are greater in more recent years and decline over time (Leonardo et al., 2020; Martinello et al., 2021) after analyzing different publications on the topic, highlight that this function has the advantage of less error indication in the short term. Table 2 presents a summary of the statistical parameters obtained in modeling the forecast for the world and only for Brazil.

Table 2. Statistical parameters of the predictive model.

Parameter	World	Brazil
Alpha	0.25	0.10
Beta	0.25	0.10
Gama	0.00	0.00
MASE (mean absolute scale error)	1.88	3.77
SMAPE (symmetric mean absolute scale error)	0.06	0.26
MAE (mean absolute error)	9.93	2.59
RMSE (root mean square error)	12.29	3.29

Finally, to prepare the study agenda, the ten most cited articles in the *Web of Science* were selected only in Brazil and around the world. These articles were chosen as argued by Chain et al. (2018) when explaining that the most cited articles tend to make up the mainstream research, being valid for preparing a study agenda. Firstly, we read these articles, highlighting the main aspects they highlighted as flawed, research gaps and suggestions for future studies. Then, a framework was created that synthesizes these aspects.

RESULTS AND DISCUSSION

The trajectory of publications on the subject showed a similar pattern in Brazil and in the world: few publications in the initial years, increasing the amount of research only from the second decade (Figure 1). Since the first publication in the world (1979) and in Brazil (1992), there have been 9 and 12 years with few publications, equivalent to 28.57% and 31.03% of the total years analyzed, respectively.

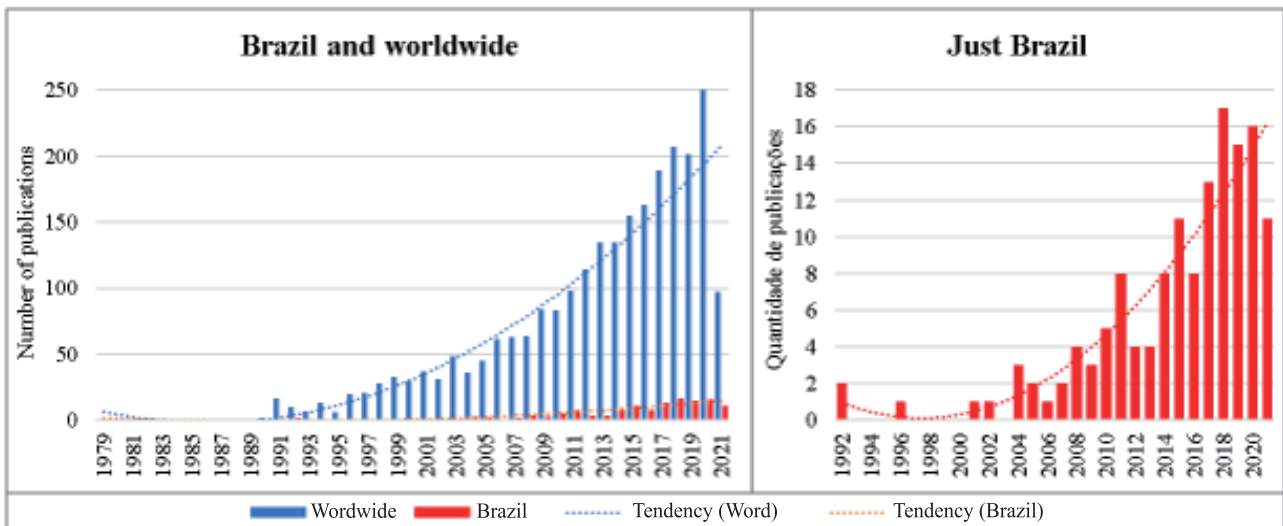


Figure 1. Evolution of scientific publications in Brazil and worldwide on efficiency and risk in dairy farming, from 1979 to 2021

Considering the worldwide research on the subject (including Brazil), the average annual growth rate observed for publications was 14.87% since the first publication (1979), and 6.01% in the last 20 years (since 2002). Brazil had an annual growth rate of 8.46% (since 1992) and 14.25% (since 2002). These results indicate that the scientific field that analyzes efficiency and risk in dairy farming is expanding, as in the last 20 years, and that Brazilian publications have maintained an annual growth rate of approximately 137% higher than the world rate. This understanding can also be identified in

the trend curve (Figure 1), which indicates a greater ascendancy in Brazilian publications than in global publications.

Since 1979, the country with the highest number of publications has been the United States, with 22.59% of the publications on efficiency and risk in dairy farming, followed by Canada (9.43%), the Netherlands (8.33%), Germany (7.41%), Australia (6.92%), England, and New Zealand (5.82% each). Brazil ranked eighth, with 5.33% of publications worldwide on the subject. A projection was performed for the number of possible publications in 2031, from the annual number of articles published in each of the ten countries which have researched the subject in the last ten years (Table 3).

Table 3. Ten countries that published the most scientific articles on efficiency and risk in dairy farming between 2002 and 2021, and projections from 2022 to 2031

Country	1992-2001			2002-2011			2012-2021			2022-2031 ⁽¹⁾			Annual growth (%) ⁽²⁾
	Qty.	%	C	Qty.	%	C	Qty.	%	C	Qty.	%	C	
USA	80	48.03	1	160	32.16	1	340	24.30	1	447	23.63	1	14.92
Canada	22	17.02	2	51	10.61	3	168	11.94	2	217	11.45	2	28.81
Netherlands	27	10.34	3	66	14.00	2	125	9.09	5	172	9.07	4	24.50
England	13	5.72	4	34	7.16	6	106	7.46	8	138	7.28	8	29.96
Germany	11	5.35	5	45	8.58	4	137	9.24	3	192	10.3	3	26.50
Australia	11	4.34	6	41	8.50	5	130	9.10	4	171	9.00	5	7.85
France	9	4.29	7	23	4.93	9	87	6.11	10	111	5.85	10	28.33
Brazil	4	2.36	8	29	5.43	7	107	7.52	7	152	8.00	7	1.22
N. Zealand	6	2.21	9	29	5.38	8	118	8.25	6	158	8.34	6	-0.96
Ireland	1	0.32	10	19	3.25	10	99	6.98	9	137	7.24	9	9.16
Total	184	100.0	-	497	100.0	-	1,417	100.0	-	1,894	100.0	-	-

C: placement of the country in the ranking of the ten most published articles. ⁽¹⁾ Calculated considering the variation of the number of publications between 2002-2011 and 2012-2021; ⁽²⁾ Indicates the average growth between decades.

Netherlands, England, and France seem to have research fields on the subject of reduced growth, as they lost positions in the rank of the most relevant countries (Table 3). It is possible that the annual growth rate of the number of publications from England and France is lower than the world growth rate, which would explain the loss of rankings. The United States, the leader in publications on the subject over three decades, continues to be the country that would publish the most on the subject in the world from 2022 to 2031. Germany, Australia, Brazil, New Zealand, and Ireland gained positions in the aforementioned ranking, indicating that their research fields on efficiency and risk in dairy farming are expanding.

The results indicate the importance of Brazil in the context of research on efficiency and risk in dairy farming worldwide (Figure 1 and Table 3). The Brazilian research field is growing, and national researchers seem to value the main international journals dedicated to publishing articles on the subject. This implies that there are Brazilian articles with quality and scientific alignment with important international journals.

Another analyzed aspect is the coparticipation of different countries in published scientific articles, with the line thickness indicating a greater relationship between nations (Figure 2). The most relevant countries in the world (United States and Canada) have a high rate of coparticipation with European countries, Australia, and New Zealand. In addition, it is possible to identify a greater diversity of publications from these countries that are in coparticipation with others. In Brazil, the coparticipation with other countries is lower, and it is mainly limited to the United States, Canada, Australia, New Zealand, and some European countries.

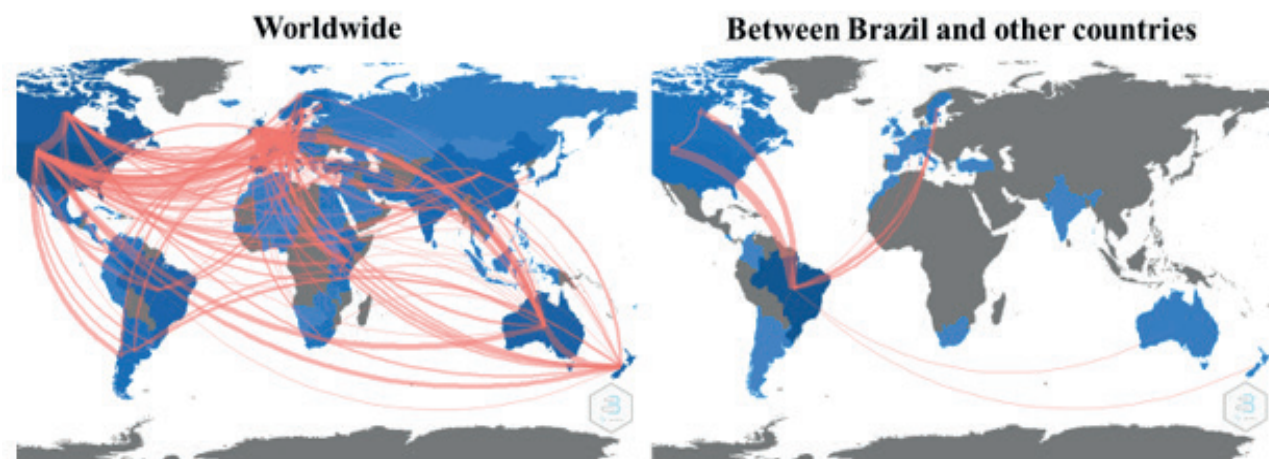


Figure 2. Coparticipation between countries in articles published in Brazil and worldwide on efficiency and risk in dairy farming from 1979 to 2016. Source: Aria & Cuccurullo (2017).

The coparticipation of Brazil with other countries also seems to be limited (Figure 2), indicating that there is a need for greater involvement between Brazilian research institutions and researchers in other countries. Less international involvement may contribute to the lower number of national publications for the advancement of scientific knowledge on dairy farming in the national realm. In addition, this condition may contribute to national and international scientific articles researching different topics on dairy farming (Bassotto et al., 2022).

The most relevant scientific journal in the world was the *Journal of Dairy Science*, which stands out for the number of published articles and impact factor (JCR), being the second most relevant journal in Brazil (Table 4). Its high rank in the national ranking list indicates that many Brazilian researchers publish in this journal. In Brazil, the *Semina: Ciências Agrárias* ranks first in the aforementioned ranking, with the highest impact factor among the national journals (JCR = 0.967).

National publications seem to be very concentrated still in national scientific journals and with low representativeness in the world scenario, since no Brazilian journal has entered the ranking of the most relevant in the world, and, in most cases, the impact factor of these journals is less than 1,000 (Table 4). This weakens the relevance of Brazilian publications, due to certain limitations, such as the language of the publications (most Brazilian studies were published in Portuguese), which limits the visibility of these articles.

The analysis of citations indicated that Brazilian and international studies were based on different publications (Figure 2). In Brazil, 142 articles cited between 1976 and 2021 were identified and grouped into a single cluster (cost management), while in the world, there were 3,135 articles cited between 1953 and 2021, and they were grouped into three clusters (production efficiencies, production systems, and specific research).

The main work cited in Brazil on the efficiency and risk in dairy farming is Matsunaga et al. (1976). In this study, the authors propose the methodology of operational costs, classifying them into effective (COE) and total (TOC) operating costs. In addition, these authors calculated the operating and net results of the activity by means of gross (revenue minus EOC) and net (revenue minus TOC) margins. This study seems to be very much in line with the assumptions of the costs and income theories that, as Vasconcellos & Garcia (2009) point out, is on the main themes addressed by them.

Table 4. Scientific journals that most publish studies on the efficiency and risk in dairy farming in Brazil and worldwide in 2021 (continued).

Journal	Country	JCR 2020	Number of publications				Growth rate (%) ⁽²⁾
			1992- 2001	2002- 2011	2012- 2021	2022- 2030 ¹	
World							
1. Journal of Dairy Science	USA	4,034	37	102	300	414	135.97
2. Preventive Veterinary Medicine	Netherlands	2.67	28	32	58	70	38.83
3. Agricultural Systems	Netherlands	5.37	4	19	46	65	186.46
4. Animals	Switzerland	2,752	0	0	55	75	12.36
5. Livestock Science	Netherlands	1,943	0	16	36	53	57.85
6. Animal Production Science	Netherlands	1,559	0	3	33	46	346.48
7. Tropical Animal Health and Production	England	3.24	0	16	29	44	44.20
8. Animal	Australia	1,533	0	9	33	48	103.60
9. Agriculture Ecosystems & Environment	England	6,789	0	5	20	29	114.51
10. Journal of Environmental Management	Netherlands	5,567	2	5	19	26	155.75
Brazil							
1. SEMINA: Ciências Agrárias	Brazil	0.967	0	0	15	21	12.36
2. Journal of Dairy Science	Brazil	4,034	0	0	9	12	12.36
3. Revista Brasileira de Zootecnia ³	Brazil	0.442	1	7	7	11	217.98
4. Tropical Animal Health and Production	USA	4,034	0	0	7	10	12.36
5. Arq. Bras. de Med. Vet. e Zootecnia	Brazil	0.584	0	4	6	9	34.77
6. Pesquisa Veterinária Brasileira	Brazil	0.803	0	3	5	8	39.75
7. Preventive Veterinary Medicine	Netherlands	1,559	0	1	5	7	147.42
8. Acta Scientiae Veterinariae	Netherlands	2.67	0	0	5	7	12.36
9. Ciência Rural	Brazil	0.337	0	3	4	6	29.93
10. Ciência e Agrotecnologia	Brazil	1,390	0	4	1	2	21.81

USA: United States of America. JCR: impact factor of the *Web of Science* (Journal Citation Reports). ⁽¹⁾ Calculated considering the variation in the number of publications between 2002-2011 and 2012-2021. ⁽²⁾ Did not consider the values of the projected decade (2022 to 2031); ⁽³⁾ also known as *Brazilian Journal of Animal Science*. Source: Web of Science (Clativate Analytics, 2021).

In the worldwide scenario, the production systems cluster (Figure 2) showed 742 articles cited since 1963. A more detailed analysis of this cluster, isolating it from the others, indicated that there was no work that stood out, because it is a reference for the field of production studies. The main topics addressed were the use of nitrogen in cattle feed, management and sustainability strategies, and performance of dairy farms. With 698 publications since 1967, the specific research cluster addresses issues related to reproduction, automation of milk production systems, feeding, and nutrition of dairy herds. This cluster also did not show any article that had stood out in the area due to the great diversity of topics researched.

In the productive efficiencies cluster, with 446 publications starting in 1953, the most significant work was by Farrel (1957), who proposed a method for measuring the technical efficiency of organizations. Another three works, published in the late 1970s, were the basis for the segmentation of this cluster. Charnes et al. (1978) proposed and expanded the studies on the relative efficiency technique called data envelopment analysis (DEA). Meeusen & van den Broeck (1977) addressed the efficiency of the Cobb–Douglas production function, which discusses the representation of the relationship between two or more production factors with a given product. Finally, Aigner et al. (1977) formulated and proposed estimates of models of the production function at the stochastic frontier. These studies contributed to the large number of publications on efficiency in dairy farming, although they did not address this topic specifically. In addition, none of these studies analyzed issues related to risk, suggesting that research related to this topic is more recent than the efficiency of milk production processes.

In Brazil, the mainstream research on efficiency and risk relied mainly on cost management in dairy farming. Worldwide, the most cited work analyzes the technical efficiency of organizations based on the importance of this topic for the field. This shows that the main works cited by the analyzed articles do not show relationships between each other, a condition that helps explain the distinctions between the research themes analyzed, especially in the last decade.

The analysis of the citations indicates that, in Brazil, there is a greater predominance of studies that consider efficiency and risk in the context of costs and economic performance of dairy farms. Within the theory of the firm, these concepts seem to be more aligned with the theories of costs and yields that, according to Vasconcellos & Garcia (2009), focus on the costs and yields of a production process. However, the international research seems to be more aligned with the assumptions of the production theory, since the three identified clusters (Figure 3) advocate the milk production process.

The ten most relevant authors from Brazil and the world on efficiency and risk in dairy farming are presented (Figure 4). The larger are the circles, the greater is the number of articles published in the year, and the darker are these circles, the greater is the number of citations in the year. Marcos Aurélio Lopes was the most significant researcher in Brazil (Figure 4), with two publications in 2004, the main article of which analyzes the management controls and production costs, using two calculation methodologies (operating costs and total cost), in dairy farms with different production systems (Lopes et al., 2004). The year with the highest number of publications by this author was 2018 (four articles), and the highest number of citations (7.5) occurred in 2020, with the highest number of citations/year in Brazil. In addition, an analysis of national and international publications (together) placed Marcos Aurélio Lopes in the seventh place in the ranking of the most relevant authors in the field. Rezende & Domingues (2020) also identified that this author was the most relevant in a bibliometric study analyzing dairy farm management.

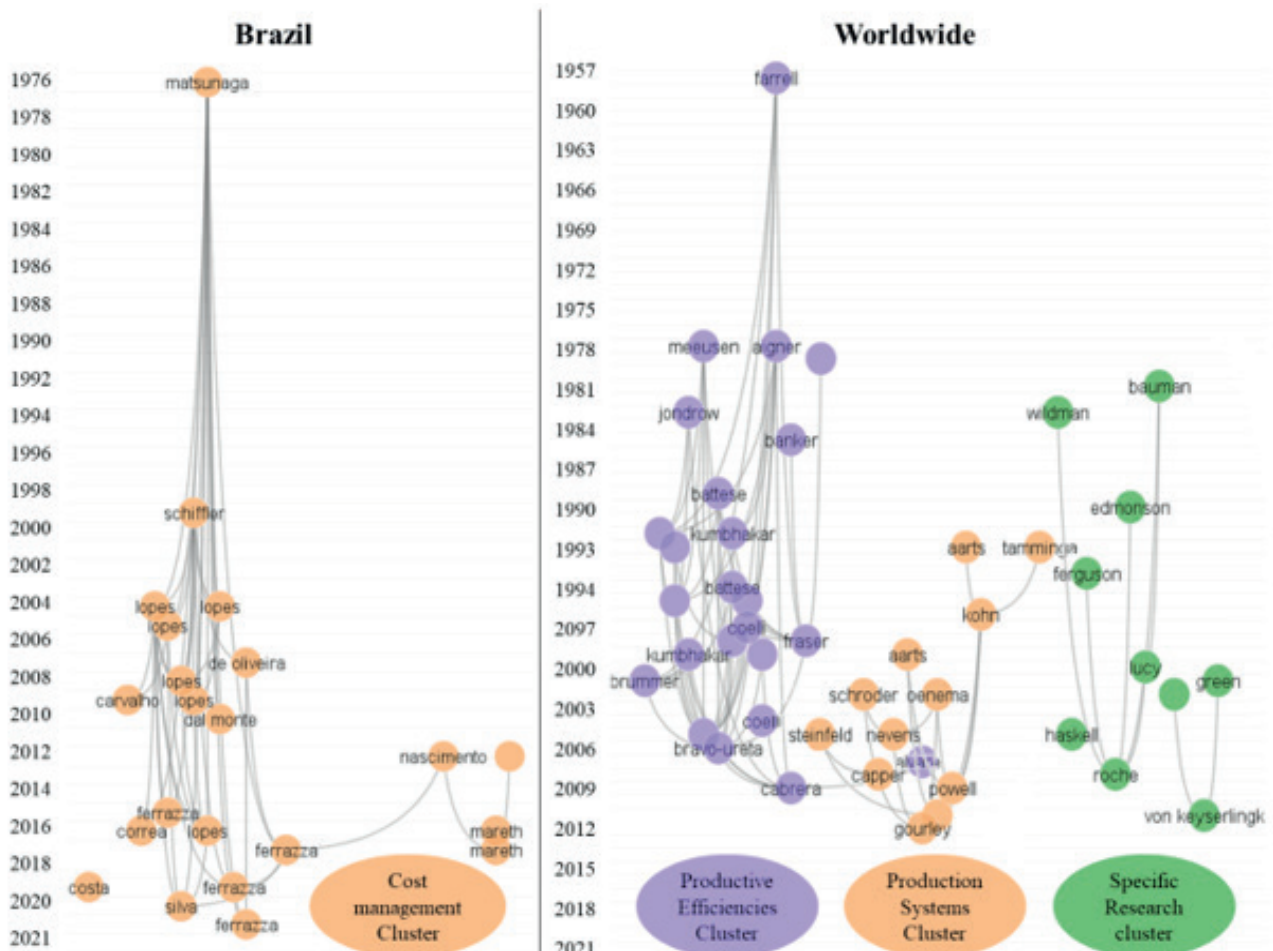


Figure 3. Analysis of citations of articles published in Brazil and worldwide on efficiency and risk in dairy farming from 1976 to 2021. Source: Van Eck & Waltman (2014).



Figure 4. List of the most relevant authors on efficiency and risk in dairy farming, in Brazil and worldwide. Larger and darker circles indicate, respectively, a greater number of published and most cited articles in the year. Source: Aria & Cuccurullo (2017).

The most relevant researcher in the world was Herman W. Barkema (Figure 4). The years in which he published the most articles (four articles) were 2016 and 2015, with the highest number of citations (51.43). His most expressive work presents relevant information on the changes that have occurred in the sector, in recent years, and they are related to the health and animal welfare of dairy herds (Barkema et al., 2015).

The main terms were also analyzed, defined by keywords classified by the *Web of Science*, called “keywords plus”, and they occurred in the last two decades (Figure 5). From 2002 to 2021, 136 and 2,252 articles were published related to efficiency and risk in dairy farming in Brazil and worldwide, respectively.

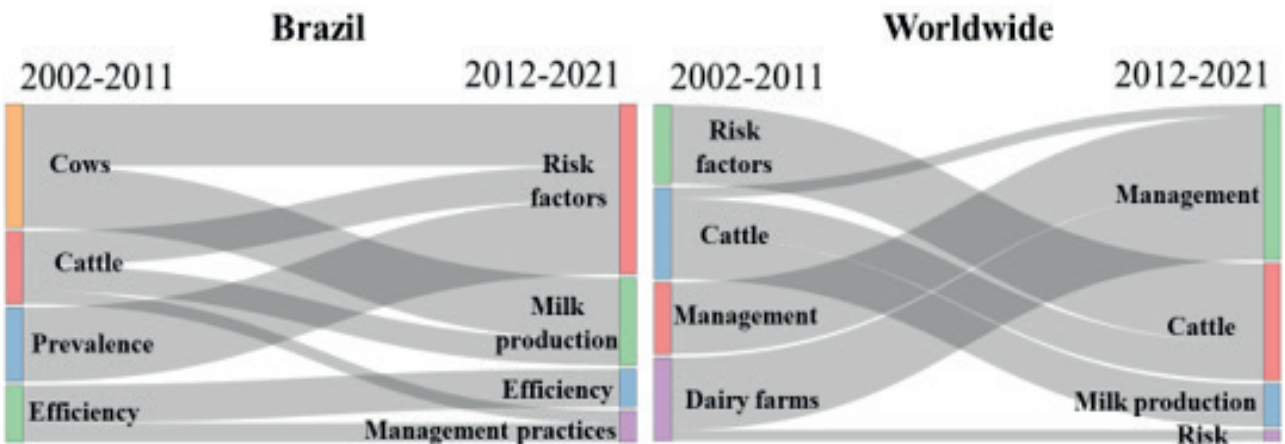


Figure 5. Evolution of the research themes obtained from the analysis of the “keywords plus” terms of articles published in Brazil and worldwide, on the efficiency and risk in dairy farming, from 2002 to 2021. Source: Aria & Cuccurullo (2017).

In Brazil, the main topic in evidence in the last decade is research on risk factors (Figure 5). This is a recent topic that originated from studies on cows, prevalence and herd, in the previous decade. The second most evident topic, milk production, evolved from studies whose most commonly used terms were cows and herds. In the comparison between the two decades, cows are no longer the most recurrent as cows, herd, and prevalence; articles that advocated efficiency were kept in evidence; and two new themes that emerged were risk factors and management practices. These results suggest that the most recent research on dairy farming in Brazil has been concerned with issues related to efficiency, management, and risks, unlike the decade from 2002 to 2011, which seems to have centered on the operational process of dairy farming. It is possible that, in recent decades, research has been more focused on more strategic than specific themes in dairy farming.

Worldwide, four themes began to be more in discussion (Figure 5). The first of these, management, which is very recurrent in the last two decades, gained strength with the incorporation of research that previously analyzed mainly dairy farms. The second term, herd, was already recurrent in the penultimate decade, but incorporated studies related it to risk factors, increasing its relevance. It is possible that, although the word theme herd has not changed in the two worldwide analyzed decades, its context has changed, and publication started to consider more risks related to herds and less risks related to the milk production process. This can be observed due to studies that, from 2002 to 2011, addressed the subject of herd and began to refer specifically to milk production. Thus, the evolution of studies on dairy farming has undergone the following variations: (i) risk factors and dairy properties have lost evidence; (ii) herd and management are growing themes, but they seem to portray a new change in the focus of research studies; and (iii) last, milk production and risk are considered emerging themes.

A more detailed analysis allows us to understand the variation between the density and centrality of the topics under analysis. It shows the evolution map of the main research topics – in Brazil and worldwide – stratified into two decades (2002 to 2011 and 2012 to 2021) and classified into four quadrants: 1) emerging or declining; 2) specific or linked to a particular niche; 3) most researched topics; and 4) basic themes for research in the area (Figure 6).

In Brazil, although the topic of efficiency has been maintained in the two analyzed decades (Figure 5), it is found that it has been reducing its centrality in research and increasing the number of publications on it (Figure 6). Topics that, from 2002 to 2011, were essential to the area ceased to be recurrent, a condition in which new themes emerged and assumed this position (Figure 5, quadrant 4). In addition, studies on the subject of cows ceased to be recurrent. The topic of milk production is also in the quadrant 4 (Figure 6) with both in Brazilian studies and in the rest of the world. In Brazil, the herd theme, which is the foundation between 2002 and 2011 and has lost momentum in the last decade, has a different behavior in the world, since it is the main theme researched (Figure 6, quadrant 3).



Figure 6. Evolution the research themes obtained from the analysis of the keywords plus of articles published in Brazil and worldwide for the efficiency and risk in dairy farming from 2002 to 2021. The evolution map is divided into the following quadrants: 1, emerging or declining themes; 2, more specific or very specialized topics; 3, main themes researched in the field; and 4, basic themes for research in the field of analysis. Source: Aria & Cuccurullo (2017).

Distinctions for the main research topics between Brazil and worldwide were also evident. Based on these results, two possible scenarios can be forecasted for the main studies to be conducted on dairy farming in Brazil (Figure 7). These analyses were based on the main variations of the themes (Figures 5 and 6). A comparative analysis of these figures allows us to identify that, from 2002 to 2021, international research on cattle, milk production, and management expanded, while, in Brazil, research themes that stood out were milk production and risk. The increase of studies in a certain area is presented by Chain et al. (2018) as a factor that helps identify areas requiring researches to expand scientific knowledge.

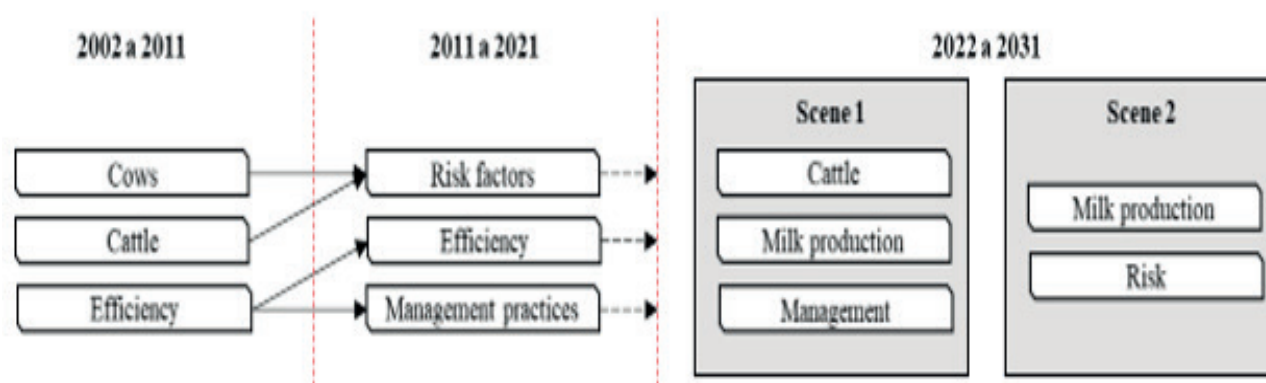


Figure 7. Perspectives of research topics for Brazilian dairy farming from 2022 to 2031, and research gaps. Scenario 1 considers that Brazilian publications will follow the global trend in dairy farming, while scenario 2 may occur if Brazil does not follow international trends.

If Brazil follows the global research on dairy farming, it is possible that, in the coming years, the thematic herd will once again be a research topic. However, it is possible that this is a topic that, as occurred in worldwide publications, considers aspects related to risk in dairy herds. Therefore, regardless of the direction of research in Brazil, risk analysis with dairy herds is a field with few studies. In addition, it is possible that research on management processes in dairy farming, an emerging topic at present, will gain strength in the coming years. The second scenario may occur if Brazil does not follow global trends in scientific research. In this case, the main topic that should continue to grow is research related to risk in dairy farming. Regardless of the scenario, studies that explore issues related to milk production may stand out, as it is an emerging theme in Brazil and of great importance in the world. This demonstrates that, even with many publications on the topic, there is still a lack of studies that understand different phenomena related to production, not limited to studies on the effects of varying the scale of production, which have been extensively studied in recent years.

Finally, it is valid to add that risk is an emerging topic and that it seems to be increasing its expressiveness in Brazil and ceasing to be studied worldwide. No studies or older citations were found on the risk in dairy farming, a reason that strengthens the understanding that its emergence is more recent than efficiency, which has been published since the first published articles. Thus, it is possible that the risks in the dairy sector are more aligned with the realities of domestic dairy farming than international dairy farming and it is a major research gap to be explored in the coming years.

In the sample, we identified those articles published in the last two years that had the highest number of citations, and from them, a *framework* was developed with the agenda for future studies (Figure 8). For the worldwide scenario, the main suggestions for future studies are based on topics such as public policies, supply chains and time series analysis in the agricultural sector. In addition, topics such as studies in Brazil and market issues (supply and demand) stand out (Figure 8).

	Journal	Authors (year)	C/A ²	Research agenda
World	Research in Veterinary Science	Krishnamoorthy et al. (2021)	386	<p>Studies on the planning of public policies aimed at the diffusion of new technologies within the productive system.</p> <p>Modeling agribusiness supply chain resilience through measures such as: time to recovery (TTR) in the objective function and re-examining the effectiveness of risk management strategies.</p> <p>Deeper research on different training methods for time series forecasting in agribusiness, in order to determine the best optimization method for each case, seeking the best set of parameters that improve the forecast results.</p> <p>To analyze trade relations in agribusiness between Brazil and other countries.</p> <p>Studies on the interruption of demand and supply.</p> <p>Research that reflects on the existing heterogeneity in agribusiness covering social relations, biodiversity, biotechnology, cultures, ecology, innovations, biophysics (soils, climate, hydrology), industries, family farming.</p> <p>Technology in the agribusiness chain and the impacts on public policies, economy, society and the environment.</p> <p>Marketing tools and their applications in studies on market, consumption and brands.</p> <p>Study the effects of indirect and direct corporate social responsibility (CSR) on agribusiness performance.</p>
	Frontiers in Veterinary Science	Creutzinger et al. (2021)	119	
	Animals	Gutierrez et al. (2021)	168	
	Frontiers in Medicine Veterinary	Zigo et al. (2021)	107	
	Applied Animal Science	Cockram et al. (2021)	135	
	Journal of Cleaner Production	Grassauer et al. (2021)	109	
	Global Business Review	Nandyet al. (2021)	130	
	Agriculture-Basel	Borawski et al. (2021)	108	
	Energy C. and Management	Luqman & Al-Ansari (2021)	106	
	Geoheath	Grout et al. (2020)	321	
Livestock Science	Almeida et al. (2021)	53		
Brazil	Animal	Vieira et al. (2021)	46	
	Animals	Sejian et al. (2021)	154	
		Consentini et al. (2021)	159	
	Journal of Dairy Science	Leso et al. (2020)	117	
		Dias et al. (2021)	45	
	Environmental Science and Pollution Research	Feil et al. (2020)	148	
	Environment Development and Sustainability	Steidle Neto & Lopes (2021)	40	
	Brazilian Journal of Microbiology	Caffarena et al. (2021)	82	
	Canadian Journal of Animal Science	Brito et al. (2020)	148	
	Livestock Science	Oliveira et al. (2021)	50	

Figure 8. Research framework: ¹ Defined by the *Web of Science* (Clarivate Analytics, 2021). ² Number of citations/year.

Other topics were also relevant for future studies, such as the importance of studying heterogeneity in the agricultural sector and the diffusion of new technologies (Figure 8). Several of these articles presented suggestions for similar future studies. This may indicate that, in the future, if researchers from Brazil choose to deepen their studies in the gaps presented, there may be a greater proximity of studies conducted in Brazil to the mainstream of research on the subject, as addressed worldwide.

FINAL CONSIDERATIONS

The present study aimed to identify the main topics addressed in the national and international literatures on the efficiency and risk in dairy farming. In general, Brazilian research is developed based on economic and cost issues, while in the international context, efficiency is advocated. Within the context of the theory of the firm, there seems to be a predominance of studies anchored on the assumptions of the theories of costs and income (in Brazil) and production (in the world).

Both in Brazil and worldwide, more articles prevail on efficiency than on risk, which is an emerging and expanding topic for future research. In addition, it is possible that if they follow the international mainstream, Brazilian research may increase its specificities in other areas, such as efficiency, production systems, and other more up-to-date topics.

The results of this research indicate that there is a lack of studies using research techniques and methods that address mainly risk analyses on dairy properties. Furthermore, Brazilian analyses focus on studying only the phenomenon of variation in the scale of production on costs and revenues, in the production process, with few analyses of other aspects, such as impact on sustainability (social and environmental), or animal welfare of dairy herds.

This study was limited to analyzing publications made only in the *Web of Science* database, being a more exploratory study on the subject. New research that deepens the knowledge on more specific topics within this universe may contribute to the identification of other emerging and current topics in the sector. Additionally, comparative studies between Brazilian and international milk markets can be useful to explain, for instance, the competitiveness of the sector in the international dairy market.

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