

REGULATORY AND TECHNICAL BASIS FOR THE HAZARD ANALYSIS AND CRITICAL CONTROL POINT SYSTEM IN BEEKEEPING ACTIVITIES

BASE REGULAMENTAR E TÉCNICA DO SISTEMA DE ANÁLISE DE PERIGOS E PONTOS DE CONTROLO CRÍTICOS NAS ATIVIDADES APÍCOLAS

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Abstract

This study aimed to integrate regulatory and technical frameworks with a case study in honey houses, for the implementation of the Hazard Analysis and Critical Control Points (HACCP) system in the beekeeping chain of the Jequitinhonha Valley, Minas Gerais, focusing on compliance with legislation and food safety. The integrated methodology combined document analysis, mapping of SDA Ordinance N^o. 795/2023 - Brazil and review of other legislation.

Resumo

Este estudo teve como objetivo integrar os quadros regulamentares e técnicos com um estudo de caso em centros de processamento de mel, para a implementação do sistema de Análise de Perigos e Pontos Críticos de Controle (HACCP) na cadeia apícola do Vale do Jequitinhonha, em Minas Gerais, com foco no cumprimento da legislação e na segurança alimentar. A metodologia integrada combinou análise documental, mapeamento da Portaria



In addition to a case study, there is an evaluation of five beekeeping units and microbiological diagnosis. The analyses highlighted the high level of legal requirements, which, although fundamental, represent a cost challenge for low-capital family beekeeping. The on-site evaluation revealed challenges regarding infrastructure and management, which served as preventive indicators. The microbiological diagnosis reinforced the need for control, even though the presence of pathogens was below the legal alert limits, signaling the importance of hygiene in handling and the control of humidity and temperature. The analysis (SWOT matrix) positioned HACCP as the main strategic tool for risk prevention. The study culminated in the proposal of an HACCP plan, which synthesizes regulatory requirements and the need to control proven risks in the field. Therefore, it focuses on critical control points (CCPs) that mitigate biological risk (W1, W3, and W4) and infrastructure challenges (W2), including the development of a simplified registration tool.

Keywords: Good Beekeeping Practices. Honey. Sanitary Legislation.

SDA n.º 795/2023 - Brasil e revisão de outra legislação. Além do estudo de caso, foi realizada uma avaliação de cinco unidades apícolas e um diagnóstico microbiológico. As análises destacaram o elevado nível de exigências legais, que, embora fundamentais, representam um desafio em termos de custos para a apicultura familiar de baixo capital. A avaliação no local revelou desafios em termos de infraestruturas e gestão, que serviram como indicadores preventivos. O diagnóstico microbiológico reforçou a necessidade de controlo, embora a presença de agentes patogénicos estivesse abaixo dos limites legais de alerta, sinalizando a importância da higiene no manuseamento e do controlo da humidade e da temperatura. A análise (matriz SWOT) posicionou o HACCP como a principal ferramenta estratégica para a prevenção de riscos. O estudo culminou na proposta de um plano HACCP, que sintetiza os requisitos regulamentares e a necessidade de controlar riscos comprovados no terreno. Por conseguinte, centra-se em pontos críticos de controlo (PCC) que mitigam o risco biológico (W1, W3 e W4) e os desafios de infraestruturas (W2), incluindo o desenvolvimento de uma ferramenta de registo simplificada.

Palavras-chave: Boas Práticas Apícolas. Mel. Legislação Sanitária.

1 INTRODUCTION

Honey is a natural product that is not immune to contamination. Therefore, it is essential to monitor its characteristics (Nastain et al. 2024; Tafere, 2021). Quality and food safety are ensured through the adoption of Good Manufacturing Practices (GMP) and Good Beekeeping Practices (GBP) (Massous et al. 2023). The lack of control over factors such as humidity, temperature, and hygiene can compromise the quality of honey during harvesting and processing (Lomiso, 2019; Klutse et al. 2021), making quality control a priority (Medeiro and Souza, 2021).

The Hazard Analysis and Critical Control Point (HACCP) system is internationally recognized as the most effective tool for promoting food safety, acting preventively and systematically (Figueiredo and Costa Neto, 2001; FAO and WHO, 2003). For an HACCP plan to be robust and legally accepted, it must be directly based

on current health legislation. In Brazil, the reference for establishments producing bee products and their derivatives is SAD (Secretariat of Agricultural Defense) Ordinance No. 795, of May 10, 2023 (Brasil, 2023), which defines sanitary and technological standards for establishments that produce bee products and their derivatives.

Beekeeping in the Jequitinhonha River Valley, although vital for rural development (Melo, 2022), is predominantly family-based and, in many cases, with minimal infrastructure (Marinho et al. 2021). The application of HACCP and GBPA represents a technical alternative to overcome these difficulties and ensure that honey from the Jequitinhonha Valley meets the safety and quality standards required for food (Silva, 2023).

In this sense, the main objective of this study was to conduct a documentary analysis of the health legislation applicable to the beekeeping chain (PORTARIA 795/2023), supported by other national and international legislation inherent to the sector, to support the implementation of an HACCP model in the region, complementing this analysis with a practical case study of microbiological diagnosis in honey houses.

2 MATERIAL AND METHODS

This study was conducted at the Jequitinhonha River Valley, Minas Gerais, between 2024 and 2025. Beekeeping activity was properly characterized in the region, and the main product from beekeeping enterprises, honey, was described and identified in terms of its intended use for proper contextualization of the study.

The method used in the research was descriptive and propositional, beginning with documentary analysis, followed by detailed analysis of current legislation and case studies, culminating in the proposal of the HACCP model.

2.1 Documentary analysis to support the HACCP model

The initial and central phase of this study consisted of a systematic analysis of current legislation to establish the legal and technical basis for validating the principles of the HACCP system.

The documentary survey was conducted in accordance with Brazilian regulatory hierarchy and international standards, aiming to cover good practices, identity and quality standards, and critical microbiological limits. To this end, SDA Ordinance N°. 795, of May 10, 2023 (Brazil, 2023) was the main document used to extract the minimum infrastructure and GMP/GBP requirements. Normative Instruction of the Ministry of Agriculture, Livestock, and Supply N°. 11, of October 20, 2000 (Technical Regulation on Honey Identity and Quality) (Brazil, 2000) was used to define physical-chemical critical limits (CLs), such as moisture and hydroxymethylfurfural (HMF). Consolidation Ordinance N°. 5/2017 (Annex XX) of the Ministry of Health (Brazil, 2017) established water potability standards, providing a fundamental CL for biological hazards. Normative Instruction of the National Health Surveillance Agency N°. 161, dated July 1, 2022, and RDC N°. 724/2022 (Brazil, 2022) establishes microbiological standards for food for human consumption. Although there are no microbiological criteria for honey, this standard is used as a comparative and risk reference for food safety assessment. Internationally, the *Codex Alimentarius* (CODEX STAN 12-1981) was analyzed to identify international standards for HMF and moisture, serving as a market reference and for detailed analysis. Finally, the "Safety and Quality Manual for Beekeeping" (SEBRAE, 2009) was used as a technical reference for validating the management steps in the honey production flowchart.

The primary legislation (SDA Ordinance 795/2023) was organized into a compliance matrix. This matrix categorized the requirements into five main areas: physical structure, equipment and utensils, hygiene and operational sanitation, raw material control, and management and personnel. This categorization ensured that the hazard analysis and the creation of research instruments were well-founded and legally oriented.

The document analysis served as the basis for the creation of the instruments used in the survey. The checklist used during site visits was constructed directly from the requirements of SDA Ordinance 795/2023. For each legal requirement mapped, a binary verification question (Compliant/Non-Compliant) was created, ensuring that the non-conformities (NCs) observed had a direct regulatory basis. The flowchart that groups the stages of the honey production and processing process was prepared based on GMP guidelines (SEBRAE, 2009) and adjusted to cover legally controllable risk points.

2.2 Detailed analysis of current legislation

In addition to extracting the minimum requirements, a detailed analysis of the selected legislation was conducted to identify regulatory alignment and socioeconomic implications for beekeeping in the Jequitinhonha Valley. The analysis process followed four steps. First, the regulatory requirements extracted from the legislation selected in this study were categorized into three dimensions of critical control, namely infrastructure and flow (physical risk and cross-contamination), hygiene and sanitation (operational biological risk), and quality parameters (physical-chemical risk).

As a complement, a direct comparison was made between Brazilian CLs (Ministry of Agriculture, Livestock, and Supply) and the global reference standard (*Codex Alimentarius* - CODEX STAN 12-1981), especially for the HMF and moisture parameters. The objective was to establish the compliance gap necessary for access to export markets.

Next, for each dimension mapped, a strategic assessment was carried out, transforming legal requirements into impact factors for the local reality. This culminated in a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis (Lima et al., 2025).

The conclusions of this detailed analysis were integrated into the case study, ensuring that the analysis was not merely a review of the literature, but a systematic process of strategic interpretation of the standard in the socioeconomic context and empirical risks of the Jequitinhonha Valley. This justifies the need for the HACCP proposal.

2.3 Case study: practical and complementary application

To illustrate the risk and justify the need to enforce the legislation, five honey houses (AP1 to AP5) were selected as case studies. The field research stage took place in June 2024, when visits were conducted to observe the production process and apply the previously prepared checklist. The honey houses visited are located in the municipalities of Felício dos Santos, Itamarandiba, Turmalina, Carbonita, and the district of Planalto de Minas (Diamantina). All are located in the Jequitinhonha Valley, Minas Gerais.

Surface (walls, equipment, countertops), honey, and water samples were collected to investigate microbiological contamination. On surfaces, samples were collected with swabs moistened with peptone water, using the hatching technique in a 30 cm² area delimited by a sterile mold. After collection, the swabs were transferred to Eppendorf tubes and immediately placed in a cooler with ice, ensuring proper preservation until laboratory analysis.

In the laboratory, each swab was washed in an Eppendorf tube containing 1 ml of peptone water. After resting for 1 hour at 20 °C, plating was performed by inoculating 1 ml of the sample in the center of the Compact Dry plates. The plates were then incubated in BOD, according to the manufacturer's recommendations, depending on the target microorganism. At the end of the incubation period, the plates were photographed for subsequent counting of the microorganism colonies. Total bacteria, molds and yeasts, fecal coliforms, and *Staphylococcus aureus* were investigated. The results were expressed in Colony Forming Units (CFU) per milliliter, in the case of honey and water, or CFU per square centimeter, in the case of surfaces.

2.4 HACCP model adapted to beekeeping activities in the Jequitinhonha Valley

The HACCP plan proposal for honey producers in the Jequitinhonha Valley methodologically followed the seven principles of the HACCP (Ibrahim, 2020).

The model production flowchart and visits to honey houses were used to identify biological, physical, and chemical hazards (Principle 1), prioritizing the stages where loss of control resulted in a risk to health or quality. The determination of CCPs (Principle 2) was based on points where control measures could be applied and were economically viable.

The CLs (Principle 3) for each CCP were defined through document analysis, in which the CLs were established in accordance with the requirements of the legislation selected for this study. In addition, the definition of the CLs was based on microbiological diagnosis, in which the presence of risk indicator microorganisms in honey, surfaces, and water served to validate the accuracy of the CLs.

In establishing monitoring, corrective action, and verification measures (Principles 4, 5, and 6), the methodology included a detailed proposal for subsequent procedures, adapted to the reality of family beekeeping.

In addition, in accordance with Principle 7, the methodology included the development of a simplified record-keeping system, such as the HACCP compliance card, that will serve as a formal record of monitoring and verification activities, essential for traceability and for the continuous maintenance of the system in the reality of low capitalization and low education levels among producers.

The formalization of these methodological steps ensures that the proposed HACCP Plan is not only theoretical but a comprehensive risk management tool, supported by legal and scientific evidence and sustainable due to its documentary simplicity.

3 RESULTS AND DISCUSSION

3.1 Information about beekeeping and Jequitinhonha honey

Beekeeping in the Jequitinhonha Valley is typically a family-based and complementary activity, although constantly growing (Melo, 2022). This development is supported by local organizations such as cooperatives and associations. The age range of local producers is predominantly between 40 and 60 years old, with a majority of males, low levels of education, and a prevalence of family labor, working part-time (Melo, 2022). This socio-technical profile poses a direct challenge to the implementation of formal quality systems, justifying the need for specific training and intensive technical assistance (Dantas and Cavalcante, 2024). Although the activity is profitable and has low environmental impact, it requires the adoption of appropriate techniques and business acumen (Embrapa, 2007), points that the HACCP system aims to formalize.

The honey produced in the Jequitinhonha Valley is recognized for its traditional value and contribution to rural development (Melo, 2022) and is marketed under the collective brand "Mel Jequitinhonha" (Silva, 2023). The composition of the product complies with national regulations for honey (Brasil, 2000). The honey is intended for general human consumption, not recommended for children under one year of age due to

the risk of infant botulism. However, the use of GMP and GBPs during all stages of harvesting, extraction, and processing can prevent subsequent contamination by *Clostridium botulinum* (Pereira, 2007). The control of chemical, biological, and physical hazards must therefore be rigorous from harvest to packaging, justifying the intervention of HACCP as an essential preventive measure.

3.2 Mapping of SDA ordinance N°. 795/2023 (Brazil)

Detailed mapping of health legislation established the legal basis for HACCP system validation, allowing the construction of a compliance matrix (Table 1). It was noted that the Brazilian legislation, aligned with the preventive principles of the *Codex Alimentarius*, is comprehensive but imposes a high level of infrastructure requirements that challenge family beekeeping in the Jequitinhonha Valley.

Table 1

Compliance matrix and the rationale for HACCP principles.

Legal requirement	Regulated hazard	Implication in HACCP	Function in the inspection checklist
Facilities with smooth, intact, impermeable, and easy-to-clean surfaces	Biological and physical	CCP and CL: For accumulation of dirt and presence of cracks, which prevent effective sanitation.	Check the integrity of surfaces and the absence of dirty grout.
Processing flow that prevents cross-contamination	Biological and physical	Monitoring: Continuous visual control of process stages	Assess whether the operational flow is linear
Potable water supply, free of contaminants	Biological and chemical.	CCP and LC: Potability standards	Check analysis documentation and water reservoir
Hygiene, health, and clothing of handlers	Biological	CCP and monitoring: Personal hygiene and Standard Operating Procedures (SOPs)	Visual inspection of handlers
Temperature control	Chemical and biological	LC: Maximum temperature and maximum heating time.	Check calibration and temperature recording

The mapping shows that Brazilian legislation is guided by preventive principles, exploring the steps of the recommended procedures for the effective implementation of the HACCP system (Santos and Souza, 2020). The greatest implication of this analysis

for the Jequitinhonha Valley lies in the need to translate and adapt legal requirements to a low-capitalization context.

The CLs proposed in the HACCP Plan for the Jequitinhonha Valley are not arbitrary; they are derived from legal obligations. For example, the CL for “Absence of total coliforms in 100 ml of water” is the microbiological standard for water for human consumption (Consolidation Ordinance N°. 5, of September 28, 2017).

Therefore, the methodological validity of the checklist used in honey houses was ensured by the compliance matrix (Table 1). Thus, this documentary analysis provides the legal framework for the study. Without this basis, the HACCP proposal would be merely a technical recommendation. With it, it becomes a legal requirement to ensure the safety and quality of honey from the Jequitinhonha Valley.

3.3 Evidence of regulatory requirements

The application of the verification tool, derived from SDA Ordinance N°. 795/2023, in the five Honey Houses (AP1 to AP5), revealed few isolated deviations, but nevertheless represented operational difficulties in complying with legislation and exemplifying the threats mapped in the documentary analysis. The presence of these difficulties demonstrates the fundamental importance of applying HACCP. Table 2 summarizes the areas with specific deviations in the units studied.

Table 2

Mapping of points of intervention, through technical assistance, in honey houses based on SDA Ordinance No. 795/2023

Deviation category	Regulatory implication (Example)	Implication in HACCP risk
Infrastructure and sanitary barrier	Failures in the physical structure (light bulbs, drains, windows, flooring)	Physical and biological risk
Hygiene and operational sanitation	Failures in sanitation and use of ineffective products	Biological risk
Personnel (health and uniforms)	Failures in health control and uniform use	Biological risk

Field management and BPA	Failures in the apiary, in management, and in the use of gloves	Physical and biological risk
Management and traceability	Failures in labeling, registration, and analysis	Legal and economic risk

Although NCs were in the minority in terms of compliance, the occurrence of infrastructure deviations, such as the lack of adequate protection for light bulbs, can expose the product to the physical danger of contamination by glass, for example. Similarly, irregularities in flooring and fencing can compromise sanitation effectiveness and pest barriers, validating the requirements of the legislation. At the operational level, specific deviations related to uniforms and sanitary control point to a weakness in the handler's CCP. Data from the literature show that the detection of *S. aureus* in honey and on surfaces confirms that the biological risk is transmitted by non-compliance with personal hygiene requirements (De Resende et al. 2023). In addition, non-conformities observed in field practices, such as the absence of drinking fountains and the placement of honeycombs on the floor, demonstrate that the potential risk of contamination can begin at the source, pointing to the need for the HACCP Plan to act in an integrated manner (Ribeiro et al. 2023).

From this perspective, deviations in infrastructure and personnel control demonstrate the need for investment in public policies aimed at family beekeeping in the Jequitinhonha Valley. This proves that the HACCP proposal is an important step toward helping honey producers in the region migrate from vulnerable informality to the legality and food safety required by law.

3.4 Microbiological diagnosis

The microbiological diagnosis in the five honey houses served as quantitative scientific evidence to validate the documentary analysis and the deviations observed. The results are not alarming, but they indicate the need for intervention by the HACCP system.

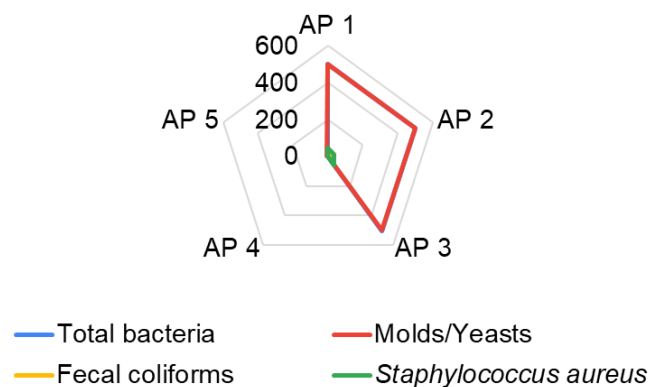
Although Normative Instruction 161/2022 - Brazil does not establish a specific limit for *S. aureus* in honey, the detection of the pathogen with counts above 10^3 CFU.g⁻¹ is unacceptable according to the legislation. The *S. aureus* count in the present study is

below the limit established for pathogens in various categories of ready-to-eat foods, which highlights the current quality and safety of the product. However, the presence of *S. aureus* in honey (33 and 59 CFU.ml⁻¹), even at low levels, requires preventive attention (Figure 1). In this case, implementing the HACCP system is not only about meeting the minimum legal limit, but also about establishing preventive control to eliminate sources of contamination and ensure low risks of human origin, ensuring the continued excellence of honey from the Jequitinhonha Valley.

Andrade Júnior et al., 2019 validate the use of *S. aureus* as an indicator of failure in quality and hygiene control. Although the authors do not establish the exact count of *S. aureus* as a cut-off limit, the literature agrees that detection at levels above zero in ready-to-eat foods, such as honey, is evidence of contamination by handlers, justifying HACCP intervention. Once detected, even at low counts, corrective measures and reinforcement of handling hygiene are mandatory (Andrade Júnior et al., 2019).

Figure 1

Investigation of microorganisms in honey samples (CFU.ml⁻¹)

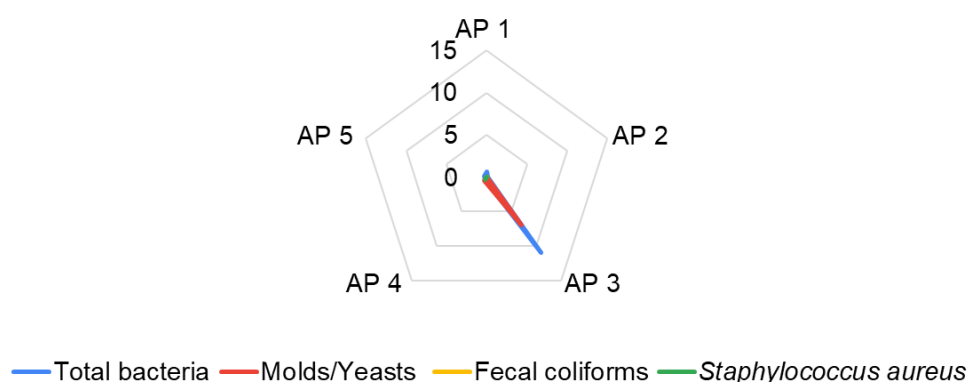


The results of the microbiological analysis, although indicating that the product remains at a low risk level and within the general safety limits for human consumption, provided essential data for improving quality control and the quality management system. Regarding the presence of molds and yeasts, their detection in some samples (Figure 1) is an indicator that the extraction or storage stages need attention to prevent deterioration of the final product, signaling the importance of stricter control of humidity and/or temperature (Silva et al., 2021; Viveros-Lizondo et al., 2024).

Surface analysis demonstrated the overall effectiveness of sanitation procedures in the honey houses analyzed, but pointed to areas for improvement that are essential for prevention (Figure 2). The detection of coliforms and *S. aureus* on surfaces, even in small quantities, is an early warning sign for the risk of cross-contamination. This validates the importance of structural maintenance, avoiding flaws in floors and grout, and reinforces the need for equipment cleaning and sanitization as a CCP.

Figure 2

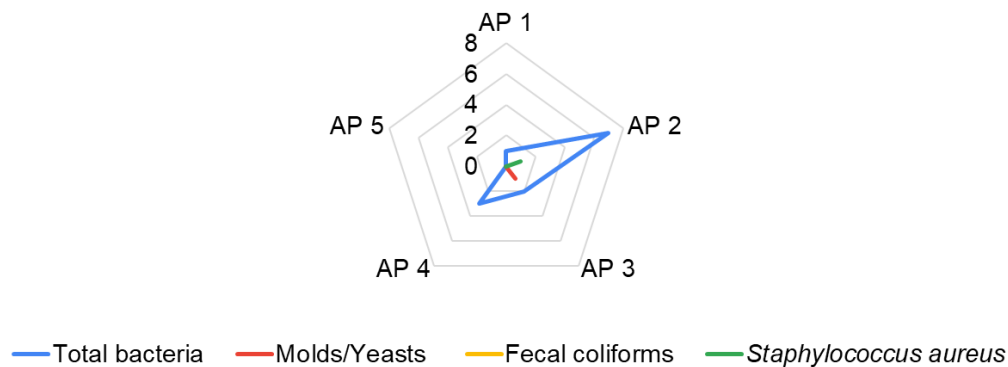
Investigation of microorganisms in surface samples (CFU.cm⁻¹)



Analysis of the water used in processing showed that the fecal coliform parameter, the main indicator of fecal contamination, complies with the potability standard established by the Brazilian Ministry of Health (Figure 3). This finding is essential, as it ensures that water is not a significant source of biological risk. However, the insignificant and sporadic detection of *S. aureus*, molds, and yeasts reaffirms the need for prevention. The presence of *S. aureus* in water and honey signals a gap in operational hygiene that needs to be corrected, such as contact between the water source and surfaces or handlers (Andrade Júnior et al., 2019). The occurrence of molds and yeasts suggests the need to review and protect the water reservoir to prevent it from becoming an undesirable vector of honey contamination (De Figueiredo, 2024).

Figure 3

Investigation of microorganisms in water samples (CFU.ml⁻¹).



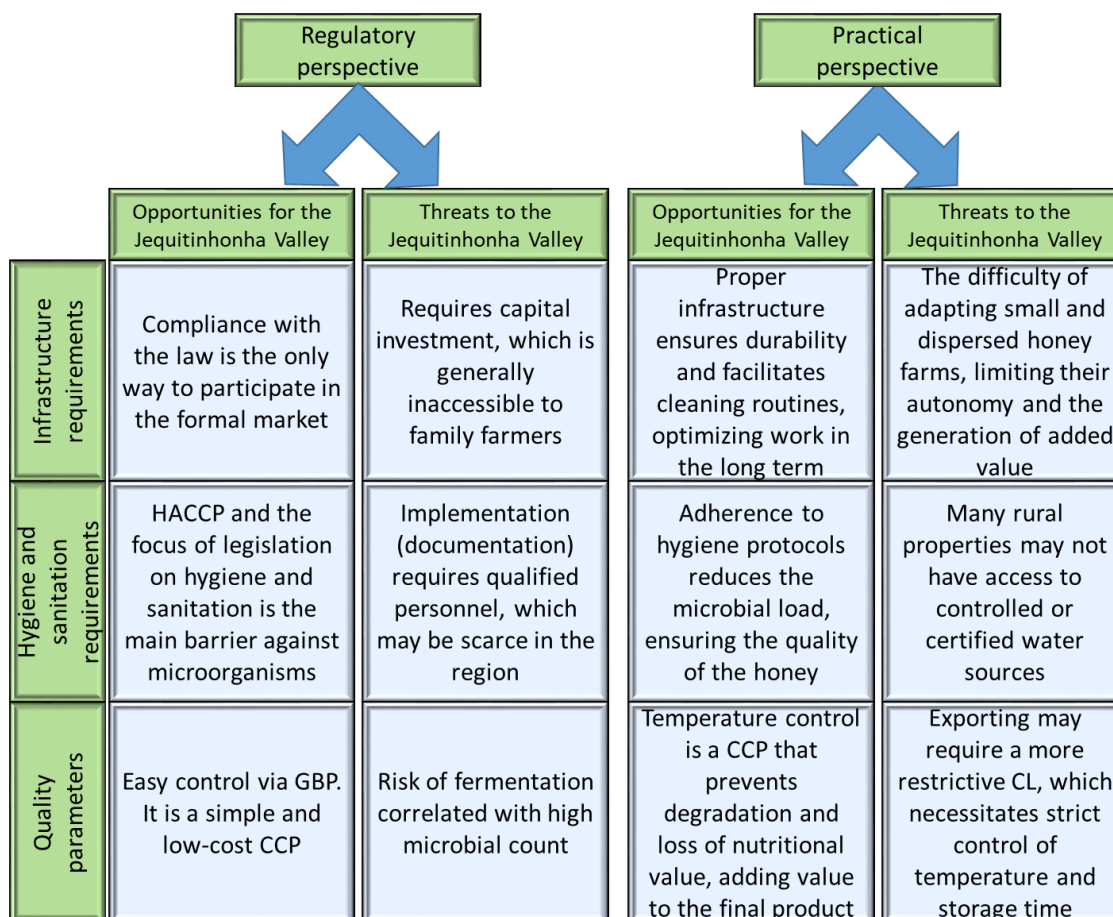
It is important to note that units such as AP4 and AP5 demonstrate that the production of high-quality honey, with no pathogens in the final product, is fully achievable in the region. However, the need for continuous improvement of the process and the final product validates the requirement for a HACCP Plan with strict and legally justified CLs. HACCP will be a tool for standardizing and achieving the excellence already demonstrated by many beekeepers in the Jequitinhonha Valley.

3.5 Detailed analysis of legislation, integrating with the scenario in the Jequitinhonha Valley

A detailed analysis of regulatory frameworks reveals a scenario of technical and sanitary requirements that, although essential for food safety, pose challenges for family beekeeping in the Jequitinhonha Valley. From this perspective, Figure 4 shows the opportunities and threats for beekeeping in the Jequitinhonha Valley, based on the legislation selected for this study.

Figure 4

Detailed regulatory and practical perspectives for opportunities and threats for the Jequitinhonha Valley regarding minimum infrastructure, minimum hygiene and sanitation, and quality parameters requirements.



With regard to minimum infrastructure requirements, Brazilian legislation (Ordinance 795/2023) stipulates that floors, walls, ceilings, and countertops must be resistant, smooth, impermeable, non-absorbent, and easy to clean. In addition, facility design should minimize cross-contamination through linear flow, in accordance with *Codex Alimentarius* principles.

In terms of hygiene and sanitation requirements for equipment and surfaces, the legislation details the need for equipment in good condition, easy to clean, and the use of Standard Operating Procedures (SOPs) for cleaning and disinfection. Complementary Brazilian standards, which regulate microbiological analyses, recommend the use of potable water and the absence of pathogens.

Regarding the critical limits of quality parameters, HMF and moisture, Normative Instruction N^o. 11/2000 defines the limits for moisture at 20% and HMF at 60 mg.kg⁻¹, in addition to other parameters. The *Codex Alimentarius* (CODEX STAN 12-1981), as an international standard, establishes HMF at 40 mg.kg⁻¹ for honey.

Considering the overall context, it is clear that the current legislation represents both a threat and an opportunity. It is a threat due to the cost of adapting the infrastructure and the lack of technical assistance for the management of SOPs. However, it represents the greatest opportunity, since compliance with the standards, combined with the implementation of HACCP, transforms a subsistence product into a certified and safe product, capable of competing in the formal market, both nationally and internationally. The challenge for the Jequitinhonha Valley is to make this regulatory requirement the focus of technical assistance and cooperative investment.

3.6 Discussion on the honey production and processing flowchart

After conducting research in beekeeping enterprises, a flowchart was defined, grouping the stages of the production process. The purpose of grouping each stage of the process was to facilitate the identification of hazards. Similarly, it was proposed that only a well-structured, clear, and well-thought-out flowchart facilitates understanding of what is happening in the production process, which makes it much simpler to identify potential problems (Marques et al., 2012).

The model flowchart of honey production and processing was submitted to methodological verification through on-site validation and feedback collection from beekeepers and meliponiculture practitioners. This step revealed discrepancies and heterogeneity in the production processes of the study units. The absence of a uniform operating standard was evident, with significant variations in management practices and the sequence of steps. The main factors attributed to this variability were the lack of specialized technical assistance and economic limitations for investment in standardized equipment. The finding of non-uniformity in the process was essential for the hazard analysis, as it confirmed that the HACCP plan should be flexible enough to adapt to different production realities, but strict enough in the CCPs to ensure food safety, regardless of the methodology used by each producer.

3.7 Strategic analysis of beekeeping activity in the Jequitinhonha Valley using the SWOT matrix

The following SWOT (Strengths, Weaknesses, Opportunities, Threats) matrix (Table 3) summarizes the internal assessment (Strengths and Weaknesses) of the Jequitinhonha Valley beekeeping chain and compares it with the regulatory and market pressures (Opportunities and Threats) revealed by the documentary analysis and practical results.

Table 3

Integrated SWOT Matrix summarizing the strategic analysis of beekeeping activity in the Jequitinhonha Valley

Internal Environment	External Environment
Strengths	Opportunities
S1. Consolidated cooperativism: the presence of cooperatives and associations is essential for large-scale processing and quality control.	O1. Legislation: official standards provide the legal instrument for product certification and differentiation.
S2. Brand recognition: Jequitinhonha honey has traditional value and local/regional recognition, facilitating differentiation in the market.	O2. Demand for food safety: consumers increasingly demand certification, making the HACCP system a competitive advantage in the market.
S3. Sustainable production: beekeeping is a profitable activity with low environmental impact.	O3. Targeted institutional support: the study's findings can be used to advocate for public policies focused on infrastructure adequacy and specific training.
S4. High-quality potential: evidenced by microbiological analyses in honey houses, proving that the standard of excellence is achievable in the region.	O4. Search for international standards: the adoption of more rigorous international standards opens doors to the export market.
Weaknesses	Threats
W1. Socio-educational fragility: low level of education and a family/part-time work profile is a hindering factor.	T1. Investment needs: infrastructure requirements impose a cost, threatening the continuity of individual activity.
W2. Need for structural adaptation: the need for adjustments to the infrastructure was perceived, which are a priority for compliance with legislation.	T2. Risk of exclusion from the formal market: non-compliance with regulatory requirements prevents expansion to large centers and supermarkets.
W3. Need to strengthen process control: prioritize prevention, reinforcing the handler's CCPs and humidity/temperature controls to eliminate the risk of cross-contamination and deterioration.	T3. Competition with certified honey: competition with producers from other regions with higher levels of investment may devalue the product.

W4. Need to optimize GBP: field handling practices need improvement. These adjustments are essential, as risk control must begin at the source of the raw material.	T4. Restrictive critical limit: the need to adopt the international limit for export requires greater rigor in quality control.
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As a way to transform weaknesses and threats into strengths and opportunities for the development of beekeeping in the Jequitinhonha Valley, the HACCP model becomes a tactical tool to mitigate threats, such as compliance costs and biological risk, directing investments towards legally required priority CCPs.

3.8 Priorities of the HACCP model for beekeeping in the Jequitinhonha Valley

The proposed HACCP plan for Honey Houses in the Jequitinhonha Valley is a synthesis of regulatory requirements and the need to control proven risks in the field. Therefore, the plan needs to focus on CCPs that mitigate biological risk (W1, W3, and W4) and infrastructure challenges (W2). Table 4 details the essential CCPs and their CLs, which are justified by evidence from the case study.

Table 4

Proposed CCPs and justification based on the case study

Proposed CCP	Controlled hazard	Critical limit (CL)	Justification for CL
CCP-1: Cleaning and sanitizing equipment and structures	Biological contamination due to cleaning failure.	Surfaces and equipment: sanitized to eliminate pathogens.	Regulation validated by case study as a preventive measure to maintain the profile of excellence in product quality.
CCP-2: Hygiene and health of the handler	Biological contamination by handlers.	Personnel: use of complete and clean uniform. Updated health declaration/control.	
CCP-3: Humidity and temperature control (storage)	Biological deterioration. Chemical risk (HMF due to overheating).	Moisture and HMF content: Moisture and temperature recorded and controlled at each stage.	
CCP-4: GBP in the field	Biological contamination due to handling failures in the field.	Correct field practices to avoid contamination of raw materials.	

The definition of these CCPs translates the requirements of current legislation into practical controls, directly addressing the main weaknesses of beekeeping in the Jequitinhonha Valley, based on the case study. CCPs 1 to 4 combat the source of biological risk. Intolerance to the presence of microorganisms establishes a fundamental safety standard to overcome weaknesses W3 and W4. Regarding structural compliance, maintaining CCP-1 acts as a compensatory measure for structural challenges (W2). By practicing continuous improvement, focusing on CCP-3, especially when aligned with the most rigorous international standards, prepares producers for export and ensures the physicochemical quality of the product, using HACCP as a strategic development tool.

4 CONCLUSIONS

This study achieved its objective of establishing the regulatory and technical framework for the implementation of HACCP in the beekeeping chain of the Jequitinhonha Valley, using SDA Ordinance N°. 795/2023 (Brazil) as the main basis. The research tests the essential integration between regulatory theory and operational practice.

The document analysis highlighted the legal requirement to guarantee the quality and safety of the product, pointing out areas for continuous improvement in both infrastructure and management and operational procedures in beekeeping units.

The complementary case study demonstrated the importance of rigorous monitoring of hygiene indicators, since the presence of certain microorganisms on surfaces and in honey and water samples signals the need for adjustments in handling procedures and CCPs to ensure safety.

From this perspective, the HACCP plan with critical limits based on legal evidence and directed to the local reality can guarantee the food safety of honey from the Jequitinhonha Valley and strengthen the competitiveness of the regional beekeeping chain. In this sense, a simplified product, such as the HACCP compliance card, is proposed to facilitate producers' adherence to control measures, overcoming socio-educational and economic barriers.

It is necessary to continue this study in order to monitor the implementation and maintenance of the model in the day-to-day beekeeping activities of the Jequitinhonha Valley.

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During the preparation of this study, the author(s) used ChatGPT and GEMINI to refine the manuscript's language, ensure grammatical correctness, and enhance readability. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the publication's content.

DATA AVAILABILITY

All the generated data are included in the manuscript.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

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