

TECHNOLOGICAL SURVEILLANCE IN THE LINKS OF THE COASTAL CHEESE SUPPLY CHAIN

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ABSTRACT

Costeño cheese is a typical dairy product from the Caribbean region of Colombia, it has a soft or semi-hard texture, a white color and is characterized by being fresh and having a high salt content. It is necessary to expand the level of knowledge about the current conditions that frame the supply chain of CSQC coastal cheese, since this productive sector presents a great lag in terms of science, technology, and CTI innovation. The study of VT technological surveillance in the links that make up the CSQC coastal cheese supply chain allows the identification of dynamics, research trends and new technological developments, therefore the consolidation and analysis of all this information represents an opportunity for improvement in the different processes and activities that are currently carried out in the CSQC, therefore the application of STI advances in the CSQC contributes to improving the levels of productivity and competitiveness of this productive sector in the Caribbean region. Four phases were carried out, which are: Identification of critical surveillance factors in the CSQC, Scientiometric Analysis, Bibliometric Analysis, and Analysis of results. Specialized databases were consulted for the review of articles and patents such as SCOPUS, WIPO, SPACENET, PUBLINDEX and Superintendence of Industry and Commerce (SIC). The VOS Viewer software was used to carry out the topological representation, and finally an analysis of the results was made in the links of the CSQC. 2,602 scientific articles were found, and more than 800 patents associated with the CSQC, which are registered in specialized scientific databases. The United States is the leader in the publication of scientific articles associated with the CSQC, followed by Germany and Italy. China is the country with the highest number of patents associated with the CSQC, followed by the United States and Japan. In Colombia, the departments that have the highest number of publications of scientific articles associated with the CSQC are Antioquia Boyacá and Cundinamarca.

Keywords: Article; Scientiometric; Patent; PUBLINDEX; SCOPUS; SPACENET; WIPO.

INTRODUCTION

The formulation and execution of Research, Development, and Innovation (R&D&I) projects aim to promote the design, adoption, and transfer of hard and soft technologies, which is essential for the Colombian agricultural/agroindustrial sector. This facilitates the generation of strategies and actions that allow it to move toward comprehensive, sustainable, and competitive use in production systems, the consolidation of traditional products in the national and international markets, and diversification toward a portfolio of value-added products that generate differential income through technological developments [1] – [4].

The Colombian agricultural sector needs to boost Science, Technology, and Innovation (STI) activities focused on regions, thematic areas, production chains, production systems, international trends, among others. In this context, the Agroindustrial STI Strategic Plan seeks, based on the principles of territorial focus, prioritization, targeting, and relevance, to achieve better coordination and utilization of the capabilities of the National System of Agroindustrial Science and Technology, based on the guidelines of the national STI policy [5] – [8]. Additionally, in the agroindustrial sector of the Caribbean region of Colombia, the goal is to strengthen the processes of the dairy supply chain, which are affected by the continuous flow of small-scale actions in the chain (supplier - processor - retailer) [9] – [13].

Cheese is one of the main dairy products, its production is a symbol of regional distinction, as an element of social and cultural identification [14] – [17], it is one of the most popular foods for its nutritional value [18] – [20] and is known in many countries for its distinctive varieties, generating high demand in the global market [21] – [24]. In recent years, international cheese exports have reached 2.8 million tons in 2020, maintaining the expansion of 4.1% in 2020 for the fifth consecutive year [25], [26].

It is estimated that there are more than 2,000 types of cheese worldwide. Depending on the type of milk, cheeses can be made from cow's, goat's, sheep's, buffalo's, and a mixture of milks; depending on the aging process, they can be fresh or ripened [27], [28]. Costeño cheese is a type of fresh cheese, typically produced by artisanal means by small producers. This product integrates traditional knowledge and ancestral wisdom. It is also part of the roots and gastronomic identity of the Colombian Caribbean region.

The cheese supply chain is an important part of the food industry, ensuring consumers have access to dairy products. It includes raw materials, inputs, and products at all stages of supply, production, distribution, and marketing. It encompasses all activities associated with the transformation and flow of goods and services, from the source of raw materials to the final consumer [27] , [28].

The objective of this article is to carry out a Technological Surveillance (TS) study in the links of the Coastal Cheese Supply Chain (CSQC) to analyze the state of knowledge, scientific and technological advances at the international, national and regional levels of this productive sector, the consolidation and analysis of this information represents an opportunity for improvement in the processes and activities that are currently carried out in the links of the CSQC, and also the application of CTI that contributes to the improvement in the levels of productivity and competitiveness of this productive sector.

MATERIALS AND METHODS

The methodological design developed in this study for the CSQC in the Colombian Caribbean corresponds to the adaptation of the Technological Surveillance (VT) model of [29], which links methods and analysis tools with the implementation of a 5-phase system, through a set of methods, procedures and resources (Figure 1). This model is based on planning, search and capture, analysis and organization, intelligence and communication [11].

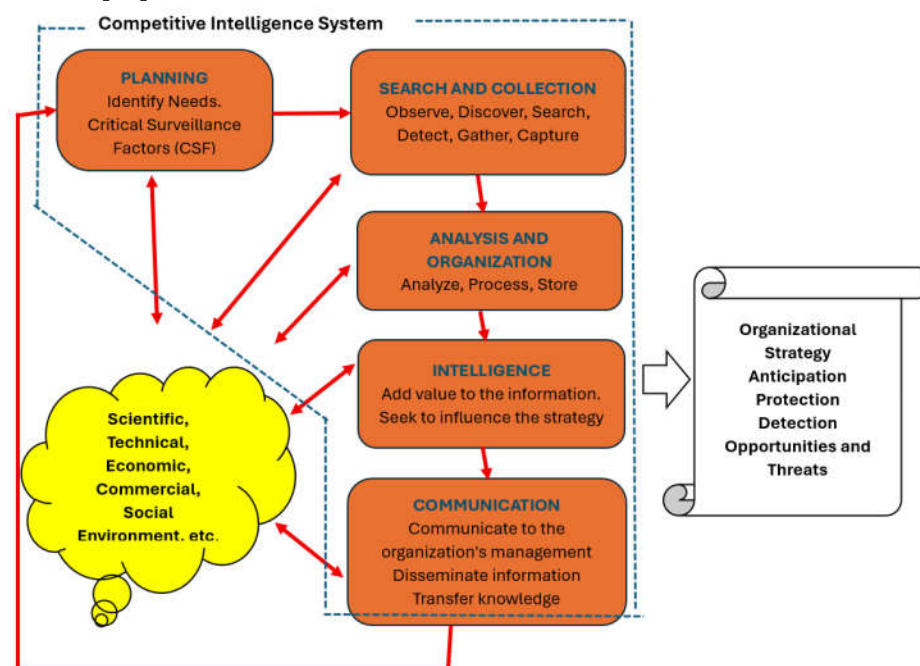


Figure 1. Sánchez and Palop's Technological Surveillance Model.

Source: Adapted from [29].

For the present case, the methodological framework of the VT study in the links of the CSQC is made up of four phases: 1) Identification of critical FCV surveillance factors in the CSQC¹, 2) Scientometric Analysis, 3) Bibliometric Analysis, and 4) Analysis of Results (Table 1).

Based on a literature review and direct observation, it was determined that the CSQC is comprised of the following links: supply, production, distribution, and marketing; subsequently, after analyzing the current conditions of the CSQC, the critical factors of FCV surveillance were identified. These constitute the reference point and main input for performing the scientometric analysis, which seeks to establish a quantitative measurement of CTI parameters in patents and scientific articles associated with the CSQC. At the international level, specialized databases such as SCOPUS, SPACENET, and WIPO were consulted.

¹ In the field of Technology Watch (TS), Critical Watch Factors (CSFs) are key elements that are continuously monitored to anticipate significant changes, trends, or advances in the technological field. These factors serve as reference points for identifying emerging risks, opportunities, and challenges in the technological sector.

For the national context, databases (DB) where scientific articles and patents are registered were consulted, such as PUBLINDEX and the Superintendency of Industry and Commerce (SIC). In international databases such as Scopus, the information review and debugging process was developed automatically, since they allow the use of search equations and Boolean operators, while in the case of national databases, these processes were done manually, since these databases are not as robust, are not articulated, and it is more expensive to consolidate all the information. A bibliometric analysis was performed using VOSviewer software, in order to establish a topological (graphic) representation of patterns, correlations, and clusters between the different links and actors that are part of the CSQC. Finally, the results are analyzed and pertinent conclusions are issued for the links that comprise the CSQC (Table 1).

Table 1. Technological Surveillance in the Coastal Cheese Supply Chain

FCV Identification	Scientometric Analysis	Bibliometric Analysis	Analysis of Results
Identification of the FCV in the links associated with the CSQC, based on the study of the current conditions in the CSQC	Based on the FCV, the aim is to establish the measurement of CTI parameters for scientific articles and patents associated with the CSQC, using databases such as SCOPUS, SPACENET, and WIPO. PUBLINDEX and SIC	The VOS Viewer tool was used for topological representation, which allows establishing patterns, correlations and Clusters, between the different links and actors that make up the CSQC	The information was analyzed and consolidated, issuing the relevant conclusions for the links that make up the CSQC

Source: Prepared by the authors.

A PRISMA 2020 flowchart is presented to show the systematic reviews, which included searches in national and international databases for scientific articles and patents associated with the CSQC [30] (Figure 2).

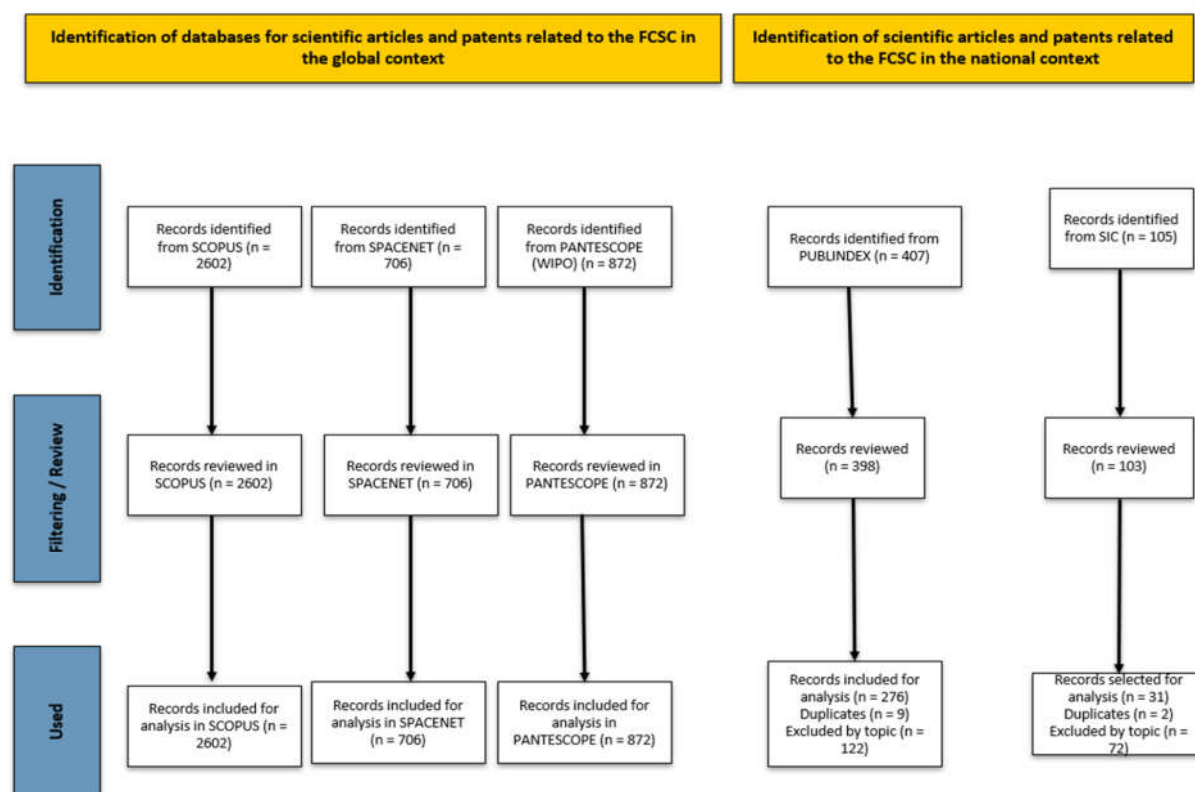


Figure 2. PRISMA 2020 flowchart for the CSQC.
Source: Prepared by the authors Adapted from [30].

RESULTS

• Scientometric Analysis

The FCVs were identified by studying the current conditions of the CSQC as a reference point for defining thesauri or descriptors and constructing search equations for the CSQC links (Table 2). These equations were supported by the use of Boolean logical operators such as AND and OR and were written in English in order to obtain a greater number of results on the subject [21].

Table 2. Search Equations and Descriptors in CSQC Links

CSQC Links	Search Equation
Catering	<i>[("raw milk" AND (harvest OR handling OR treatment OR conservation OR monitoring Parameter OR physiochemical OR microbiological)) OR ("Milking systems") OR ("hand milking")]</i>
Production	<i>["fresh cheese" AND (machinery OR equipment OR utensil OR device OR production OR prosecution OR input OR additive OR transformation OR rennet OR pasteurization OR chopped OR salty OR molding OR pressing OR kneaded)]</i>

Distribution Marketing *["fresh cheese" AND (harvest OR Distribution OR commercialization OR Transport OR "Cold chain" OR Storage OR "vacuum packaging" OR packing OR container OR intermediary OR wholesaler OR retail)]*

Source: Prepared by the authors.

Analysis of results of scientific publications in SCOPUS

Searching in SCOPUS², yielded a total of 2,602 publications in high-impact scientific journals related to the links associated with the CSQC. The Supply link represents 74% of the total publications, with 2,027 investigations, of which 1,491 (54%) and 536 (20%) are associated with milking systems and raw milk handling, respectively. The Production link has 439 publications, representing 16%; and the Distribution - Marketing link has 283 publications, representing 10%. It is worth noting that 147 scientific publications are associated with more than one link. The period analyzed was from 1952 to the present day of 2023; this query was conducted on August 1, 2023. Furthermore, the year with the most publications related to the CSQC was 2021, with 201 publications (Figure 3a).

The leading country in publications is the United States, with a total of 274 publications, followed by Germany and Italy with 226 and 224 respectively. The United States and Germany lead the research on milking systems, while Italy and the United States lead the publications on raw milk handling and treatment. In the production, distribution, and marketing of fresh cheese, the countries with the most publications are Italy and Brazil. In Latin America, Brazil leads the way with 177 publications, Mexico with 52, Colombia with 22, and Argentina with 14 publications (Figure 3b).

The authors Hogeveen, H; DeVries, TJ; and García S.C. have each published 57; 34 and 33 respectively and are the authors who lead the publications of scientific articles on milking systems; Bittante, G. and Cecchinato, lead in publications in the fresh cheese production link (Figure 3c). On the other hand, the thematic lines with the most scientific publications are: Agricultural and Biological Sciences, with 1,976 publications, Biochemistry, Genetics and Molecular Biology with 627, Veterinary Medicine 499, Immunology and Microbiology with 269 (Figure 3e).

The leading institutions in these scientific publications are Wageningen University (Netherlands) with 125 publications, the Swedish University of Agricultural Sciences with 87 publications, and the Dutch university with 57 publications (Figure 3d). Furthermore, the institutions with the highest number of sponsors of these scientific publications are the Coordination of Higher Education Personnel Training (CAPES) and the National Council for Scientific and Technological Development (CNPq), the Amparo Pesquisa Foundation of Sau Paulo, all institutions from Brazil (Figure 3f).

² SCOPUS is a specialized database for peer review of scientific and academic articles. Launched in 2004 by Elsevier, this database contains more than 84 million records. Access to Scopus requires a subscription, which is typically paid for by organizations belonging to STI networks.

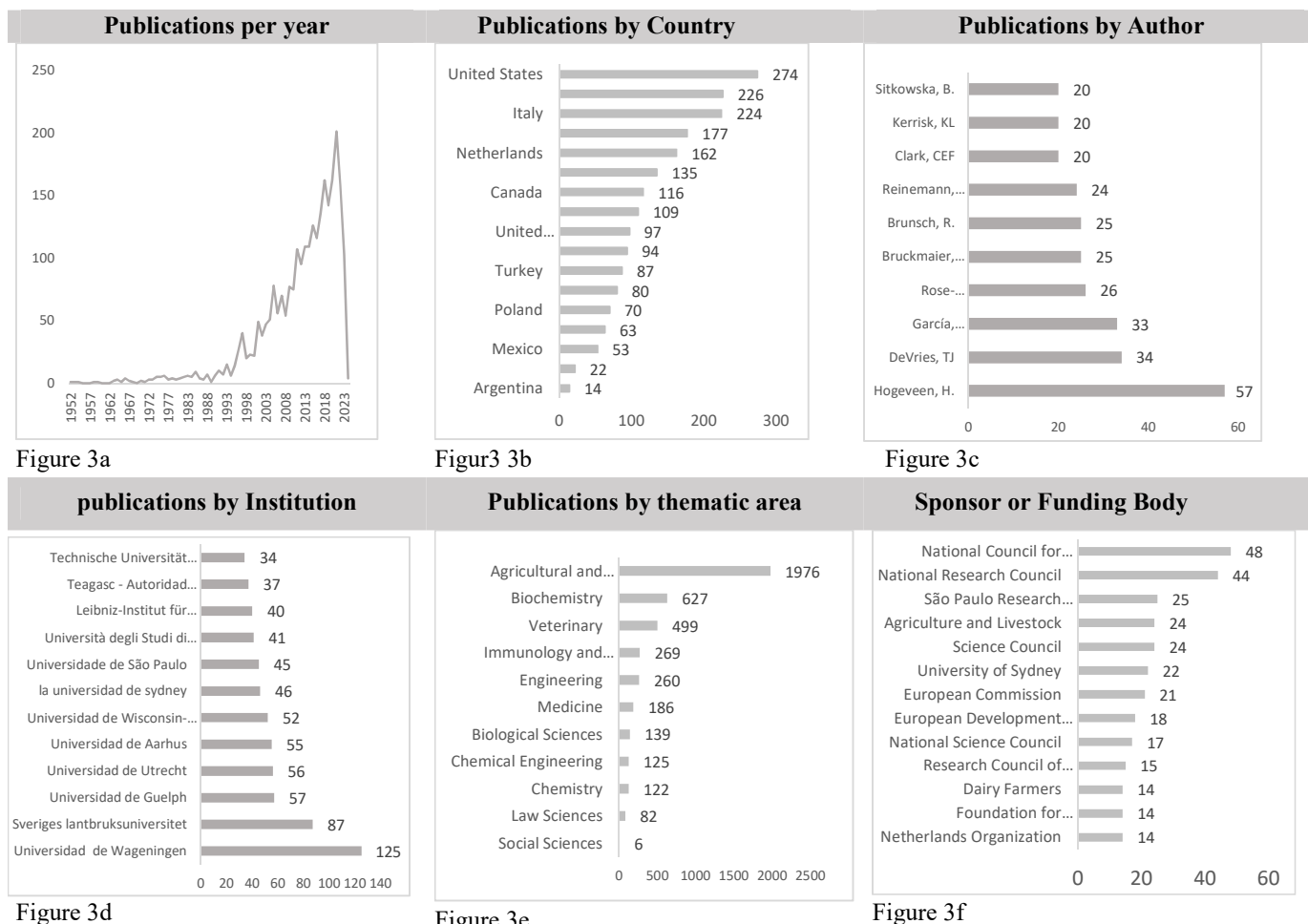


Figure 3. Results of Scientific Publications in SCOPUS.

Source: Prepared by the authors based on SCOPUS.

• Analysis of results for patents

The analysis of patents associated with the links that make up the CSQC was conducted in the ESPACENET and WIPO databases.

• Patent Analysis in ESPACENET

In the SPACENET Database, seven hundred and six (706) patents were found in total, related with the CSQC. In the Supply link, with 558 patents representing (66%) of the total patents, which are divided into 388 patents 46% and 170 patents 20%, related respectively to the handling of raw milk, and with milking systems. In the Production and Distribution - Marketing links, 118 and 169 patents were obtained, representing 14% and 20% of the total patents related to the CSQC; likewise, about 123 patents belong to more than one link. The period analyzed was from 1911 to 2022, starting in 2011 there is considerable growth in the publication of patents; Subsequently, in 2021, 53 patents were published, representing the year with the most publications of patents related to the CSQC (Figure 4a).

The countries with the highest number of CSQS-related patent registrations are China, the United States, and Japan, with 357, 128, and 82 patents, respectively. The European Patent Office (EPO) has 95 patents, and the World Intellectual Property Organization (WIPO) has 79 registered patents (Figure 4b). The entities with the most registered patents related to CSQS are: *BRIGHT DAIRY & FOOD CO LTD* and *INNER MONGOLIA YILI IND GROUP*, both Chinese companies dedicated to the manufacture of dairy products, with 59 and 22 patents, respectively; *SNOW BRAND MILK PROD CO LTD*, a Japanese dairy products company; and *WAIKATO MILKING SYSTEMS LP*, a New Zealand company specializing in milking systems and equipment, with 16 patents each (Figure 4e).

Additionally, the Chinese inventors Liu Zhenmin, Xu Zhiyuan, and Su Miya register 60, 20, and 13 patents each respectively (Figure 3c). Moreover, depending on the subject matter, the patents are associated with an international CIP patent classification code A23C9: Milk preparations or mixtures with 219 patents, A23C19: Cheese or cheese preparations with 153 patents, A01J5: Milking machines or devices with 107 patents (Figure 4d).

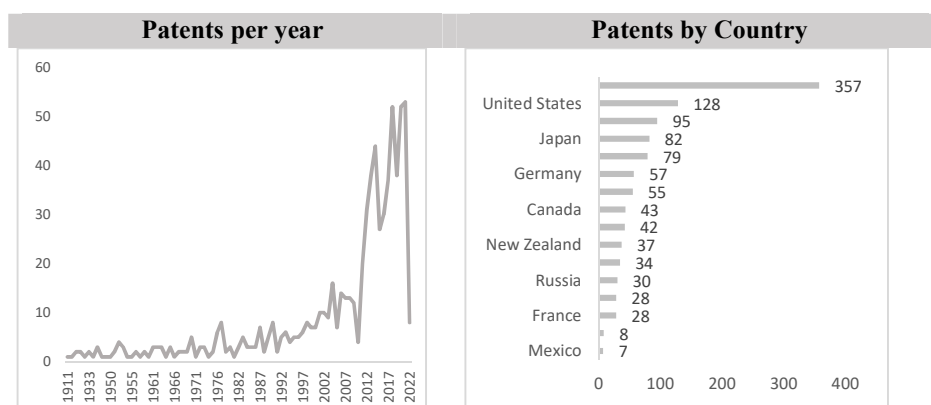


Figure 4a

Figure 4b

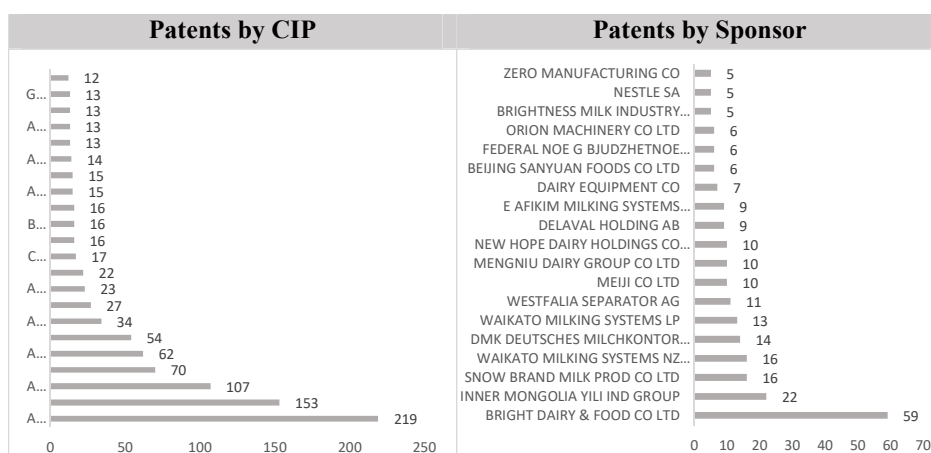


Figure 4d

Figure 4e

Figure 4. Patent Analysis in SPACENET.

Source: Prepared by the authors based on the WIPO database.

• WIPO Patent Analysis (PANTESCOPE)

In the PATENTSCOPE database³ 872 patents were found, related to the CSQC coastal cheese supply chain. The Supply link presents 673 patents, which represents 75% of the total patents, these are divided into 425 patents (47%) and 248 patents (28%), related to the handling of raw milk and milking systems respectively. In the Production and Distribution - Marketing links, 166 patents (18.5%) and 58 patents (6.5%) were obtained respectively. 25 patents belong to more than one link. The period analyzed in this database was 2014 – 2022; in 2021, 72 patents were published, corresponding to the year with the most CSQC-related patents published (Figure 5a).

The countries that register the most patents related to CSQC are China, the United States and New Zealand with 267, 104 and 70 patents respectively; it is worth noting that 70 patents appear in the name of the (WIPO) Patent Cooperation Treaty (PCT) and 68 patents are registered in the name of the European Patent Office (EPO) (Figure 5b). The inventors Liu Zhenmin; Xu Zhiyuan; Su Miya registers 44, 18 and 13 patents each respectively; these three inventors have Chinese nationality (Figure 5c)

The entities that have registered the most patents related to the CSQS are *WAIKATO MILKING SYSTEMS: LP, NZ LIMITED*, a New Zealand multinational dedicated to the manufacture of milking systems and equipment with 59 patents, followed by *BRIGHT DAIRY & FOOD CO LTD* with 43 patents and *DELAVAL HOLDING*, a German multinational dedicated to the manufacture of milking equipment with 25 patents (Figure 5e). The patents are classified according to the IPC with the code A23C, which corresponds to Treatment of Food products with 510 patents, A01J: Manufacture of dairy products with 240 patents, A23L: Food products with 71 patents (Figure 5d).

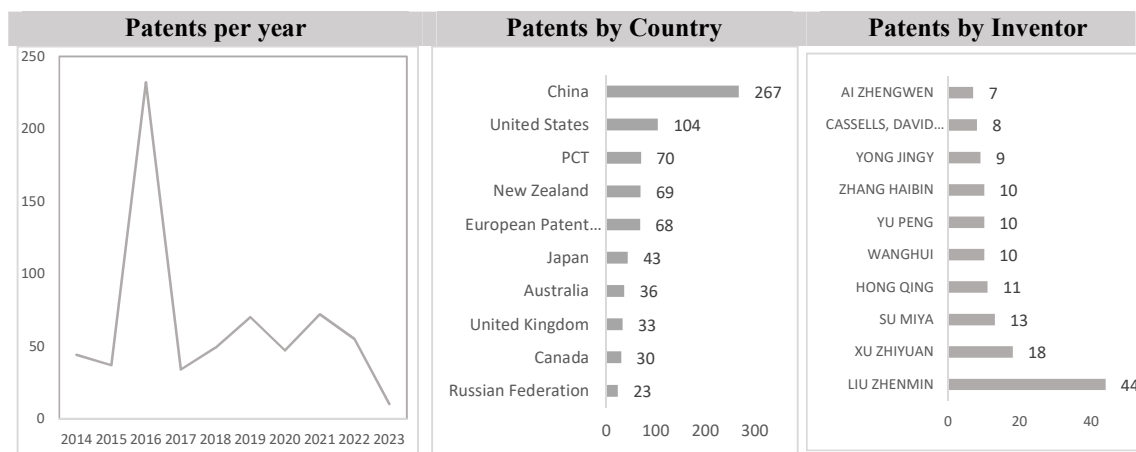


Figure 5a

Figure 5b

Figure 5c

³ PATENTSCOPE is a specialized patent database owned by the World Intellectual Property Organization (WIPO). This database is freely accessible and contains over 74 million patent documents.

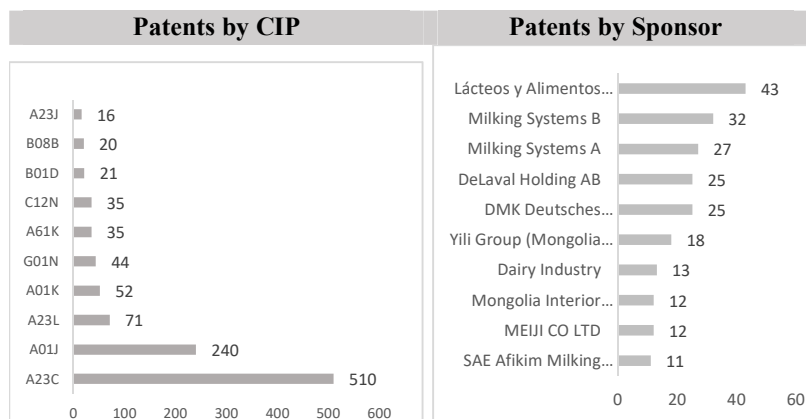


Figure 5d

Figure 5e

Figure 5. Patent Analysis in PATENTSCOPE (WIPO).

Source: Prepared by the authors using the PATENTSCOPE (WIPO) database.

• Analysis of scientific publications in PUBLINDEX

At the national level, a total of 276 scientific articles related to the CSQC were found and which have been published in journals indexed to PUBLINDEX⁴. The Supply link represents 87%, with 240 studies. The Production link has 31 publications, representing 11%; and the Distribution-Marketing link has 5 publications, representing 2%. The period analyzed was from 2003 to 2023 (Figure 6a). In the Publinindex database, the search equations used in SCOPUS, ESPACENET, and WIPO could not be applied. The search was developed using the keywords milk and cheese, and the publications associated with the CSQC were manually filtered.

The department where the most research associated with the CSQC has been developed is Antioquia with 80 publications, followed by Boyacá and Cundinamarca with 33 and 31 publications respectively. Nariño and Córdoba appear with 20 publications each (Figure 6b). Meanwhile, the authors leading the publications in the CSQC at the national level are: Cerrón Muñoz with 19 publications, Alfonso Caldearon with 12 publications, Roy Andrade with 11 publications and José Echeverri with 10 publications (Figure 6c). Most of these authors' research is related to the supply chain.

The journals that have published the most articles related to CSQC at the national level are REVISTA MVZ CÓRDOBA, with 28 publications, the journal LIVESTOCK RESEARCH FOR RURAL DEVELOPMENT with 24 publications, and the journal BIOTECNOLOGÍA EN EL SECTOR AGROPECUARIO Y AGROINDUSTRIAL with 17 publications (Figure 6d). The institutions that have published the most related to CSQC are the University of Córdoba and the National University with 28 publications each, the Center for Research in Sustainable Agricultural Production Systems (CIPAV) with 24 publications, and the University of Cauca with 14 publications (Figure 6e).

⁴ PUBLINDEX es una BD del Ministerio de Ciencias y Tecnología (Minciencias), esta plataforma es la encargada de identificar, evaluar y categorizar las revistas nacionales de ciencia, tecnología e innovación, según evidencias de calidad científica, calidad editorial, visibilidad y accesibilidad (Causado-Rodríguez, et al., 2019).

The topics on which most publications have been made correspond to quality, production, supplementation, Genetics and forages, among others (figure 6f).

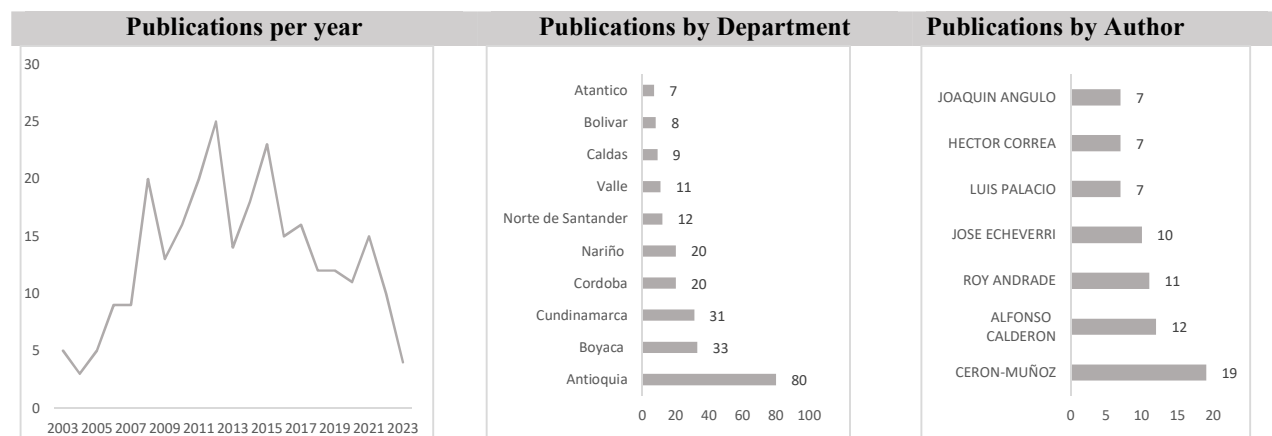


Figure 6a

Figure 6b

Figure 6c

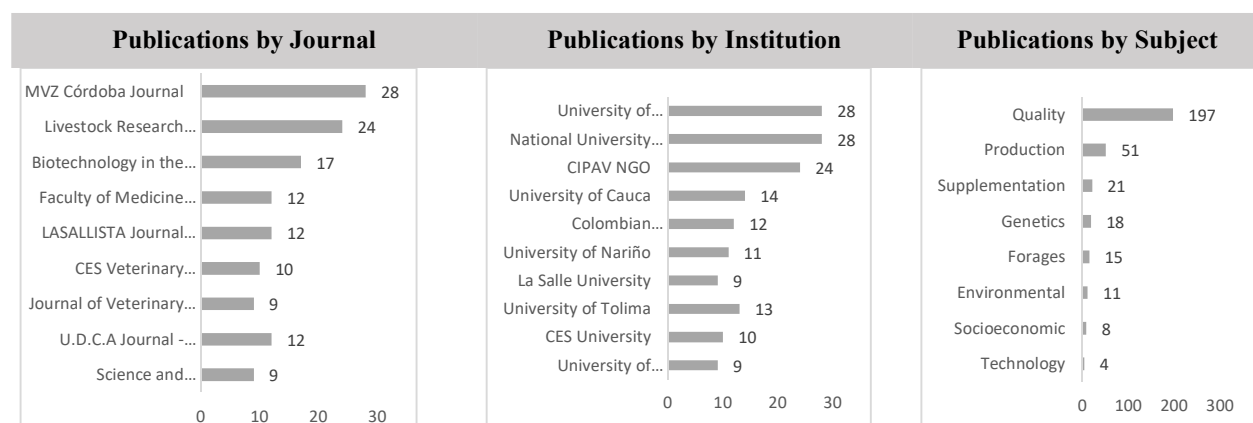


Figure 6d

Figure 6e

Figure 6f

Figure 6. Results of Scientific Publications in PUBLINDEX.

Source: Prepared by the authors based on PUBLINDEX.

• Patent Analysis at the Superintendency of Industry and Commerce (SIC)

From the SIC database, 31 patents were obtained for the CSQC. The Supply link presents 23 patents, representing 74%. Most of these patents are related to handling, milk quality, and milking. In the Production link, 7 patents were obtained, representing 23%, and in the Distribution-Marketing link, 1 patent was obtained, representing 3%. The period analyzed in the SIC database was 1969–2022 (Figure 7a). Regarding the status of these patents, it was found that 9 of these patents were denied, 7 abandoned, 7 granted, 4 expired, 3 are under substantive examination, and 1 was withdrawn, as can be seen in (Figure 7b). Regarding the technological sector to which the CSQC patents belong, 15 are related to chemistry, 10 are related to mechanical engineering, 4 belong to other sectors, 2 are associated with instruments as shown in (figure 7c). The natural persons or institutions that file patent application records with the SIC are Carlos Alberto Gutiérrez with 4 patents, the University of Quindío with 3 patents, Deval Holding, Nestlé and

Sterrenbeld Biotechnologie with 2 patents each. The National University, Kraft Foods, the University of Boyacá, and the Catholic University of Pereira with 1 patent, as shown in (Figure 7d).

According to the International Patent Classification (IPC), the A23C classification corresponding to dairy products is associated with 10 patents, and the A01J classification corresponding to the manufacture of dairy products has 8 patents as can be seen in (Figure 7e).

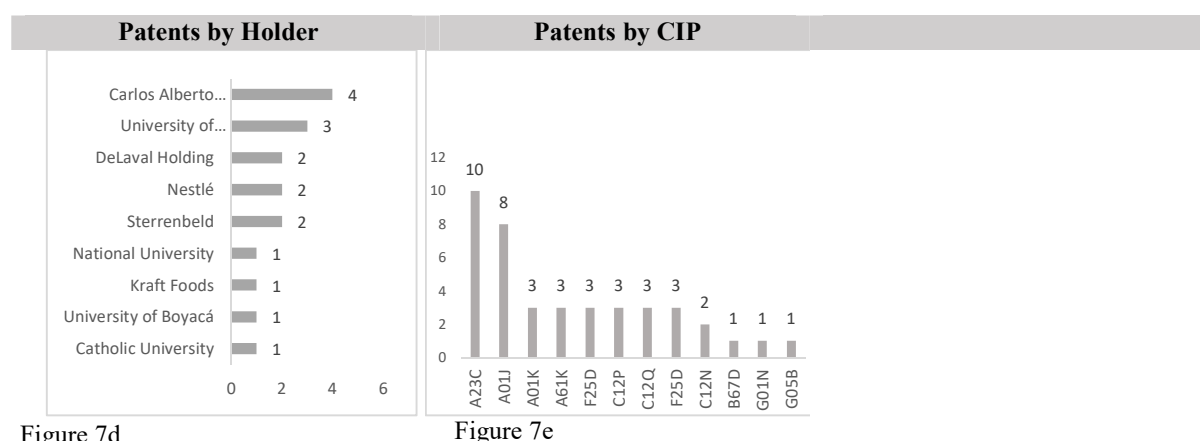
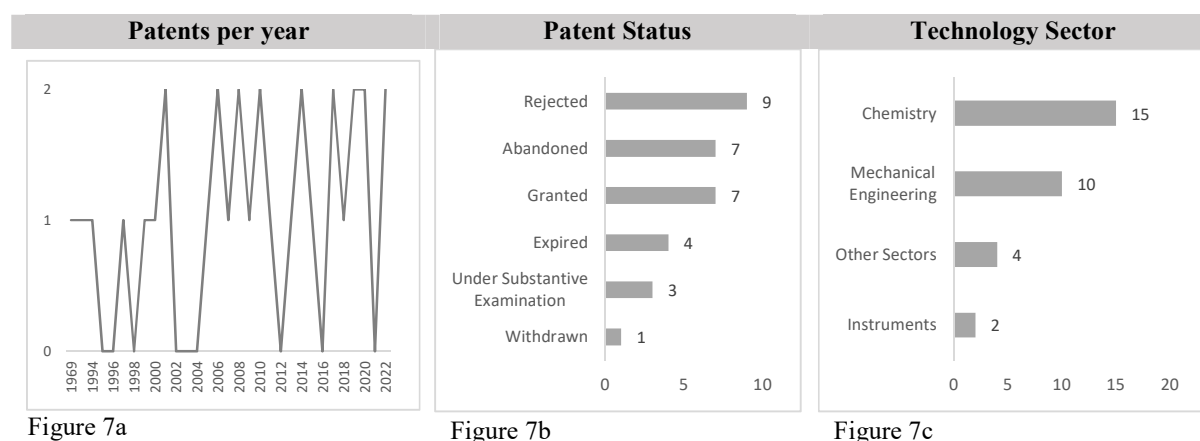


Figure 7d

Figure 7e

Figure 7. SIC Patent Analysis.

Source: Prepared by the authors using the SIC database.

Bibliometric Analysis in VOSviewer

The VOSviewer software was used with the CSV extension file (Metadata-Excel) from SCOPUS, where a total of 558 scientific articles associated with the links that make up the CSQC were obtained. From this information, VOSviewer establishes 10,838 keywords from the supplied database, taking the 1,000 most frequent keywords, in this way, 7 clusters are established with 343, 193, 165, 158, 96 and 20 Keywords respectively, differentiated by a color, within the keywords with the highest frequency of repetition are: animals, animal, milk, female cattle, article, among others (Figure 8).

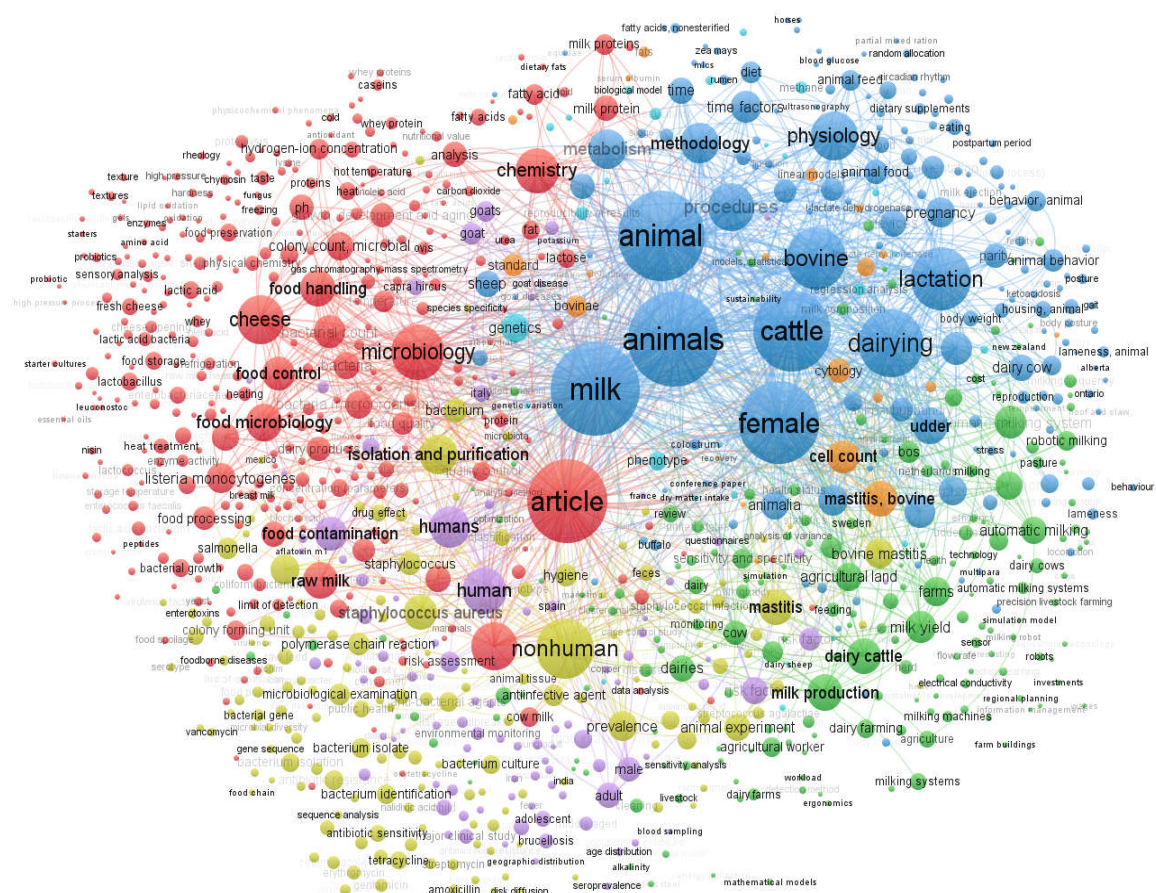


Figure 8. Graphical representation of Keywords in CSQC publications.

Source: Prepared by the authors using VOSviewer software.

64 countries are observed that contribute scientific publications related to the links of the CSQC, the information provided by the scientometric analysis of SCOPUS is corroborated, where it is established that the leading countries in the publication of scientific articles are the United States, Germany, Italy and New Zealand, VOSviewer establishes 7 clusters made up of 14, 9, 9, 8, 7, 6, 5, 3 countries respectively. In the context of Latin America, Brazil is the leader in scientific publications, followed by Colombia and Argentina respectively (Figure 9).

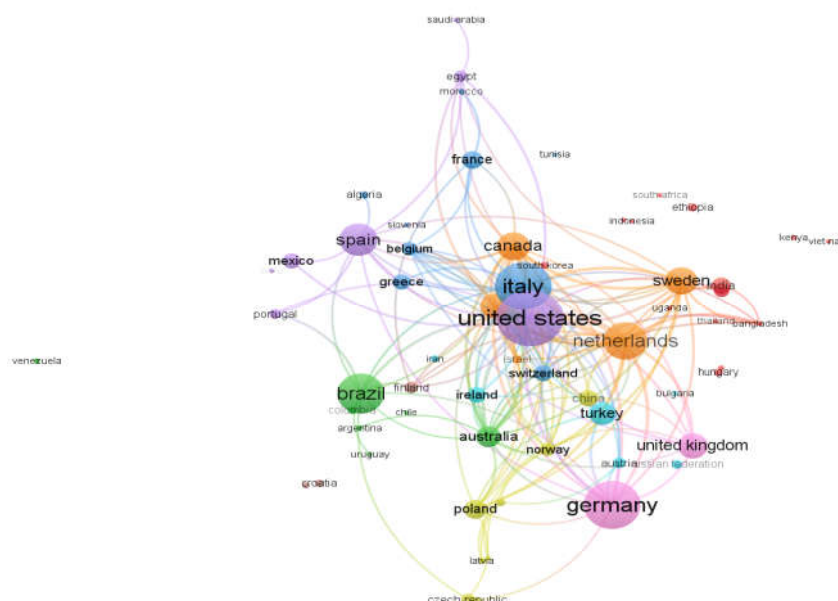


Figure 9. Graphic representation of scientific publications by country in the CSQC.

Source: Prepared by the authors using the VOSviewer tool.

ANALYSIS OF RESULTS

In scientific articles and patents related to CSQC, it was found that more than 70% of all information consulted belongs to the supply chain. The United States, Germany, and Italy lead the publication of articles, China, the United States, and Japan lead the production of patents, and the topics with the most article publications are milking systems and raw milk treatment. In the Latin American context, the country with the most publications is Brazil, followed by Spain, Mexico, Colombia, and Argentina. In Colombia, the departments with the highest number of publications of scientific articles associated with CSQC are Antioquia, Boyacá, and Cundinamarca.

Precision livestock farming (PLF) and biotechnological techniques to produce synthetic milk are the most relevant scientific and technological advances in the supply chain of the CSQC.

One of the research trends in the Production branch of the CSQC is the use of rennets of microbial, plant, and animal origin, and their effects on the physicochemical, microbiological, rheological, and sensory parameters of the fresh cheeses produced. The use of probiotics (microorganisms) is also being implemented in this branch, which improves the nutritional content and extends the shelf life of fresh cheese.

Among the most important technological advances for the Distribution-Marketing link is the development of smart packaging. The function of these devices is to preserve the product's condition and alert its status before consumption.

This type of VT research contributes to expanding the level of knowledge of STI aspects related to CSQC and increases the possibility that the actors that make up the CSQC, especially decision-makers, can implement actions that impact the improvement of the levels of productivity and competitiveness of this productive sector.

AUTHORSHIP CONTRIBUTION

First author: Methodology, conceptualization, research, data analysis, writing. Second author: Supervision, writing, review, and editing. Third author: Analysis, methodology, writing, review, and editing.

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