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Tracing paratuberculosis in Colombia: A scoping review

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A R T I C L E I N F O

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A B S T R A C T

Mycobacterium avium subsp. *paratuberculosis* (MAP) and the disease it causes in cattle were first officially documented in Colombia in 1924 and originated from imported cattle. Since then, paratuberculosis (PTB) has received little attention, and there is currently no literature offering an updated overview of this disease in Colombia. This scoping review aims to synthesize the evidence and information compiled over the last 100 years to understand the epidemiology and public health response to PTB in Colombia. Using four academic databases, we retrieved articles that mentioned MAP/PTB in Colombia, had no language limitations, and were published between 1924 and 2024. In addition, we manually searched for proceedings from the 3rd to 16th International Colloquia on Paratuberculosis for existing published primary studies. A total of 48 original studies on MAP/PTB were identified and analyzed. Most related studies have been conducted during the past two decades and have focused primarily on cattle (89.4 %). ELISA (59.6 %) and PCR (42.6 %) were the most commonly used diagnostic methods. The study designs were predominantly descriptive or cross-sectional, with no cohort or case—control studies reported. Despite being a notifiable disease since 2015, no research has addressed MAP detection in food or humans. The findings revealed a fragmented research landscape, with significant gaps in diagnostics, epidemiology, molecular characterization, and public health impact. Policy issues are discussed, including the absence of legal frameworks to coordinate responses to the disease and its relationship with bovine tuberculosis. Colombia should acknowledge the presence of MAP/PTB within the country and address it as a national priority.

1. Introduction

Paratuberculosis (PTB) is an infectious disease that affects animals and is caused by the intestinal invasion of *Mycobacterium avium* subsp. *paratuberculosis* (MAP). This gram-positive, acid-fast bacterium belongs to the *M. avium* complex. The hallmark symptoms of the disease include granulomatous inflammation of the intestinal mucosa and mesenteric lymph nodes (Meles et al., 2024).

Paratuberculosis primarily affects ruminants such as cattle, buffalo, goats, and sheep, all of which can become infected with MAP. In some cases, these species develop diarrhea as the disease progresses. Other susceptible animals include donkeys, antelopes, llamas, pigs, alpacas, horses, deer, rabbits, primates, and camels (Carta et al., 2013; Meles et al., 2024). In several of these species, MAP infection leads to chronic, progressive, and contagious conditions. Furthermore, infected animals exhibit increased susceptibility to other diseases (Garcia and Shalloo, 2015). MAP has also been implicated in Crohn's disease in humans (Meles et al., 2024). Additionally, various studies have detected MAP contamination in food sources, including milk, cheese, and other dairy products, whether pasteurized or unpasteurized, as well as in raw meat (Waddell et al., 2016a; 2016b).

This disease is distributed worldwide and causes significant economic losses in animal production species, primarily cattle, sheep, and goats. These losses are particularly pronounced in countries where effective control strategies or programs are not implemented (Whittington et al., 2019). This is often due to the disease not being subject to compulsory reporting or to limitations in the sensitivity and specificity of current diagnostic tests (Whittington et al., 2019; Idris et al., 2022; Meles et al., 2024). Conversely, in countries with a significant dairy industry where control programs are in place—primarily based on hygiene and management strategies, test-and-cull approaches, and vaccinations—the effectiveness of these programs varies considerably in terms of success, participation, and overall progress (Whittington et al., 2019; Tuberquia-López et al., 2022; Weber et al., 2024).

Globally, PTB represents a major health and economic challenge in ruminant production. The estimated herd-level prevalence ranges from 2 to 70 % depending on the region, with economic losses arising from reduced milk yield, premature culling, and increased susceptibility to

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other diseases. In dairy cattle alone, annual losses have been estimated at more than USD 200 million in the United States and up to EUR 500 million across Europe (García and Shalloo, 2015; Whittington et al., 2019). These findings underscore the importance of PTB as a neglected yet impactful disease in livestock systems worldwide.

The presence of PTB in Colombia was first mentioned in 1924 by the Cuban veterinarian Ildefonso Pérez Vigueras based on information from Plata-Guerrero (1931). This mention and confirmation were apparently performed on a farm known as "El Hato" in the municipality of Usme (Cundinamarca) in imported cattle (Vega-Morales, 1947). However, despite being a notifiable disease only since 2015 by the Colombian Agricultural Institute (ICA, by its name in Spanish)—the national animal health authority—PTB is not a priority for animal health authorities. As a result, its management and control largely involve individual farmers (Fernández-Silva et al., 2014). Therefore, a century after the initial report, crucial information about the precise distribution of PTB, the role of wild animals, its true economic impact on livestock production, and its public health significance remains unclear.

To date, only two reviews have included Colombian studies, each with different objectives. First, a Latin American-level review incorporated some Colombian studies and documents. However, despite claiming to be systematic, it does not adhere to any specific guidelines and lacks a comprehensive and conclusive assessment of PTB in Colombia (Espeschit et al., 2017). The second review summarized original studies and abstracts on MAP in Colombia from 1924 to 2016 (Correa-Valencia et al., 2018). While this review focused on diagnostics and epidemiology, it did not follow established guidelines and concluded that the available studies were insufficient to accurately determine the epidemiological status of MAP or its economic and public health impact in Colombia. This highlights the need for further research to enhance the understanding of PTB in the country.

Therefore, to the best of our knowledge, no structured review following a systematic approach and adhering to established guidelines has been conducted on MAP/PTB evidence in Colombia over the past century. For this reason, a scoping review (ScR) was chosen. A ScR provides a preliminary assessment of the scope and volume of available research literature, aiming to identify the nature (characteristics), range (variety), and extent of research evidence on a topic, including ongoing studies. While it typically does not involve a quality assessment process, it can inform policymakers on whether a full systematic review is necessary. Additionally, an ScR can summarize findings from a diverse body of research across different methodologies and disciplines or highlight gaps in the literature to guide future research planning and funding decisions (Grant and Booth, 2009; Munn et al., 2018).

This ScR was specifically conducted to systematically identify the available evidence, assess how research on MAP/PTB in Colombia has been conducted, and analyze existing knowledge gaps over the past 100 years (1924–2024). To guide the review, the following research question was formulated: What is the current state of evidence on MAP/PTB in Colombia? Therefore, this ScR systematically compiles and analyzes the scientific evidence on MAP/PTB in Colombia from 1924 to 2024, aiming to map the available literature, identify research gaps, and inform future research and policy agendas.

2. Materials and methods

Our study follows the ScR format and adheres to the recommendations outlined in the PRISMA Extension for Scoping Reviews (PRISMA-ScR) by Tricco et al. (2018).

2.1. Eligibility criteria

The primary search was carried out on January 10th, 2025. We included original research (full articles), conference abstracts, and undergraduate theses when not published elsewhere and reporting evidence on MAP or PTB in Colombia between 1924 and 2024. The eligible populations included cattle, buffaloes, small ruminants, and wildlife. Eligible diagnostic approaches included ELISA, PCR (and variants), culture, and histopathology. We excluded narrative reviews, opinion/theoretical papers, and duplicate publications. Studies on MAP together with concomitant diseases were eligible if MAP-specific data were extractable. No language restrictions were applied at any stage of the systematic process.

(PCC framing for a ScR): Population = domestic/wild animals in Colombia; Concept = MAP/PTB presence, detection, epidemiology, or control; Context = Colombia across production systems and settings.

2.2. Information sources

We searched Ovid MEDLINE®, PubMed®, SciELO Citation Index®, and Redalyc, complemented by Google Scholar and standard Google for gray literature. These sources were chosen to ensure broad coverage of international peer-reviewed and regional/Spanish and Portuguese-language outputs. We also manually consulted proceedings of the 3rd-16th International Colloquia on Paratuberculosis (ICP) (http://www.paratuberculosis.info/).

2.3. Search strategy

Searches were conducted by combining controlled vocabulary and free-text terms (e.g., "paratuberculosis", "Johne's disease", "*Mycobacterium avium* subsp. *paratuberculosis*", "Colombia") with Boolean operators (AND/OR). The full search strings used in PubMed and SciELO are provided in supplementary material 1 (SM1).

2.4. Selection of sources of evidence

All records were exported to Excel, where a deduplication process was also performed by sorting/filtering titles, authors, and years, followed by manual verification. Two reviewers independently screened the titles, abstracts, and full texts; disagreements were resolved by discussion and consensus. Interrater agreement at each stage was quantified with Cohen's kappa and interpreted via standard benchmarks (e.g., 0.41–0.60 moderate, 0.61–0.80 substantial, 0.81–1.00 almost perfect). No automated screening tools were used. A "snowballing" approach was subsequently followed by reviewing reference lists from both narrative and systematic reviews to identify additional original research findings not captured through database searches. Studies from conference proceedings and undergraduate theses detected from the primary search were included in the ScR if they had not been published in peer-reviewed journals, prioritizing the inclusion of peer-reviewed sources whenever available.

2.5. Data charting process

The two reviewers independently extracted the data into a predefined Excel matrix. The data included bibliographic details, study design, species, sample size, diagnostic method(s), matrix, geographic location, frequency/prevalence estimates, risk factors/associations, and salient notes on molecular typing or control measures. Discrepancies were resolved by consensus after joint review. The charting form was pilot tested on a subset of studies before full extraction.

2.6. Synthesis of results

We produced a narrative synthesis supported by summary tables and figures, describing temporal trends, geographic distributions, diagnostic approaches, and key knowledge gaps. Consistent with the scoping review methodology, no formal critical appraisal of study quality was conducted (PRISMA-ScR guidance). Furthermore, the ICA portal was searched (https://www.ica.gov.co/normatividad/normas-ica) to identify regulations governing responses to MAP/PTB, aligning with our objective of developing informed recommendations.

3. Results

A detailed description of the PRISMA-ScR flowchart is provided in Fig. 1. The records identified include both peer-reviewed publications and gray literature sources (Google, Google Scholar, theses, and conference proceedings). At the full-text screening stage, records were excluded primarily for being narrative reviews, opinion pieces, theoretical analyses, or duplicates. A total of 55 citations were identified from the databases after deduplication. Of these, 48 original research articles met the inclusion and exclusion criteria and were included in the narrative synthesis, spanning publications from 1931 to 2024. The overall publication trends over time related to the topic of interest, including the publication of the complete MAP genome by Li et al. (2005), are shown in Fig. 2. The included studies were published in 20 different journals (where applicable) across 10 countries. Among them, 29 were published in Spanish and 18 in English, all of which were published from 2010 onward.

Author affiliations were primarily associated with the Colombian Agricultural Institute (ICA) and the Colombian Corporation for Agricultural Research (AGROSAVIA), which contributed to one and two of the included studies, respectively. National universities—both public and private—were involved in 46 of the 48 publications, whereas international universities, research institutes, and other organizations participated in 9/48 publications.

A timeline outlining major events in the history of MAP/PTB in Colombia from the first reported case to the present is presented in Fig. 3. A map of Colombia highlighting the frequency of MAP detection or PTB case reporting identified in this ScR is shown in Fig. 4. Studies that did not report frequency data were not included, nor were those that followed a serial diagnostic approach, in which only the results of the first diagnostic test were reported. The full database is available as supplementary material 2 (SM2).

In addition to the original studies, 15 review articles (Góngora and Villamil, 1999; Barragán and Brieva, 2005; Calderón and Góngora, 2008; Zapata-Restrepo et al., 2008; Ramírez-García and Maldonado-Estrada, 2013; Fernandez-Silva et al., 2014; Espeschit et al., 2017; Fernández-Silva and Correa-Valencia, 2018; Correa-Valencia et al., 2018; Whittington et al., 2019; Buitrago-López et al., 2021; Tuberquia-López et al., 2022; Correa-Valencia et al., 2021; Correa-Valencia et al., 2024) were not included in this review but are valuable contributions to national knowledge and reflect longstanding concerns about MAP and its impact in Colombia.

Most MAP/PTB studies have been published within the past two decades, primarily focusing on animal populations in the provinces of Antioquia (39.6 %) and Cundinamarca (17 %), with additional research in Boyacá (11.3 %) and Córdoba (7.5 %). These studies have examined MAP in cattle, sheep, goats, buffaloes, and wildlife, with cattle being the most frequently studied species (89.4 %). To date, no studies in the country have investigated the presence of MAP in food or human samples.

The most commonly employed diagnostic method is the enzyme-linked immunosorbent assay (ELISA) (59.6 %), followed by polymerase chain reaction (PCR) (42.6 %) and Ziehl–Neelsen (ZN) staining for microscopy (14.9 %), which is applied to fecal samples, rectal mucosa scrapings, or tissues, and a variety of less frequently used tests. Published studies include descriptive and cross-sectional designs, diagnostic test comparisons, risk factor analyses, and clinical trials involving treatment protocols. However, no cohort or case—control studies have been conducted to date. Notably, two studies adopted a longitudinal approach at the same farm, using preabsorbed indirect ELISA on serum samples (Fernández-Silva et al., 2011b; Jaramillo-Moreno et al., 2017).

Tables 1 and 2 summarize the characteristics and main findings, respectively, of the studies included in this ScR (1924–2024). They collectively illustrate the progression of MAP/PTB research in Colombia, highlighting methodological developments, epidemiological patterns, and evolving scientific focus over the past century.

Resolution, (3714) of, (2015), issued by the ICA, established a list of notifiable diseases, infections, and infestations in Colombia. This regulation covers 124 diseases affecting various animal species, including cattle, sheep, goats, equines, poultry, swine (domestic pigs and wild boars), rabbits, hares, bees, fish, mollusks, amphibians, and crustaceans. The resolution specifies the diseases for each species as well as those common to multiple species. Among the notifiable diseases listed are PTBs. Cases must be reported in writing or digitally to the nearest ICA

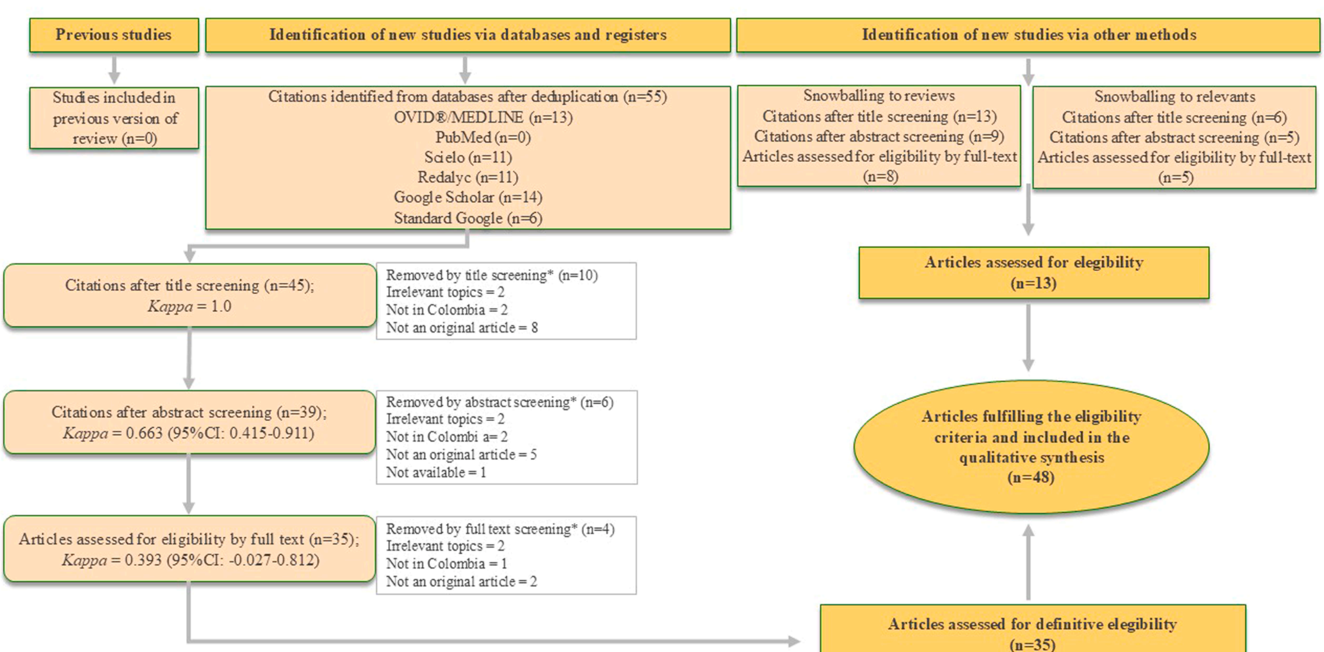

Fig. 1. PRISMA-ScR flow diagram of the study selection process, according to Tricco et al. (2018).

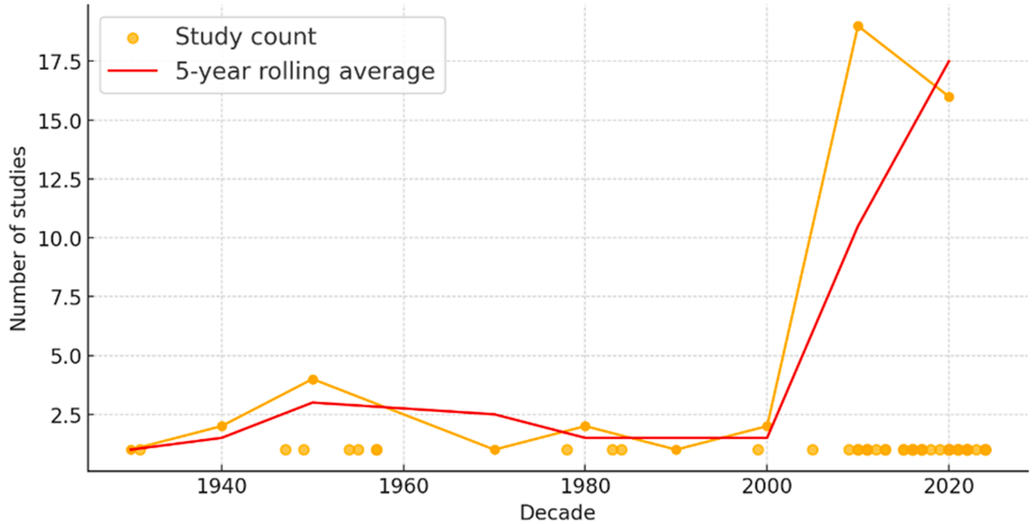

Fig. 2. Distribution of the 48 relevant articles in the scoping review concerning *Mycobacterium avium* subsp. *paratuberculosis* and paratuberculosis in Colombia (1924–2024) every 20 years. The red line represents the 5-year rolling average.

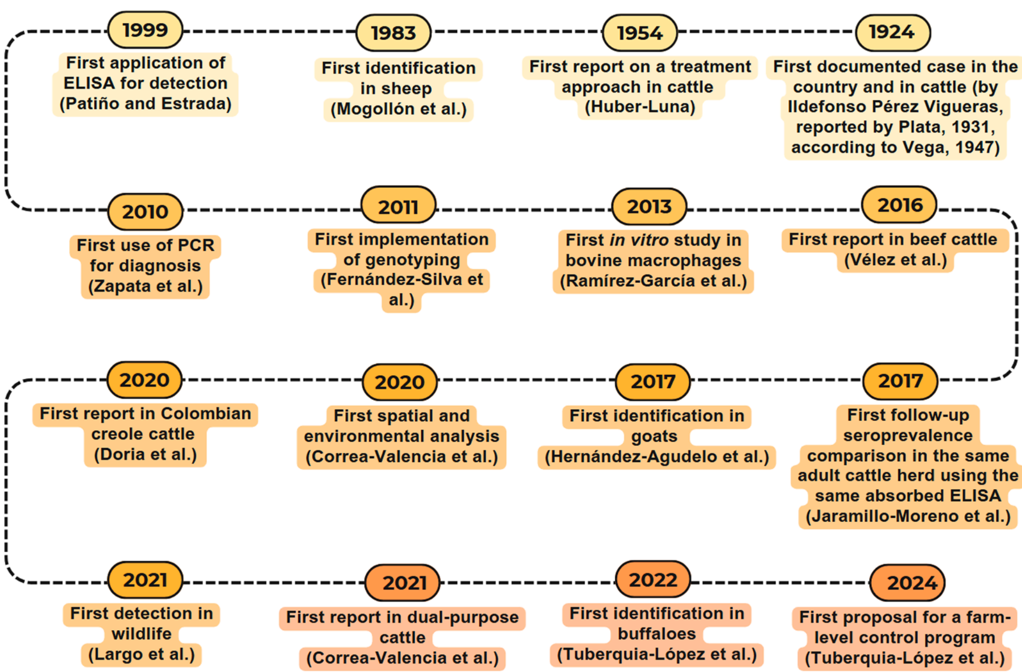

Fig. 3. Milestones of *Mycobacterium avium* subsp. *paratuberculosis* and paratuberculosis research in Colombia (1924–2024).

offices, the regional epidemiologist, or the National Directorate of Epidemiological Surveillance, providing detailed information about the detected disease and affected animals. This measure aims to strengthen epidemiological surveillance and prevent the spread of diseases that could impact livestock production in Colombia.

Resolution 115687, of, 2021, issued on December 24, 2021, by the ICA, also established sanitary measures for the prevention, control, and eradication of bovine tuberculosis (bTB) in cattle and buffalo species in Colombia. It also outlines the requirements for certifying farms as free from bTB. The key provisions detail procedures for the prevention, control, and eradication of bTB, including diagnostic testing, quarantine protocols, and guidelines for the culling of infected animals, and specify the criteria and processes for farms to be recognized as free from bTB, aiming to increase animal health and public safety. While this resolution focuses primarily on bTB, it acknowledges the use of avian tuberculin in diagnostic procedures. Specifically, the comparative cervical test (CCT) involves the intradermal injection of both bovine and avian purified protein derivatives (PPDs) into the middle third of the neck. The test is read 72 ± 6 h post-injection to differentiate between infections caused by *Mycobacterium bovis* and those caused by other mycobacteria, such as those causing PTB. Therefore, the inclusion of avian PPD in diagnostic tests helps identify cross-reactions and ensures accurate diagnosis of bTB by distinguishing it from other mycobacterial infections.

4. Discussion

A comprehensive review of the disease in Colombia is essential given its multifaceted implications for veterinary and public health. Although definitive evidence of the zoonotic nature of MAP remains controversial, numerous studies have suggested a potential association between MAP

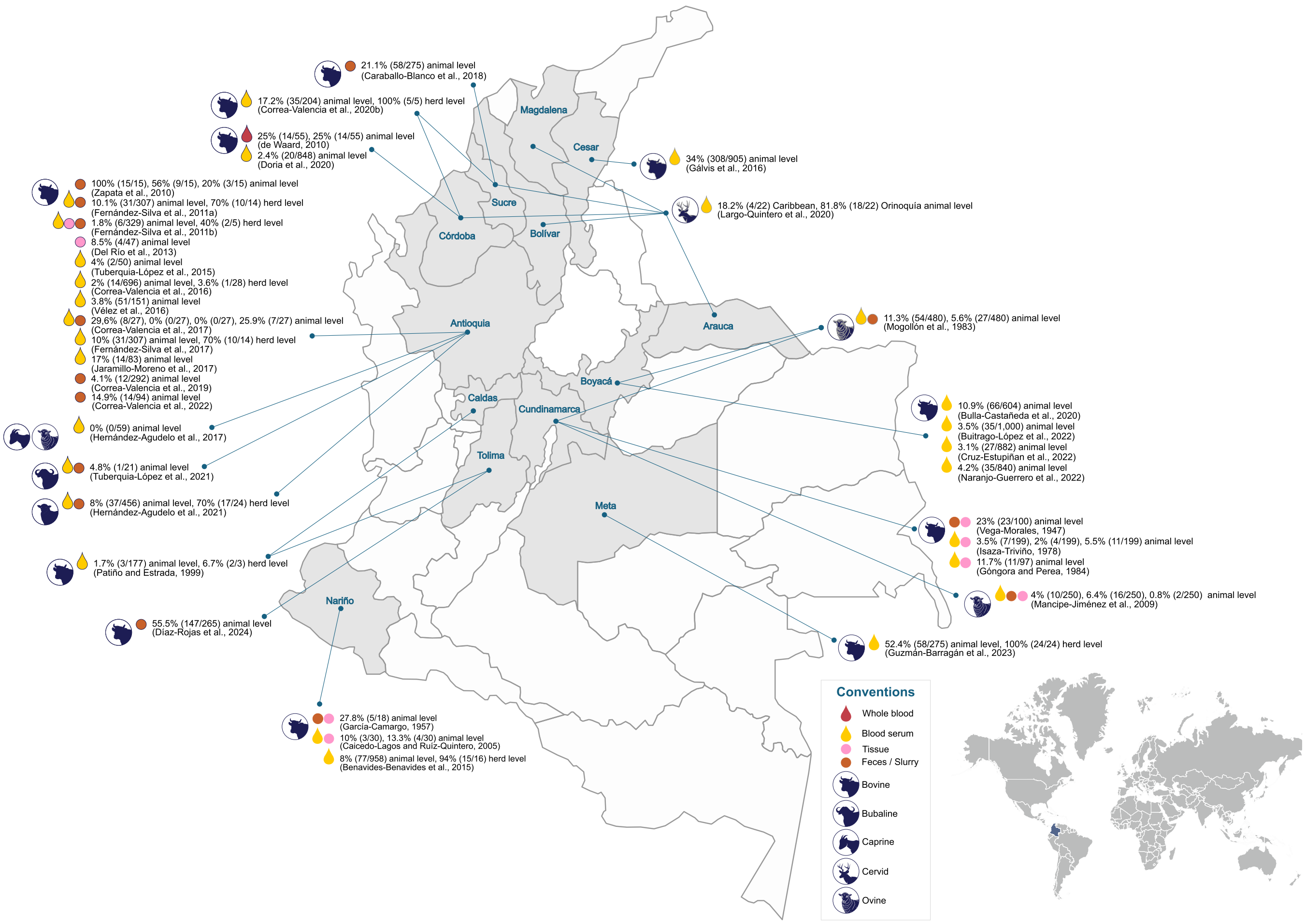

Fig. 4. Geographic distribution of the frequency of *Mycobacterium avium* subsp. *paratuberculosis* and paratuberculosis reported in Colombia (1924–2024) at the province level by animal species, matrix, and diagnostic test.

and Crohn's disease in humans (Chiodini et al., 2012; Waddell et al., 2016a; 2016b). MAP has been isolated from patients with Crohn's disease and has also been detected in pasteurized and unpasteurized dairy products, as well as in raw and processed meat intended for human consumption (Waddell et al., 2016a; 2016b; Botsaris et al., 2016). This raises concerns regarding the foodborne transmission of MAP, particularly in countries where surveillance and control strategies are minimal or absent.

Moreover, MAP infection poses a significant challenge to bTB eradication programs because of immunological cross-reactivity. Both MAP and *Mycobacterium bovis* share antigenic components, particularly purified protein derivatives (PPDs), which can lead to false-positive results in intradermal tuberculin testing (Nunney et al., 2022). This cross-reactivity complicates the accurate identification of bTB-infected animals, potentially resulting in unnecessary culling, economic losses, and misallocation of disease control resources. In Colombia, where both MAP and *M. bovis* are endemic and PTB is not yet prioritized at the national level, understanding the extent of MAP infection is crucial for improving the specificity of bTB diagnostics and ensuring the integrity of bTB eradication efforts.

In Colombia, PTB represents a significant challenge for both dairy and beef production systems. In addition to productivity losses, MAP infection has implications for animal welfare and food safety. A comprehensive review of the disease in Colombia is essential given its multifaceted implications for veterinary and public health. Although definitive evidence of the zoonotic nature of MAP remains controversial, numerous studies have suggested a potential association between MAP

and Crohn's disease in humans (Chiodini et al., 2012; Waddell et al., 2016a; 2016b). MAP has been isolated from patients with Crohn's disease and has also been detected in pasteurized and unpasteurized dairy products, as well as in raw and processed meat intended for human consumption (Waddell et al., 2016a; 2016b; Botsaris et al., 2016). This raises concerns regarding the foodborne transmission of MAP, particularly in countries where surveillance and control strategies are minimal or absent. In Colombia, there is currently no official national control program for PTB, although the pathogen is recognized as a disease of concern by veterinary authorities, and some voluntary herd-level initiatives have been implemented.

While global estimates point to substantial economic losses, local studies suggest that MAP contributes to decreased milk yield, increased culling, and reproductive inefficiency in Colombian herds. Although the economic burden has not been systematically quantified, it is likely to affect both smallholder and commercial dairy systems, further emphasizing the importance of coordinated interventions.

Although the first mention of the disease in the country dates to 1924, the disease has received limited attention from animal health authorities, and efforts toward its control have largely relied on private initiatives. In the same manner, the public health response of Colombia concerning the risk of exposure to MAP through food, water or the environment has been even more limited or nonexistent. MAP and members of the *Mycobacterium avium* complex are poorly investigated from a human disease perspective, and epidemiological surveillance is very limited. Since the association between MAP and CD is widely accepted, measures to avoid exposure and other likely associated human

Table 1
Characteristics of the studies included in the 48 relevant articles in the scoping review concerning *Mycobacterium avium* subsp. *paratuberculosis*/paratuberculosis in Colombia, chronologically (1924–2024).

Reference	Province	Municipality/location	Animal species	Study design
Pérez-Vigueras, 1924 (reported by Plata-Guerrero, 1931 according to Vega-Morales, 1947)	Cundinamarca	Usme	Bovine (not explicitly reported)	NR
Plata-Guerrero (1931)	Cundinamarca	Bogotá, D.C. El Corzo Zipaquirá Viotá	Bovine	Case series report
Vega-Morales (1947)	Cundinamarca	Bogotá, D.C. Sopó Usaquén Fontibón	Bovine	Case series report
Albornoz (1949)	NR	NR	Bovine (not explicitly reported)	Case report and theoretical comparison
Huber-Luna (1954)	Boyacá Cundinamarca	Maripí Bogotá, D.C. Funza Cota Simijaca	Bovine	Case series report
Albornoz (1955)	Cundinamarca	NR	Bovine	Case series report
Albornoz (1957)	Cundinamarca	Bogotá, D.C.	Bovine (not explicitly reported)	Case series report
García-Camargo (1957)	Nariño	Pasto	Bovine	Case series report
Isaza-Triviño (1978)	Cundinamarca	Bogotá, D.C. Pacho	Bovine	Descriptive
Mogollón et al. (1983)	Boyacá Cundinamarca	Paipa Sogamoso Tibasosa Pesca Iza Duitama Firavitoba Mongua Cuitiva Ventaquemada Usme Boyacá Zipaquirá Sisga Sopó Ubaté La Calera La Pradera Soacha	Ovine	Cross-sectional
Góngora and Perea (1984)	Cundinamarca	Bogotá, D.C. and surrounding areas	Bovine	Descriptive
Patiño and Estrada (1999)	Tolima Caldas	Herveo Villamaría Manizales	Bovine	Cross-sectional
Ruíz-Quintero and Caicedo-Lagos (2005)	Nariño	Pasto	Bovine	Descriptive
Mancipe-Jiménez et al. (2009)	Cundinamarca	Soacha	Ovine	Descriptive
de Waard (2010)	Córdoba	NR	Bovine	Case report (pilot study)
Zapata-Restrepo et al. (2010)	Antioquia	San Pedro de los Milagros	Bovine	Descriptive
Fernández-Silva et al. (2011a)	Antioquia	San Pedro de los Milagros	Bovine	Descriptive
Fernández-Silva et al. (2011b)	Antioquia	San Pedro de los Milagros	Bovine	Descriptive
Ramírez et al., (2011)	Antioquia	San Pedro de los Milagros	Bovine	Case report series
Fernández-Silva et al. (2012)	Antioquia	San Pedro de los Milagros	Bovine	Descriptive
del Río et al. (2013)	Antioquia	NR	Bovine	Case series report
Ramírez-García and Maldonado-Estrada (2013)	Antioquia	San Pedro de los Milagros	Bovine	Case report
Benavides-Benavides et al. (2015)	Nariño	Guachucal Túquerres Pasto Pupiales	Bovine	Cross-sectional
Tuberquia-López et al. (2015)	Antioquia	Gómez Plata	Bovine	Cross-sectional
Correa-Valencia et al. (2016)	Antioquia	San Pedro de los Milagros	Bovine	Cross-sectional
Gálvis et al. (2016)	Cesar	Aguachica Rio de Oro	Bovine	Descriptive
Vélez-Agudelo et al. (2015)	Antioquia	Caucasia	Bovine	Cross-sectional
Correa-Valencia et al. (2017)	Antioquia	San Pedro de los Milagros	Bovine	Descriptive
Fernández-Silva et al. (2017)	Antioquia	Belmira San Pedro de los Milagros	Bovine	Cross-sectional
Hernández-Agudelo et al. (2017)	Antioquia	Barbosa	Caprine Ovine	Cross-sectional
Jaramillo-Moreno et al. (2017)	Antioquia	San Pedro de los Milagros	Bovine	Cross-sectional
Caraballo-Blanco et al. (2018)	Sucre	Sincelejo	Bovine	Cross-sectional
Correa-Valencia et al. (2019)	Antioquia	San José de la Montaña Belmira Santa Rosa de Osos Entrerríos San Pedro de Los Milagros Donmatías	Bovine	Cross-sectional
Bulla-Castañeda et al. (2020)	Boyacá	Sogamoso	Bovine	Cross-sectional

(continued on next page)

Table 1 (*continued*)

Reference	Province	Municipality/location	Animal species	Study design
Correa-Valencia et al. (2020a)	Antioquia	San José de la Montaña Belmira Santa Rosa de Osos Entrerríos San Pedro de Los Milagros Donmatías	Bovine	Descriptive
Correa-Valencia et al. (2020b)	Sucre Córdoba	Sincelejo Sampués Chinú	Bovine	Cross-sectional
Doria et al. (2020)	Córdoba	Cereté	Bovine	Cross-sectional
Largo-Quintero et al. (2020)	Córdoba Sucre Bolívar Magdalena Arauca	Montería San Pelayo Sincelejo Magangué Santa Ana Saravena	Cervid (*Mazama rufina* and *Odocoileus virginianus*)	Cross-sectional
Correa- Valencia et al. (2021)	Antioquia	San José de la Montaña Belmira Santa Rosa de Osos Entrerríos San Pedro de Los Milagros Donmatías	Bovine	Cross-sectional
Hernández-Agudelo et al. (2021)	Antioquia	The Metropolitan, Northern, and Eastern regions	Ovine	Cross-sectional
Tuberquia-López et al. (2021)	Antioquia	Gómez Plata	Bubaline	Cross-sectional
Buitrago-López et al. (2022)	Boyacá	Sotaquirá	Bovine	Cross-sectional
Correa-Valencia et al. (2022)	Antioquia	Belmira Santa Rosa de Osos Entrerríos San Pedro de Los Milagros Donmatías	Bovine	Cross-sectional
Cruz-Estupiñan et al. (2022)	Boyacá	Tuta	Bovine	Cross-sectional
Naranjo-Guerrero et al. (2022)	Boyacá	Puerto Boyacá	Bovine	Descriptive
Guzmán-Barragán et al. (2023)	Meta	Villavicencio	Bovine	Cross-sectional
Díaz-Rojas et al. (2024)	Tolima	Ibagué	Bovine	Cross-sectional
Tuberquia-López et al. (2024) (in press)*	Antioquia	San Pedro de los Milagros	Bovine	Case study

* Accepted for publication on December 9, 2024. NR = not reported.

diseases (e.g., type 1 diabetes, multiple sclerosis, and rheumatoid arthritis) should always be considered based on parsimony and precautionary criteria and based on the One Health approach perspective (Dow and Álvarez, 2022). Our findings reveal that despite isolated research efforts spanning several decades, the understanding of the disease in Colombia remains fragmented. Therefore, on the basis of the cumulative but still limited knowledge on PTB through a century of research, the conclusive evidence of its presence and circulation in several animal species in the country, and the relative inattention of government and policies, we propose a rational control plan for the infectious agent, considering the specific conditions of the country and focusing exclusively on the dairy cattle population as follows:

4.1. National program for the control of bovine paratuberculosis (PTB) in dairy herds

The objective of this program is to establish national standards for the control of bovine PTB, with a primary focus on dairy cattle herds. The Ministry of Agriculture is expected to support the development of relevant regulations and provide partial compensation for animals culled as part of the Program.

The program is structured into three key components:

1. Education and awareness
2. Herd status determination
3. Tailored control strategies by herd status

Additionally, the Program outlines its current exclusions: *vaccination and treatment for PTB prevention and control are not supported at this time in Colombia. These strategies consider only once infections caused by Mycobacterium bovis and Mycobacterium tuberculosis in cattle are effectively controlled.*

4.2. Component 1: education and awareness

Education is the cornerstone of this program and serves as the primary entry point for producer participation. This component is designed to raise awareness among dairy farmers about the economic impact of PTB, effective management strategies, and the structure and expectations of the national program.

Training can be delivered through workshops, personalized sessions, or online courses, with attendance tracked accordingly. Educational content includes the following:

- Basic knowledge of PTB: causative agents, disease progression, and transmission routes.
- Management strategies related to manure, colostrum and milk, calves and youngstock, animal purchases, biosecurity, and the handling of infected individuals.
- Diagnostic and sampling strategies: testing methods, interpretation of results, and program requirements.
- Administrative guidance and herd classification procedures within the program.

4.3. Component 2: herd status determination

Herd classification is critical for defining tailored control strategies. The program uses a stepwise diagnostic approach:

4.3.1. Initial classification via environmental sampling

Environmental sampling from two high-traffic cow areas (six fecal points total) was performed. PCR testing directly on these samples offers 70–80 % sensitivity and allows rapid classification of herds as infected or noninfected at a low cost. The results are typically available within days.

Table 2
Main findings and methodological aspects of the included studies on the 48 relevant articles in the scoping review concerning *Mycobacterium avium* subsp. *paratuberculosis*/paratuberculosis in Colombia, chronologically (1924–2024).

Reference	Matrix	Diagnostic test	Summary of results
Pérez-Vigueras, 1924 (reported by Plata-Guerrero, 1931 according to Vega-Morales, 1947)	NR	NR	The Cuban veterinarian l. Pérez Vigueras reported the presence of PTB apparently in the farm "El Hato", but no further confirmation on this finding was carried out, although the frequent importations of animals could have introduced the disease.
Plata-Guerrero (1931)	Rectal mucosa	FBE Johnin test	Four clinical cases, each involving a different animal showing PTB symptoms, were diagnosed.
Vega- Morales (1947)	Feces Rectal mucosa	FBE Avian tuberculin test	A total of 100 animals were examined using fecal bacterioscopy, yielding 23 positive, 24 suspicious, and 53 negative results. Among these, 16 positive (and symptomatic), 8 suspicious, and 6 negative animals were selected for further testing with the avian tuberculin test. Of those tested, 6/16 positives and 1/8 suspicious animals also tested positive to the latter.
Albornoz (1949)	Sciatic nerves, brachial plexus, median nerve	Anatomopathological examination and histopathology	Neurological anatomopathological and histopathological findings from eight cases are reported, with a theoretical comparison of PTB characteristics to those of human leprosy.
Huber-Luna (1954)	Feces Rectal mucosa	FBE Histopathology Johnin test	Nine clinical cases of PTB-symptomatic cattle experimentally treated with isonicotinic acid hydrazide and cortisone to evaluate their potential use in the treatment of PTB in cattle.
Albornoz (1955)	Feces or rectal mucosa (not explicitly reported)	FBE	Two clinical cases —a cow and a bull, presumably cured after treatment, although treatment details are not provided. An additional 5 cases are mentioned but not described.
Albornoz (1957)	NR	FBE (not explicitly reported)	Report on the recovery of 7 PTB-symptomatic animals treated with promanide. Two additional cases treated with sodium tritoniate showed poor response. Four animals treated with a combination of promanide and sodium tritoniate exhibited successful recovery, including weight gain and absence of detectable bacilli.
García-Camargo (1957)	Rectal mucosa Feces	ZN staining	Eight-teen cases involving asymptomatic animals and/or those with symptoms compatible with PTB or trichomoniasis, of which 5 tested positive for PTB through ZN staining of rectal mucosa.
Isaza-Triviño (1978)	Rectal mucosa Blood serum	ZN staining Complement fixation test Indirect immunofluorescence	Comparison of three diagnostic tests, two of which were implemented for the first time in Colombia for PTB diagnosis, applied to 67 animals across two different sampling periods.
Mogollón et al. (1983)	Blood serum Feces	Complement fixation test ZN staining	Prevalence of PTB was determined in 480 sheep from municipalities in two Colombian provinces using two diagnostic tests. Estimated prevalence was 11.25 % (54/480) $\pm$ 2.88 % by complement fixation test and 5.62 % (27/480) $\pm$ 1.05 % by ZN staining of fecal smears.
Góngora and Perea (1984)	Blood serum Rectal mucosa Tissue (ileocecal valve, mesenteric lymph node)	ZN staining Histopathological examination CIEP	A total of 94 animals —both healthy and clinically suspicious of PTB (diarrheic), sent to slaughterhouses were examined using rectal mucosa bacilloscopic examination, histopathology, and CIEP, to compare the performance of the three diagnostic tests. Histopathological examination identified 11 positive cases (11.7 %), of which 6 were also positive by bacilloscopic examination and 9 by CIEP. The latter two tests produced both false-positive and false-negative results. Sensitivity, specificity, and positive and negative predictive values were calculated for rectal mucosa bacilloscopic examination and CIEP.
Patiño and Estrada (1999)	Blood serum	Preabsorbed ELISA	Prevalence of PTB was assessed in 177 animals from three herds (59 animals per herd) located in three municipalities across two Colombian provinces using the ELISA test. The estimated prevalence in the herds was 3.4, 1.7, and 0 %, respectively.
Ruíz-Quintero and Caicedo-Lagos (2005)	Rectal mucosa Blood serum	ZN staining ELISA (neither the application of a preabsorbtion stage with *M. phlei* nor the commercial brand name of the ELISA kit was reported)	Thirty adult cows were sampled. Positivity rates were 10 % (3/30) by ZN staining and 13.3 % (4/30) by ELISA. The animals were also examined for clinical signs compatible with PTB, and these findings were compared with the results of the diagnostic tests.
Mancipe-Jiménez et al. (2009)	Feces Blood serum Tissue (ileum)	ZN staining Avian tuberculin test Preabsorbed ELISA Histopathology	250 adult female sheep of a single farm were tested. 4 % (10/250), 6.4 % (16/250) and 0.8 % (2/250) were found positive by ZN staining, avian tuberculin test, and ELISA, respectively. After the follow-up of one positive animal to all diagnostic tests, necropsy and histopathology confirmed PTB.

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Table 2 (*continued*)

Reference	Matrix	Diagnostic test	Summary of results
de Waard (2010)	Whole blood Blood serum	IFN-γ assay Preabsorbed ELISA Avian and bovine tuberculin test	Fifty-five dairy cows were tested using avian and bovine PPD tuberculin tests, ELISA, and the IFN-γ assay. A total of 25 % (14/55) of the cows tested positive by both ELISA and the avian PPD test.
Zapata-Restrepo et al. (2010)	Feces	IS*900* real time PCR IS*900* conventional PCR Fecal culture ZN staining	Descriptive study in which fecal samples from 15 clinically healthy and PTB-symptomatic cows from a dairy herd were analyzed by fecal culture. An equal number of culture sediment samples were examined using both conventional and real-time PCR. All fecal samples were positive by culture, while 56 % (9/15) and 20 % (3/15) of sediment samples were positive by ZN staining and real-time PCR, respectively.
Fernández-Silva et al. (2011a)	Blood serum Feces	Nonabsorbed ELISA Preabsorbed ELISA IS*900* nested PCR F57 and ISMav2 real-time PCR	Serum and fecal samples from 307 asymptomatic cows across 14 dairy herds were tested for MAP using an initial nonabsorbed ELISA (ELISA-A). Samples from ELISA-A positive animals ($n = 31$) were subsequently analyzed using an absorbed ELISA (ELISA-B) and PCR. Additionally, fecal samples from animals in herds testing positive by ELISA-A and PCR ($n = 105$) were cultured on three different media. ELISA-A detected MAP antibodies in 31 cows (10.1 %) and in 10/14 herds (70 %). Among ELISA-A positive animals, ELISA-B and PCR yielded positive results in 2 (5.1 %) and 6 (19.4 %) cases, respectively. All fecal cultures were negative for MAP on the three-culture media tested.
Fernández-Silva et al. (2011b)	Blood serum Tissue (colon, mesenteric lymph node) Feces Slurry	Preabsorbed ELISA IS*900* nested PCR F57 and ISMav2 real-time PCR MIRU-VNTR MLSSR	Serum and fecal samples from adult cows in five dairy herds were tested for MAP using ELISA and pooled fecal culture. Positive pools were subsequently tested individually by culture and PCR. In one herd, slurry and tissue samples from a single animal were also collected and analyzed by PCR and culture. MAP isolates were further characterized using MLSSR and MIRU-VNTR genotyping methods. ELISA detected MAP antibodies in 1.8 % (6/329) of the animals and in 40 % (2/5) of the herds. In one herd, four fecal samples, two tissue samples, and two slurry samples tested positive for MAP by both culture and PCR. MLSSR and MIRU-VNTR analyses identified two distinct strain profiles among the eight MAP isolates recovered.
Ramírez et al., (2011)	Whole blood Blood serum Tissue (small intestine, mesenteric lymphatic node)	Blood count Blood ureic nitrogen Aspartate aminotransferase Creatinine Glucose Avian and bovine tuberculin test Histopathological examination	Retrospective analysis of histological and clinical findings from 5 cases compatible with PTB over an 8-year period (2000–2008).
Fernández-Silva et al. (2012)	Feces Slurry	MIRU-VNTR MLSSR	Analysis of MAP genotypes reported to date in South American countries using a combination of MIRU-VNTR and MLSSR subtyping methods. The study included 8 Colombian genotypes previously identified by Fernández-Silva et al. (2011b).
del Río et al. (2013)	Tissue (mesenteric lymph nodes)	IS*900* qPCR	Forty-seven animals with chronic diarrhea and weight loss were slaughtered at an abattoir, where mesenteric lymph nodes were collected for macrophage isolation and *in vitro* culture. DNA was subsequently extracted, and IS*900* real-time PCR was performed for MAP detection. MAP infection was confirmed in 8.5 % (4/47) of the macrophage cultures.
Ramírez-García and Maldonado-Estrada (2013)	Blood serum Whole blood Tissue (secondary lymphoid organs)	Nonabsorbed and preabsorbed ELISA (Fernández-Silva et al., 2011a) Macrophage isolation IS*900* real time PCR	Bovine macrophages were isolated from lymphoid tissues, peripheral blood, and a milk sample of a 6-year-old lactating Holstein cow showing clinical signs of stage IV PTB. DNA was extracted from these samples, and IS*900* PCR was performed for MAP detection.
Benavides-Benavides et al. (2015)	Blood serum	Preabsorbed ELISA	A total of 958 cows > 2 years of age from 16 dairy farms were blood sampled to detect anti-MAP antibodies. Seropositivity was analyzed in relation to variables including breed, age, location, body condition, lactation number, and clinical status. Anti-MAP antibodies were detected in 8 % of cows (77/958), with 94 % of farms (15/16) having at least one seropositive animal. A significant association was found between seropositivity and the animal's body condition.
Tuberquia-López et al. (2015)	Blood serum	Preabsorbed ELISA	Fifty adult creole cattle of the BON breed were blood sampled for ELISA-based diagnosis of PTB and to explore the association between individual factors and seropositivity. ELISA detected anti-MAP antibodies in 4 % (2/50) of the animals. No significant associations were reported.
Correa-Valencia et al. (2016)	Blood serum	Preabsorbed ELISA	A total of 696 randomly selected bovines from 28 dairy herds located in 12 districts of the municipality were blood

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Table 2 (*continued*)

Reference	Matrix	Diagnostic test	Summary of results
			sampled for ELISA testing. Data on individual animal characteristics, herd features, and management practices were also collected. The apparent seroprevalence of MAP was 3.6 % (1/28) at the herd level and 2 % (14/696) at the animal level. MAP seropositivity appeared to be potentially associated with milk yield and lactation stage.
Gálvis et al. (2016)	Blood serum	Preabsorbed ELISA	A total of 905 animals from 27 farms were blood sampled for serological diagnosis of various cattle diseases, including detection of anti-MAP antibodies. A seropositivity rate of 34 % was reported for anti-MAP antibodies; however, it is unclear whether this percentage refers to the proportion of animals or farms testing positive.
Vélez-Agudelo et al. (2015)	Blood serum	Preabsorbed ELISA	A total of 151 beef cattle > 2 years of age were blood sampled for ELISA-based diagnosis of PTB, and individual animal characteristics were recorded. ELISA results revealed a seroprevalence of 33.8 % (51/151). No significant associations were reported.
Correa-Valencia et al. (2017)	Blood serum Feces	Preabsorbed ELISA Fecal culture End-point IS*900* nested PCR F57 real-time PCR	Twenty-seven animals > 2 years of age from a single dairy herd were sampled for blood and fecal analysis. ELISA results showed a seroprevalence of 29.6 % (8/27). All fecal samples were negative by fecal culture and F57 real-time PCR. However, 25.9 % (7/27) of the fecal samples tested positive by endpoint IS*900*-specific nested PCR.
Fernández-Silva et al. (2017)	Blood serum	Preabsorbed ELISA	A total of 307 asymptomatic adult Holstein dairy cows from 14 herds across 9 districts were randomly selected and blood sampled for ELISA-based serodiagnosis of PTB. Data on individual cow factors and herd management practices were collected. ELISA identified 10 % (31/307) of animals as seropositive, with at least one positive animal detected in 70 % (10/14) of the herds. The cow-level factor 'parity' showed a weak association with seropositivity, while the herd-level factor 'feeding of calves before weaning' showed a strong association.
Hernández-Agudelo et al. (2017)	Blood serum	Preabsorbed ELISA	ELISA did not detect any positive or suspect cases among the 59 animals tested (53 goats and 6 sheep).
Jaramillo-Moreno et al. (2017)	Blood serum	Preabsorbed ELISA	Eighty-three animals > 2 years of age from a dairy herd were blood sampled for ELISA-based diagnosis of PTB. Data on individual animal factors were collected, and their association with MAP seropositivity was analyzed. The apparent seroprevalence of MAP in the herd was 17 % (14/83), with a statistically significant association found between seropositivity and breed. Comparison of seroprevalence results in this herd using the same absorbed ELISA in the adult cattle population reveals an increase from 2.7 % (Fernández-Silva et al., 2011b) to 17 % (this study) between 2009 and 2015.
Caraballo-Blanco et al. (2018)	Feces	ZN staining IS*900* conventional PCR 16S rRNA PCR	Fecal samples were collected from 275 animals across 26 farms and grouped into 57 pools for DNA extraction. Data on individual animals and herd management practices were also gathered. ZN staining identified 21.1 % (58/275) of the fecal samples as suspicious for MAP. IS*900* PCR detected MAP DNA in pooled samples from 3 farms and 16S rRNA PCR identified positives in pooled samples from a different set of 3 farms (11.5 % in both cases).
Correa-Valencia et al. (2019)	Manure (composite environmental sample)	Duplex IS*900* qPCR	A total of 292 herds located in 61 districts across 6 municipalities were visited once for the collection of a composite environmental sample and completion of a risk assessment questionnaire. MAP detection was performed using a duplex qPCR assay. The apparent herd-level prevalence was 4.1 % (12/292). Herds with a history of mixed farming of cattle with other ruminants had higher odds of MAP infection compared to those without.
Bulla-Castañeda et al. (2020)	Blood serum	Preabsorbed ELISA	Blood samples were collected from 604 animals for ELISA-based diagnosis of PTB, along with data on individual characteristics, herd attributes, and management practices. ELISA detected anti-MAP antibodies in 10.9 % (66/604) of the animals. A statistically significant association was found between seropositivity and both the age of the animals and the provision of balanced feed.
Correa-Valencia et al. (2020a)	Manure (composite environmental sample)	Fecal culture IS*900* qPCR MIRU-VNTR MLSSR	Environmental samples from 25 IS*900* qPCR MAP-positive dairy herds were subjected to culture. Suspected colonies were confirmed as MAP by IS*900* qPCR. Positive DNA samples were subtyped using MIRU-VNTR and MLSSR. MIRU-VNTR analysis identified two different genotypes (INMV 2 and INMV 36), while MLSSR revealed no additional genetic differences among the isolates.

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Table 2 (*continued*)

Reference	Matrix	Diagnostic test	Summary of results
Correa-Valencia et al. (2020b)	Blood serum	Preabsorbed ELISA	A study was conducted on 204 crossbred dairy cows from 5 lowland dairy herds. Blood samples were collected and analyzed using a commercial ELISA kit to detect anti-MAP antibodies. Data on herd and individual animal factors were gathered through questionnaires. The results revealed a seroprevalence of 17.2 % (35/204) among the cows, with all 5 herds having at least one seropositive animal. Statistical analysis identified significant associations between ELISA-positive results and the presence of other ruminants cograzing with cattle in the past 2 years at the herd level, as well as the age and parity of the animals at the individual level.
Doria et al. (2020)	Blood serum	Preabsorbed ELISA	A total of 848 serum samples from an equal number of animals were analyzed for the detection of MAP antibodies. Seropositivity was found in 2.4 % (20/848) of the samples. Statistical analysis revealed associations between MAP seroprevalence and both sex and breed.
Largo-Quintero et al. (2020)	Blood serum	Preabsorbed ELISA	Forty-four individuals were captured and blood-sampled under field conditions for ELISA testing. Seropositivity was detected in 18.2 % (4/22) of the animals from the Caribbean region and in 81.8 % (18/22) from the Orinoquía region. No significant associations were reported.
Correa- Valencia et al. (2021)	Manure (composite environmental sample)	Duplex IS*900* qPCR	A total of 386 dairy herds across 63 districts in 6 municipalities were each visited once for the collection of a composite environmental sample. Spatial and environmental analyses were conducted to describe the spatial distribution of MAP in dairy herds and to characterize environmental variables representative of the physical context of the study area —particularly those associated with MAP-qPCR positive herds. This study reports the general environmental conditions under which MAP-positive herds are most likely to be detected.
Hernández-Agudelo et al. (2021)	Blood serum Feces	Preabsorbed ELISA Fecal culture IS*900* qPCR	A total of 456 blood serum samples from sheep across 24 flocks were analyzed using ELISA. Additionally, 90 pooled fecal samples from the same flocks were cultured and tested by qPCR. ELISA detected anti-MAP antibodies in 8 % (37/456) of the animals, with seropositive individuals present in 70 % (17/24) of the flocks. MAP was detected in 27.7 % (25/90) of the fecal pools by direct qPCR and in 71.1 % (64/90) by culture.
Tuberquia-López et al. (2021)	Blood serum Feces	Preabsorbed ELISA Fecal culture IS*900* conventional PCR IS*900* qPCR MIRU-VNTR MLSSR	Twenty-one asymptomatic adult buffaloes (>2 years old) were sampled for PTB diagnosis using fecal culture and serum ELISA. Suspected culture isolations were confirmed by MAP-IS*900* PCR. Positive DNA samples were further analyzed using quantitative MAP-IS*900* PCR and subsequently subtyped using MIRU-VNTR and MLSSR-based genotyping methods.
Buitrago-López et al. (2022)	Blood serum	Preabsorbed ELISA	Blood samples were collected from 1000 animals and analyzed using ELISA. Data on individual animal characteristics and farm management practices were also gathered and analyzed. An apparent seroprevalence of 3.5 % was observed. The only variable identified as a significant risk factor was age, with cattle > 4 years being more likely to test positive.
Correa-Valencia et al. (2022)	Manure (composite environmental sample)	IS*900* qPCR	A study was conducted involving 94 dairy herds across 60 districts in 5 municipalities. Each herd was visited once to collect two composite environmental samples and complete a risk assessment questionnaire. The apparent herd-level prevalence of MAP infection was found to be 14.9 % (14/94), with municipality-level prevalence ranging from 0 % to 33.3 %. Herds where breeds other than Pure-Holstein (e.g. Jersey, Jersey crossbreeds) were predominant had higher odds of being MAP-qPCR positive compared to herds where Pure-Holstein cattle predominated.
Cruz-Estupiñan et al. (2022)	Blood serum	Preabsorbed ELISA	A total of 882 cattle of various breeds and age groups, which were subjected to ELISA testing for multiple bovine diseases, including PTB. The analysis revealed an apparent seroprevalence of 3.1 % (27/882) for PTB. Logistic regression modeling identified that cattle > 4 years were at a higher risk for PTB infection in the evaluated herds.
Naranjo-Guerrero et al. (2022)	Blood serum	Preabsorbed ELISA	A total of 840 cows aged 2–3 years for ELISA analysis to detect various bovine diseases, including PTB. The PTB seroprevalence was found to be 4.2 %, with 35/840 cows testing positive.
Guzmán-Barragán et al. (2023)	Blood serum	Preabsorbed ELISA	A total of 1000 dual-purpose cattle from 24 farms were sampled for PTB diagnosis using ELISA. Risk factors were

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Table 2 (*continued*)

Reference	Matrix	Diagnostic test	Summary of results
			assessed through univariate and multivariate analyses. The overall seroprevalence of PTB was 52.4 % at the individual level and 100 % at the herd level (no absolute values were published). Female sex, age > 4 years, and the sale of animals were identified as significant risk factors. In contrast, the Zebu breed was considered a protective factor.
Díaz-Rojas et al. (2024)	Feces	IS*900* conventional nested PCR	Two hundred sixty-five fecal samples from cattle aged ≥ 2 years were analyzed using IS*900* nested PCR. Of these, 55.5 % (147/265) tested positive, and the positivity was associated with sudden deaths in individuals showing no signs of disease.
Tuberquia-López et al. (2024) (in press)*	NA	NA	The objective of this study was to design a bovine PTB control program for a specialized dairy herd in Colombia. The program was developed using the Risk Assessment and Management Plans methodology, specifically tailored for a dairy herd endemic to the disease.

* Accepted for publication on December 9, 2024. BON = black-ear white; CIEP = counter immunoelectrophoresis; ELISA = enzyme-linked immunosorbent assay; FBE = fecal bacterioscopic examination; IFN-γ = interferon gamma; MAP = *Mycobacterium avium* subsp. *paratuberculosis*; NA = not applicable; NR = not reported; PCR = polymerase chain reaction; PTB = paratuberculosis; MIRU-VNTR = mycobacterial interspersed repetitive unit-variable number tandem repeat; MLSSR = multilocus short sequence repeat; ZN = Ziehl-Neelsen.

- *Infected herds* must begin implementing control measures and proceed to individual animal testing.
- *Non-infected herds* enter a monitoring phase with regular evaluations to maintain their status.

4.3.2. Diagnosis in infected herds

- *Clinical cases*: Cows presenting typical symptoms (age, body condition, clinical signs) are tested with both fecal PCR (direct test) and serum ELISA (indirect test). The confirmed positive animals were culled immediately.
- *Subclinical cases*: All animals over 24 months of age are tested annually via ELISA. Positive results are confirmed via fecal PCR. If confirmed, the animal may be culled immediately, or culling may be delayed until after the next lactation, with strict restrictions: no reproduction, no use of colostrum, and no contact with maternity areas.

4.3.3. Monitoring in noninfected herds

Annual herd-level surveillance is conducted via the same methods. If a clinical case is detected, the herd is reclassified as infected and enters the corresponding control protocol.

4.4. Component 3: tailored control strategies by herd status

4.4.1. For noninfected (disease-free) herds

Maintaining PTB-free status requires robust hygiene and biosecurity protocols aimed at preventing the introduction of MAP. The key preventive strategies include the following:

- The introduction of animals from infected or unknown-status herds should be avoided.
- Refrain from purchasing animals through auctions or events with mixed-source livestock.
- Only self-replacements or purchases from certified MAP-negative sources are used.
- Prohibit the spread of manure from infected herds on pastures or feed crops.
- Prevent contamination of equipment with feces or soil from infected premises.
- Enforce biosecurity for personnel and visitors, including veterinarians and external farm workers.
- Repeated testing and risk-based planning are applied to monitor and maintain herd status.

4.4.2. For infected herds

The focus is on biocontainment—minimizing transmission and gradually reducing infection rates. The recommended measures include the following:

- Calves were separated from adult cows immediately after birth.
- Designated equipment for feed and manure handling is used, especially in confined housing.
- Exclude infected cows from maternity pens and, if possible, provide individual pens.
- The cows were ensured to be free of fecal contamination before calving.
- Newborn calves were removed and isolated within 10 min of birth to reduce exposure.
- Do not feed colostrum or milk from infected or untested cows. The colostrum from the ELISA-negative cows was collected, sanitized before collection, heat-treated (60°C for 60 min), and stored appropriately.
- Housing calves separately in uncontaminated areas.
- Feed pasteurized milk or milk replacers (65.5°C for 30 min or 72°C for 15 s) were used. Although not sterile, pasteurization significantly reduces the bacterial load.
- Preventing the contamination of calf environments (feed, water, bedding) through stringent hygiene practices includes controlling potential transmission vectors such as footwear, hands, tools, and vehicles.

This comprehensive program aims to promote a coordinated, science-based approach to reduce PTB incidence in Colombian dairy herds while increasing producer capacity and supporting long-term disease control strategies under realistic field conditions.

Bovine PTB control in beef herds follows a similar approach to that used in dairy operations, with Components 1 and 2 applied in the same manner. However, Component 3 includes additional recommendations specifically adapted to the conditions of beef production systems. In these herds, it is important to keep replacement animals separate from the breeding stock, avoiding the use of shared pastures, workers, or equipment that could facilitate disease transmission. The use of manure from infected herds on pastures should be strictly avoided, as should any practices that may lead to the contamination of equipment with feces or soil originating from herds of unknown PTB status. Effective biosecurity measures must be implemented at farm entry and exit points, with particular attention given to the potential for contact with wild ruminants, such as deer, which could act as disease reservoirs. Finally, herd status should be monitored through repeated diagnostic testing and the use of risk-based management plans designed to maintain the health and disease-free status of the population.

A PTB control plan has been proposed for Colombian dairy systems, with emphasis on early diagnosis, culling of infected animals, and improved biosecurity. Nevertheless, its implementation faces challenges such as cost, limited farmer awareness, and the absence of a coordinated national policy. Integrating PTB measures into existing bovine health programs could enhance feasibility, sustainability, and acceptance among producers.

Wild ruminants and other animal species have been reported as reservoirs of MAP in several countries, contributing to environmental persistence and interspecies transmission. In Colombia, however, no studies have addressed the role of wildlife in PTB epidemiology, representing a critical knowledge gap that should be prioritized in future research agendas.

This ScR is not without limitations. First, given the nature of scoping reviews, no formal quality appraisal of the included studies was performed, which may limit the interpretability of the results from studies with lower methodological rigor. Second, potential publication bias cannot be ruled out, particularly since local reports and theses may be underrepresented in indexed databases. In addition, the heterogeneity in study designs, diagnostic methods, and target populations reduces the comparability of findings. Most studies have been cross-sectional and focused on cattle, providing limited information for small ruminants, wildlife, or environmental matrices. The absence of cohort, case–control, and molecular epidemiological studies restricts the ability to draw robust conclusions about MAP transmission dynamics or its zoonotic potential. Furthermore, the lack of molecular characterization of local strains hinders efforts to understand pathogen diversity and its implications for diagnostic or vaccine development.

This ScR provides the first structured and comprehensive synthesis of scientific evidence on MAP/PTB in Colombia over the past century, providing a valuable assessment of the epidemiological and public health significance of the disease in the Colombian context.

The chronological reconstruction of key milestones presented herein provides critical insights into the evolution of MAP/PTB research and the broader understanding of its epidemiology. As shown, scientific engagement with the disease in Colombia has been marked by extended periods of limited activity, punctuated by isolated advances that have resulted in a fragmented and incomplete knowledge base. The earliest documented case dates to 1924, reported by Ildefonso Pérez Vigueras and later cited by Plata-Guerrero (1931), with subsequent isolated reports on treatment approaches in cattle (Huber-Luna, 1954) and the identification of the disease in sheep (Mogollón et al., 1983). These sporadic efforts suggest early awareness of the disease but a lack of consistent epidemiological surveillance, likely contributing to substantial underreporting and underestimation of its impact on livestock health. A turning point occurred between 1999 and 2013, with the first application of ELISA (Patiño and Estrada, 1999), followed by PCR (Zapata-Restrepo et al., 2010), genotyping (Fernández-Silva et al., 2011b), and *in vitro* studies on bovine macrophages (Ramírez-García et al., 2013). These advances marked a transition toward improved diagnostic capabilities and technical capacity building, although their limited implementation across regions restricted the possibility of comprehensive prevalence mapping. Since 2016, studies have documented MAP/PTB in a broader range of host species, including beef cattle (Vélez-Agudelo et al., 2015), goats (Hernández-Agudelo et al., 2017), Colombian creole cattle (Doria et al., 2020), wildlife (Largo-Quintero et al., 2020), dual-purpose cattle (Correa-Valencia et al., 2021), and buffaloes (Tuberquia-López et al., 2021). Concurrently, the first spatial and environmental analysis was conducted (Correa-Valencia et al., 2020), reflecting a shift toward ecosystem-level research. A notable contribution during this period was the implementation of a longitudinal seroprevalence study within a single herd via absorbed ELISA (Jaramillo-Moreno et al., 2017), which provided evidence of persistent infection and supported the hypothesis of endemicity. Most recently, the first formal proposal of a farm-level MAP/PTB control program (Tuberquia-López et al., 2024) marked an important step from disease characterization toward intervention strategies. Although significantly delayed, this milestone reflects a paradigm shift toward proactive disease management, with the potential to influence future prevalence and transmission dynamics. Overall, the timeline illustrates the historical neglect of PTB as a national animal health priority, despite early evidence of its presence. The recent detection of MAP across multiple hosts and production systems, along with growing evidence of its diagnostic interference with bTB testing, highlights the urgency of implementing coordinated surveillance systems, standardized diagnostic protocols, and context specific, policy-driven control strategies tailored to Colombia's diverse epidemiological landscapes.

Since 2018, to the best of our knowledge, the last review on the PTB situation of Colombia has reported 26 studies concerning this disease (Fernández-Silva and Correa-Valencia, 2018), and the 48 original studies reported in the present review have widened our perception of PTB in the country, along with 100 years of PTB awareness. According to the original studies, interest in PTB and the number of studies are increasing, but these studies are still insufficient to be conclusive enough about the epidemiologic situation on a national scale. The situation in some regions has become clear, and although new regions have begun to explore PTB status through basic epidemiologic studies, these studies are mostly based on ELISA, with some exceptions involving PCR (Caraballo-Blanco et al., 2018; Correa-Valencia et al., 2019; 2020a; 2021; 2022; Hernández-Agudelo et al., 2021; Tuberquia-López et al., 2022; and Díaz-Rojas et al., 2024), and the ability to reveal the true epidemiological situation is therefore limited. Compared with what was available in 2018, important efforts have been made to improve the design of prevalence studies on the basis of direct diagnostic methods (Correa-Valencia et al., 2019), new studies on the molecular characterization of isolates and strains (Correa-Valencia et al., 2021; Tuberquia-López et al., 2022), new studies on other-than-cattle (e.g., sheep, buffalo, and deer) susceptible populations (Hernández-Agudelo et al., 2021; Largo-Quintero et al., 2020; Tuberquia-López et al., 2022), and concerns about how to control the disease (Tuberquia-López et al., 2024). Nonetheless, several animal species are still underrepresented, and control is not a priority focus of Colombian studies. With respect to public health issues, research on the presence of MAP in food or the relationship between MAP and CD is lacking to the best of our knowledge, but it seems clear that the research capacity has improved such that epidemiological questions, as well as public health-related aspects, could be more easily responded to.

In general, since diagnostic methods for PTB became more common and accessible in approximately 1999, especially ELISA and PCR, the epidemiological situation of PTB, regardless of animal species, seems to be highly variable on the basis of ELISA reports at the regional scale, with seroprevalences ranging from 0 to 54.2 % and 0–100 % at the animal and herd levels, respectively. No regional patterns can be easily determined, which confirms that a relatively accurate seroprevalence estimation for the country is still far away and that more well-designed studies for this purpose are necessary. In only one single herd, consistent information has been obtained over the years, revealing that animal-level seroprevalence via the same absorbed ELISA increased from 2.7 % to 17 % in 6 years (Jaramillo-Moreno et al., 2017), which, according to the authors, confirms what Raizman et al. (2011) previously stated that without any control effort, the intraherd prevalence can increase to 50 % after 20 years. With respect to PCR, studies investigating individual frequency are very rare, with only one single study revealing a high frequency in fecal samples (55.5 %), whereas herd frequency estimations ranged from 4.1 % to 27.7 %, which revealed an increasing use of this diagnostic method but the need for further standardization of techniques and study designs. Microbiological culture has been very rare in recent Colombian studies, and only studies from a single institution have reported information on this diagnostic test. Consequently, some of these studies, which include microbiological culture, provided limited information on molecular epidemiology in the country. In this field, more information is needed, and further studies are necessary.

Future research in Colombia should prioritize longitudinal and case–control studies to identify risk factors under field conditions, molecular epidemiology to characterize local MAP strains, and the assessment of cost-effective diagnostic and control measures adapted to different production systems. Such efforts would contribute to evidence-based decision-making, reduce the burden of PTB, and align national strategies with international approaches to disease control.

This ScR has several notable strengths. This study represents the first structured and comprehensive synthesis of scientific evidence on MAP and PTB in Colombia over the past century. The review was conducted following the PRISMA-ScR guidelines, using a predefined research question and a systematic approach to identify, select, and chart relevant data. Multiple data sources were used, including four academic databases, gray literature, international conference proceedings, and manual snowballing of reference lists, allowing a broad and diverse set of original studies published thus far. The inclusion of studies without language or time restrictions minimized potential selection bias. A detailed findings matrix was created to organize the extracted data, which were independently reviewed by both authors, enhancing data consistency and interpretation. The analysis spans various study designs, species, diagnostic techniques, and geographic locations within Colombia, enabling a panoramic understanding of the evolution of MAP/PTB research in the country. Additionally, this ScR contributes novel insights into public health implications, diagnostic limitations, and research gaps while providing evidence-based recommendations for future policy and research.

Despite its limitations, this review provides a solid foundation for guiding future research and public policy agendas regarding MAP/PTB in Colombia. It identifies historical trends and critical knowledge gaps, underscores the need for coordinated national control strategies, and offers a basis to inform surveillance, research, and One Health policy development.

5. Conclusions

This ScR provides the first comprehensive and structured synthesis of scientific evidence on MAP and PTB in Colombia. Over the past century, research has evolved from sporadic case reports to more robust cross-sectional and molecular studies, albeit limited in scope and distribution. The evidence highlights a lack of national coordination and prioritization of the disease, despite its endemic presence and potential interference with bTB diagnostics. Notably, studies assessing MAP in food products or human populations are lacking, despite international recognition of its possible zoonotic relevance. Key knowledge gaps include limited geographic coverage, scarce longitudinal and molecular data, and minimal exploration of the role of pathogens in public health. To address these challenges, Colombia must adopt standardized diagnostic protocols, invest in surveillance infrastructure, and implement a national control strategy on the basis of scientific evidence and local epidemiological realities. These efforts are essential not only to mitigate the economic burden of PTB in livestock production but also to ensure a more effective and integrated animal and public health response.

Author contributions

NCM developed the idea and suggested the design and methods. Both authors contributed to the study conception and design as well as the literature search, data analysis, and critical revision of the manuscript. The first draft of the manuscript was written by NMC, and JFS commented on previous versions of the manuscript. Both authors read and approved the final manuscript.

CRediT authorship contribution statement

Nathalia M Correa-Valencia: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jorge A Fernández-Silva:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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Declaration of Competing Interest

None.

Appendix A. Supporting information

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