Technological Surveillance Study on the Development of Beekeeping Technologies

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Abstract

This study employed a technology surveillance process in the beekeeping sector with the objective of identifying emerging technologies that are relevant to small beekeepers in emerging economies. The analysis of patents classified under A01K 47/00 revealed the emergence of pivotal innovations in domains such as hive design, automated honey extraction, and the integration of sensors for hive monitoring. The surveillance process facilitated the collection and analysis of data on the most patented technologies in the sector, thereby addressing key planning questions. The study identified technological trends with the potential to transform beekeeping in low-tech contexts, thereby enhancing the productivity and sustainability of beekeeping operations. The findings of this study indicate that the identified technologies have the potential to significantly contribute to the well-being of small beekeepers, provided that their adoption is facilitated through the provision of governmental and organizational support. It is recommended that future research investigate the implementation of these technologies and the factors that influence their adoption in diverse production contexts.

Keywords: Technology surveillance, Beekeeping technologies, Emerging economies, Patent analysis.

1. Introduction

Beekeeping is an agricultural activity of significant economic, social, and environmental importance in numerous regions across the globe. It is indispensable for the production of honey and other derived products, as well as for the crucial process of crop pollination. Nevertheless, in low-tech agricultural sectors, particularly in emerging economies, small-scale beekeepers encounter considerable obstacles in accessing new technologies (FAO, 2021). The absence of technological dissemination in these contexts precludes beekeepers from enhancing their production processes and, consequently, their quality of life. The concentration of innovative

beekeeping technologies in countries with high levels of technological development has resulted in a significant gap in their adoption in emerging agricultural sectors (Contreras-Uc et al., 2017).

In addition to contributing to honey production, beekeeping plays a pivotal role in crop pollination and offers substantial employment opportunities (Escandón et al., 2018). This directly impacts food security and environmental sustainability. Furthermore, the advancement of beekeeping can enhance the quality of life for small-scale beekeepers who depend on this practice as a source of income and livelihood (Mateus, 2023). However, for beekeeping enterprises to flourish and be sustainable, it is imperative that they have access to technologies that are not only innovative but also affordable and replicable (Cerezo-Narváez et al., 2019). The principal challenge is the dearth of access to and dissemination of suitable technologies for small-scale beekeepers (Bressan & Matta, 2015). Technologies such as modern hives with movable frames, honey extractors, and protective clothing, which have the potential to markedly enhance efficiency and safety in production, have not been widely adopted in these sectors (Pedraza & Del Portillo, 2019). The adoption of these technologies could have a positive impact on the quantity and quality of beekeeping products, thereby contributing to the economic well-being of beekeepers (Hilmi et al., 2011).

The process of technology surveillance is a critical component of identifying, analyzing, and disseminating information on technological advancements. This enables organizations to identify potential opportunities and threats within their competitive environment (Filho & de Macedo, 2021; Vargas et al., 2018). This process is particularly pertinent in sectors where access to cutting-edge technologies is constrained. Patent-based technology surveillance, in particular, enables organizations to collect and analyze information contained in these documents, thereby facilitating awareness of new inventions and informed decision-making regarding technology adoption (Arango et al., 2012).

The utilisation of patent databases is of paramount importance in the field of technology surveillance, as they offer invaluable insight into the development status of a multitude of technologies across the globe. These databases, such as LATIPAT, provide access not only to patent applications and invention documents, but also offer a key tool for monitoring innovation and developing strategies (Hidalgo-Nuchera et al., 2009). Patent-based technology surveillance entails the collection and analysis of information contained within these documents, thereby enabling organizations to remain apprised of novel inventions and to make well-informed decisions regarding the utilization of existing technologies (Hidalgo-Nuchera et al., 2009). These databases provide a valuable resource for companies, researchers, and organizations from a range of sectors, offering access to crucial information about technological innovations that can enhance their production processes and bolster their competitiveness. Specifically, the utilisation of these sources for technology surveillance enables the identification and adoption of patented technologies that are already globally available, thereby facilitating more efficient resource utilisation and the promotion of sustainable development in emerging economies (León et al., 2006).

In the context of small-scale beekeeping, the use of technology surveillance can facilitate the adoption of already developed and patented technologies, thereby avoiding the duplication of research efforts and improving the efficiency and sustainability of beekeeping operations

(Arango et al., 2012). This approach is particularly pertinent in emerging economies, where resources for research and development are constrained. The objective of this study is to identify, through a process of technology surveillance and patent analysis, the emerging technologies that have the potential to be replicable in the context of emerging economies and low-tech beekeeping enterprises. The analysis is restricted to hard technologies, which are defined as devices, equipment, or mechanical and electronic systems, that have the potential to significantly transform beekeeping in these contexts. This will not only enhance the productivity and sustainability of beekeeping operations but also contribute to the economic and social well-being of beekeepers, thereby improving their quality of life and promoting more environmentally sustainable beekeeping practices.

The following is a description of the methodology employed in this study, which is based on the Technology Surveillance and Competitive Intelligence Cycle. This includes a description of the patent search and analysis process, which was conducted using the LATIPAT database. Subsequently, the results are presented, emphasizing the most significant technological developments in domains such as hive design, honey extraction automation, and sensor-based hive monitoring. In conclusion, the potential implications of these trends for beekeeping in emerging economies are discussed, and recommendations are made regarding the possible adoption of these technologies to enhance the productivity and sustainability of beekeeping operations.

2. Methodology

This study employs the Technology Surveillance and Competitive Intelligence Cycle as a methodological framework to identify the most pervasive and replicable technologies in small-scale apiaries in emerging economies. The cycle, based on the methodology of Sánchez & Palop (2002), comprises five stages (see Figure 1): planning, search and collection, analysis and organization, intelligence, and communication.

Figure 1: Technology Surveillance and Competitive Intelligence Cycle. Adapted from Sánchez and Palop (2002).

2.1 Planing

In the initial planning phase, the objectives and key questions that would serve to direct the technology surveillance process were established. The primary objective was to identify the most frequently patented and replicable technologies that could benefit small beekeepers, with a particular emphasis on hive management under code A01K 47/00. This area was selected due to its direct impact on the productivity and efficiency of apiaries, which are essential factors for the development of beekeeping in emerging economies.

To this end, the LATIPAT-Espacenet database was selected as the source of information. This is a publicly accessible and free portal that employs Espacenet technology for searching technical information in Spanish and Portuguese within patent documents from Latin America and Spain (WIPO et al., 2003).

This interface and the data it provides represent the primary outcome of the Latipat cooperation project, which commenced in 2003 under the aegis of the World Intellectual Property Organization (WIPO), the European Patent Office (EPO), and the Spanish Patent and Trademark Office (OEPM). In addition, the following national intellectual-industrial property offices participated in the project: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, the Dominican Republic, Uruguay, and Venezuela (WIPO et al.). (2003).

Subsequently, research questions were defined to determine which technologies are most widely adopted and replicable in the beekeeping sector, as well as their potential for implementation in low-tech contexts.

• What are the most frequently patented technologies in the beekeeping sector, particularly in hive management and honey extraction?

• What emerging technological trends are evident in the development of beekeeping technologies?

• Which technologies have the greatest potential to improve the productivity and sustainability of apiaries in low-tech contexts?

These questions guided the process of patent search and analysis, ensuring that the focus was on the most relevant, replicable, and frequently used technologies in similar productive contexts.

2.2 Search and Information Collection

The next phase of the process entailed the identification and extraction of pertinent data from the selected databases. The search commenced with the identification of beekeeping technologies based on the International Patent Classification (IPC). The initial search was conducted using Code A01K 47/00, which encompasses technologies pertaining to hives and their management. No further filters were applied beyond those established by the selected classification system. Subsequently, the patents accessible within the LATIPAT database were subjected to an in-depth examination.

From this analysis, the most representative keywords of emerging technologies in the beekeeping sector were identified. The aforementioned keywords, including "modern hives," "honey extraction devices," and "efficient hive management," were extracted from the analyzed patents and serve to illustrate the principal technological innovations present within the selected classification.

The search was conducted on patents classified under section A01K, which encompasses beekeeping technologies, with a particular focus on those pertaining to animal husbandry and beekeeping. The specific codes, as presented in Table 1, reflect the subcategories subjected to analysis throughout the course of this study.

Table 1: International Patent Classification (IPC) Beekeeping

A01K 47/00	Beehives [2006.01]
A01K 49/00	Rearing-boxes; Queen transporting or introducing cages [2006.01]
A01K 51/00	Appliances for treating beehives or parts thereof, e.g. for cleaning or disinfecting [2006.01]
A01K 53/00	Feeding or drinking appliances for bees [2006.01]
A01K 55/00	Bee-smokers; Bee-keepers' accessories, e.g. veils [2006.01]
A01K 57/00	Appliances for providing, preventing, or catching swarms; Drone-catching devices [2006.01]
A01K 59/00	Honey collection [2006.01]

Source: (WIPO, 2024)

2.3 Information Analysis

In the phase of information analysis and organization, the beekeeping-related technologies classified under the A01K code of the International Patent Classification (IPC) were identified. This analysis did not prioritize subgroups or employ the CPC system; rather, it focused on examining the retrieved patents holistically to identify the most prevalent technological trends in the beekeeping sector.

The obtained patents were grouped into subcategories for the purpose of analyzing the most active technological areas, including, but not limited to, hive design, honey extraction, and apiary monitoring. From this categorization, the most representative emerging technologies were identified, and a detailed description was provided for those with the highest frequency in the analyzed records, such as modern hives and devices for efficient honey extraction.

This approach enabled the identification of the most pertinent technological trends for small-scale beekeepers and their potential impact on the productivity and sustainability of apiaries.

2.4 Intelligence Phase

In this phase, the data gathered in the preceding stages was integrated with the objective of generating valuable insights for strategic decision-making in the beekeeping sector. The analysis concentrated on identifying the most pertinent emerging technological trends without conducting prior prioritization or a comprehensive analysis of the replicability of the technologies. The potential for the dissemination of the identified technologies was evaluated in consideration of their impact on the productivity and sustainability of apiaries.

Moreover, the potential social, economic, and environmental impacts of the adoption of these technologies on small-scale beekeepers were considered, with particular emphasis on the importance of these innovations in improving efficiency and sustainability in low-tech contexts.

2.5 Communication Phase

Communication phase focuses on the dissemination of the results through a detailed report, which included recommendations on the identified technologies for their adoption in small apiaries in emerging economies. The report was designed to be shared with beekeepers' associations, government agencies, and other stakeholders interested in improving the productivity and sustainability of the beekeeping sector, thereby facilitating the adoption of the most accessible and replicable technologies.

3. RESULTS

In the LATIPAT-Espacenet database, specifically in the Worldwide file, a total of 5,622 patent records were found under the international classification A01K 47/00 and its derivatives. However, there was a limitation: the database only allowed the download of the last 500 patents, which were used for the following analysis.

Identification of the latest technologies

Code A01K 47/06, which appears 75 times in the LATIPAT dataset, is the most frequent patent in the analysis.

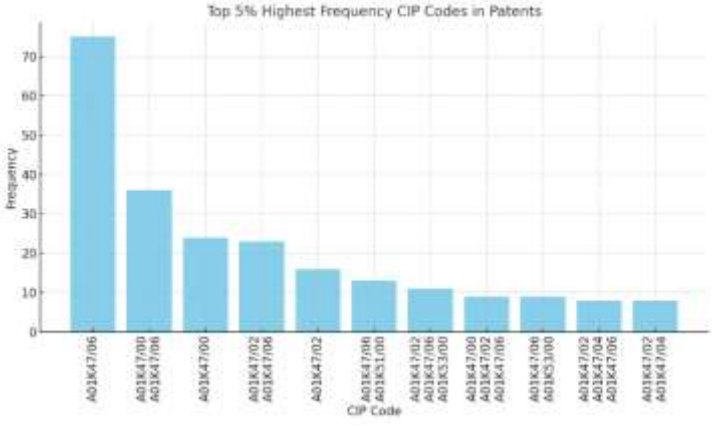

Figure 1: Frequency diagram of patents related to section A01K, which covers technologies related to animal husbandry and beekeeping. Only patents in the top 5% in terms of frequency are shown.

This code belongs to the International Patent Classification (IPC), within section A01K, which covers technologies related to animal husbandry and beekeeping. Specifically, subgroup A01K

47/06 refers to hive devices, particularly those designed to facilitate honey extraction and the efficient management of hives.

The high frequency of this code suggests that innovations in hive design and management are areas of significant interest and activity, likely due to their direct impact on the efficiency and profitability of beekeeping. These technologies aim to improve the devices used for hive management, which may include more accessible hives, more efficient devices for honey extraction, and methods that reduce the negative impact on bees during the management process. The frequency of the A01K 47/06 code also indicates that patents related to this subgroup are proven and replicable technologies, suggesting that both small and large beekeepers could adopt these innovations quickly to optimize their processes and increase production.

Additionally, the use of these patents has the potential to translate into greater productivity in beekeeping, especially for small producers looking to adopt affordable yet effective technologies. Advanced hive devices would not only make hive management easier but also improve honey quality, which would have a direct impact on income and market competitiveness. These innovations position the A01K 47/06 code as a key technology for the development of the beekeeping sector.

Based on the analysis of patents under classification A01K 47/06, it is possible to identify several emerging technological trends in the beekeeping sector, as shown in Table 2. These trends reflect the growing interest in improving the efficiency, sustainability, and profitability of beekeeping through technological innovations.

Table 2: Emerging Trends and Technologies in the Beekeeping Sector

Category	Trend	Technologies
Hive Design and Optimization	The largest subcategory, with 194 patents, focuses on improving structure, ventilation, insulation, and access to optimize honey production.	New materials for hives, modular designs, controlled ventilation systems, methods for honey collection without disturbing the bees.
Automation in Honey Extraction and Processing	With 44 patents, this area focuses on automating honey extraction and processing to increase efficiency and reduce impact on bees.	Automatic honey extraction devices, efficient filtration and storage systems, advanced tools to optimize product quality.
Monitoring and Advanced Sensors	The 10 patents in this category highlight the adoption of remote and real-time monitoring technologies to manage hives and detect health issues.	Temperature, humidity, CO_2 sensors, cameras, microphones to monitor bees, AI systems to prevent diseases.
Other Innovative Beekeeping Technologies	With 166 patents, this category reflects various innovations, including pest control and bee health improvements.	Non-chemical pest control techniques, bee feeding methods, environmental monitoring tools.
Data-Driven Beekeeping Management and Automation	Emerging patents suggest a future of interconnected systems for remote hive supervision and management.	Mobile apps, big data platforms, drone use for apiary supervision.

Bee Sustainability and Welfare	There is growing interest in the sustainability of beekeeping processes, minimizing human impact and promoting biodiversity.	Development of eco-friendly hives, natural pest control, methods to preserve biodiversity in beekeeping environments.

Source: Own elaboration.

Figure 3 shows the predominance of patents related to hive design, followed by other beekeeping technologies, honey extraction and processing, and monitoring and sensors. Meanwhile, Figure 4 shows the keyword map of patents related to those under classification A01K 47/06.

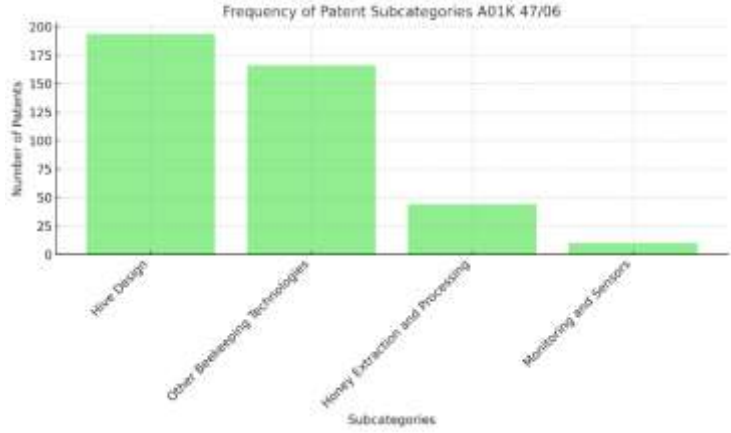

Figure 3: Diagram of the frequencies of the subcategories of patents A01K47/06. Source: Own elaboration.

Figure 4: Keyword map. Note: The larger words in the graph correspond to the most frequent keywords, clearly showing the relative importance of each. Source: Own elaboration.

Once the most promising technologies were identified and prioritized, useful knowledge was generated to support strategic decision-making in the beekeeping sector. This knowledge was generated through a comprehensive assessment that included the potential for dissemination and replication of the technologies, as well as their social, economic and environmental impacts.

Technologies were prioritized based on their ability to improve the productivity and sustainability of smallholder beekeepers. The analysis also considered the economic accessibility of the technologies and their applicability in rural contexts, where resource and technical knowledge constraints may affect their adoption. Five key areas of innovation were identified: Advanced hive design, honey extraction and processing technologies, monitoring and sensors, and other beekeeping technologies. Table 3 provides a detailed assessment of the technologies identified, including their potential impact on the beekeeping sector.

Table 3: Technologies Identified Through Technology Surveillance and Their Potential Impact.

Technology	Dissemination Potential	Social Impact	Economic Impact	Environmental Impact	Recommendation
Modern Hive Design	High	Improves working conditions for beekeepers, increases efficiency in bee management	Significant increase in honey production	Contributes to biodiversity, more sustainable hives	Highly recommended
Honey Extraction and Processing	Medium	Improves the efficiency of the collection and processing process	Enhances the final product quality, optimizes production costs	Reduced environmental impact compared to traditional methods	Recommended with initial investment
Monitoring and Sensors	Low	Facilitates remote hive management, reducing time and effort	Increases operational efficiency, reduces disease-related losses	Helps prevent environmental issues by monitoring the surroundings	Recommended in regions with access to technology
Other Beekeeping Technologies	Medium	Diverse innovations that can improve beekeeping practices in various areas	Variable impact depending on the specific technology	Reduced environmental impact in most cases	Recommended depending on specific needs

Source: Own elaboration.

This analysis suggests that modern hives are the most promising technology due to their high diffusion potential, ease of adoption, and multiple benefits in terms of both productivity and sustainability. Honey extraction and processing technologies are also recommended, although they require a higher initial investment for implementation, which may limit their adoption in some rural areas. The use of sensors and monitoring technologies is promising, but their diffusion will depend on access to technological infrastructure and training of beekeepers.

Finally, it is important to emphasize that the adoption of these technologies has the potential to have a positive impact not only on productivity, but also on environmental sustainability and the social well-being of beekeeping communities. The integration of these innovations is key to ensuring a sustainable future for small-scale beekeepers, who could benefit from more efficient and profitable practices.

4. CONCLUSIONS

This study has identified the main emerging technological trends in the beekeeping sector through a technology monitoring process that followed each stage of the technology monitoring and competitive intelligence cycle. Throughout this process, relevant information on beekeeping patents was collected and analyzed to effectively address the key questions posed during the planning phase.

At the outset, the key questions were defined as: (1) What are the most frequently patented technologies in the beekeeping sector? (2) Which technologies have the greatest potential for replication and adaptation by small-scale beekeepers? and (3) Which patents offer clear and affordable solutions to improve the productivity and sustainability of beekeeping operations? In response to these questions, a strategy was developed that focused on patent analysis under classification A01K 47/00.

During the search and information gathering phase, databases such as LATIPAT were used to identify the most recent and relevant patents related to hive management and honey extraction. As a result of this analysis, keywords such as "modern hives" and "honey extraction equipment" were identified, which answered the first question about the most patented technologies.

Subsequently, in the information analysis phase, the patents retrieved were categorized to identify emerging technological trends. This process allowed the identification of key areas of innovation, such as hive design, automation of honey extraction, and the use of advanced sensors for hive monitoring. These findings partially addressed the second question, although the replicability of these technologies could not be definitively determined due to a lack of information on their implementation in small-scale apiaries.

In the intelligence phase, the process focused on generating strategic knowledge for decision making in the beekeeping sector. By assessing the dissemination potential of the most promising technologies, the analysis provided insights into how these innovations could improve beekeeping productivity and sustainability. Although replicability was not a priority, the social, economic and environmental impacts of these technologies were carefully analyzed, which ultimately addressed the third question.

This comprehensive technology monitoring process not only facilitated the identification of key trends in beekeeping technology development, but also provided recommendations on how these innovations could be adopted. The report highlighted the importance of government support and the provision of resources to small-scale beekeepers to ensure the successful adoption of these technologies.

Further analysis of the patents classified under A01K 47/06 revealed that the most relevant technologies focus on hive design, automation of honey extraction and processing, and hive monitoring through sensors. Among these, the design of modern hives emerged as the most patented, reflecting a significant demand for innovations that optimize hive management and contribute to apiary productivity. However, it remains uncertain how replicable these technologies are in small-scale apiaries.

Meanwhile, automation in honey extraction and processing shows great potential to improve efficiency, although its adoption in rural areas may be limited due to high initial implementation costs. In addition, advanced hive monitoring technologies, although less common, offer promising solutions for remote hive management, which could enable faster responses to bee health issues and improve operational efficiency. Overall, the adoption of these technologies is expected to increase apiary productivity and profitability, while promoting environmental sustainability through practices that minimize negative impacts on beekeeping ecosystems. While the exact replicability of all these technologies remains uncertain, their potential to improve beekeeping is undeniable.

To maximize the impact of these innovations, it is recommended to focus on increasing the dissemination of the most accessible technologies for small-scale beekeepers. In addition, the role of government and organizational support is critical. This includes training programs and the provision of necessary resources to facilitate the adoption of these technologies, especially in low-tech contexts.

Looking ahead, several avenues of research emerge from this study that could further complement and expand knowledge on technological innovation in the beekeeping sector. One of the key areas to be explored is the empirical assessment of the replicability of the identified technologies in small-scale beekeeping operations in emerging economies. Conducting field studies to analyze the implementation of these innovations would help validate their effectiveness and adaptability in different production contexts.

In addition, further research could focus on examining the socio-economic and cultural factors that influence the adoption of beekeeping technologies. This would include assessing the role of government policies, access to finance and technical training programs in the diffusion of these innovations. It would also be valuable to examine the long-term impact of these emerging technologies on environmental sustainability and biodiversity, particularly in rural areas where beekeeping plays a critical role in local ecosystems.

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