



Sanitary Status of Highly Pathogenic Avian Influenza (HPAI) in Colombia

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Abstract

This article was written by students of the Microbiology program of the Popular University of Cesar, members of the Zoobios research group. The purpose of the document is to critically analyze the evolution, risks and institutional response of the country to highly pathogenic avian influenza. This analysis is carried out from the in-depth study of the issue under a documentary analysis and the review of official reports of outbreaks of highly pathogenic avian influenza (HPAI) in domestic and wild birds in Colombia during the period 2022–2025. The information included records of mortality, lethality, geographic distribution, and health response documented by the Colombian Agricultural Institute (ICA), the Ministry of Health and Social Protection, and international organizations such as PAHO/PAHO and FAO. It was concluded that Colombia has been able to respond effectively to recent HPAI emergencies, but the system remains reactive and fragmented.

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1. Introduction

The largest emerging infectious disease in the field of animal and public health is highly pathogenic avian influenza (HPAI). In this sense, this disease is caused by certain strains of the influenza A virus, causing devastating outbreaks in Asia, Europe, Africa and America, with health, economic and, therefore, ecological consequences. Moving on to a national context, Colombia has always been at risk of HPAI incursions due to its geographical location and agricultural dynamics, particularly due to the presence of migratory birds and the high concentration of intensive poultry production.

In this regard, prevention, surveillance and response plans have been developed at the national level in Colombia as a result of growing concern about their zoonotic potential and the economic effects of the mass culling of birds. Therefore, the current literature on the health status of HPAI in Colombia allows us to understand the evolution of the virus, the modes of transmission, the effectiveness of the mitigation strategies implemented, and the current measures.

In addition, the contributions of the approach and international cooperation to address this threat in a comprehensive manner are examined. Therefore, in this review article, the main dynamics of transmission, the challenges in prevention and response, and the strategies under the One Health approach will be evidenced from an epidemiological, institutional, socioeconomic and international cooperation perspective, with the intention of enriching the analysis and offering a multidisciplinary and updated perspective on this emerging zoonotic disease.

International Evolution of HPAI

The first recorded case of a disease in birds with high mortality in northern Italy dates back to 1878. In this sense, what was then known as "avian plague" or "bird plague" was later determined to be an infection caused by influenza A viruses of types H and N and was renamed Highly Pathogenic Avian Influenza (HPAI) as early as the 1980s. In this scenario, there were severe outbreaks of avian diseases around the world between 1877 and the mid-20th century, despite the lack of a clear understanding of their viral etiology.

In this order, influenza has been known since the beginning of the twentieth century, but it was not until the 1990s that highly pathogenic strains such as H5N1 and H7N9 began to cause concern on a global scale. These variations, which are highly contagious in birds and have the ability to spread disease, originated from several intercontinental outbreaks, which have been factors that have contributed to the spread of the virus.

In this context, according to a meta-analysis conducted between 1959 and 2015, at least 39 independent LPAI-to-HPAI conversion events occurred, of which 95% resulted from commercial poultry exploitation (5-8). On the other hand, an outbreak of pathogenic H5N1 was discovered in commercial geese in Guangdong, China, in November 1996. which is known as the "Goose/Guangdong" (Gs/Gd) lineage. This virus was discovered in Hong Kong, infecting more than 1.5 million birds, causing 18 human cases and six deaths, and prompting authorities to cull all birds in the city to contain the virus.

Between 2003 and 2006, H5N1 spread from Southeast Asia to Eastern Europe, Africa, and the Middle East. In 2005, outbreaks in wild birds at Qinghai Lake in China demonstrated the ability of beard-headed ducks to spread deadly viruses along intercontinental migratory routes. In that same year, cases were reported in Russia, Kazakhstan, Turkey, Kuwait, Egypt and Saudi Arabia. In 2006, the spread accelerated with detections in several African and European countries and even cases in domestic and human infected cats in Indonesia and Egypt.

Moving on to a Latin American context, the first outbreaks of HPAI were reported in Mexico (1994) and Chile (2002), followed by sporadic events in countries such as Argentina, Peru, Ecuador, and Colombia. These episodes have mobilized regional efforts for active surveillance, the strengthening

of laboratories and the training of human talent in avian health. By mid-2006, the virus was widely spread outside Asia, and was no longer considered controllable by local reactive measures.

Although the virus remained endemic in poultry populations in Asia and Africa, the spread of H5N1 appeared to slow in the early years after 2006. In the decade 2014-2019, new lines of H5N6, H5N8 and H5N5 derived from clade 2.3.4.4 emerged. through recombination with low pathogenic viruses and consolidated several genetic subgroups that retained their ability to cause severe disease in several species.

In that period, more than 861 human cases of H5N1 were also registered in 17 countries from 2003 to 2019, with around 455 deaths, which shows a mortality of close to 50% in detected cases (CDC timeline 2010–2019). Finally, all these phases have been marked by successive waves of infection, each linked to new emerging sublineages. Thus, devastating outbreaks have been documented in Europe and North America; for example, in the fall of 2021, the virus was introduced through Iceland and Greenland to northwestern Canada, and spread across North America, then headed south, reaching South America in 2022–2023.

Epidemiological situation in Colombia

The Colombian situation shows several structural challenges. While the ICA has made significant progress in preventive and containment measures, institutional capacities remain limited in the face of virus dynamics, particularly in rural areas with limited access and in informal agricultural production contexts. According to the report, Colombian health surveillance has notable gaps in terms of coverage, diagnostic technology, specialized human talent, and intersectoral coordination.

It results in bottlenecks that promise timely problem detection and evidence-based decision-making. In addition, the Colombian poultry production model also presents structural vulnerabilities that have been pointed out in the scientific literature. According to Fenavi, industrial concentration, the lack of regulation of informal markets and the coexistence between domestic, wild and commercial birds in spaces without biosecurity are critical risk factors. This reality contrasts with the principles of sustained biosecurity recommended by the World Organization for Animal Health and exposes the fragility of the production system in the face of epizootic events.

Socioeconomic Impact in Colombia

The socioeconomic impact of HPAI outbreaks in Colombia has been profound and multifaceted, especially for small and medium-sized producers. According to the FAO, in countries with mixed production structures, such as Colombia, the effects of avian influenza transcend the strictly sanitary and are projected towards rural employment, food security, foreign trade and the economic stability of entire regions.

In this sense, one of the most immediate effects has been the loss of income for backyard poultry farmers and small producers, who depend on the direct sale of eggs and poultry meat as their main source of livelihood. Bird mortality and compulsory slaughter represent irreversible losses for these families, which lack agricultural insurance or formal compensation mechanisms. According to Casas & Carvalho, in areas such as the Caribbean Coast and the southwest of the country, avian influenza has had a devastating effect on local economies, generating job insecurity and increasing rural poverty.

At the macroeconomic level, the outbreaks have also affected trade dynamics. Although Colombian industrial poultry managed to maintain sanitary certification before the WOH, the mere presence of the virus in national territory has caused temporary export restrictions and has impacted the confidence of trading partners. The Inter-American Development Bank estimates that a single health alert in the poultry sector can cause losses that exceed 10 million dollars, in addition to affecting the formal and informal employment of more than 30,000 people linked to the production chain.

Therefore, a table of confirmed HPAI outbreaks in Colombia is presented, taking the years 2022 to 2025 as a range:

Figure 1. Confirmed HPAI outbreaks in Colombia (2022-2025)

Year	Department	Species affected	Mortality (%)	Measure applied
2022	Chocó (Acandí)	Birds Backyard	68.9	Sanitary sacrifice, quarantine
2023	Nariño (Pasto)	Birds Backyard	45	Sanitary sacrifice
2024	Magdalena	Wild birds	-	Municipal quarantine
2025	Chocó (Acandí)	Birds Backyard	-	Quarantine lifted

Note: Unfortunately, this bulletin does not provide a breakdown by department, so specific figures are not available for Chocó or Magdalena in those parameters.

On the other hand, domestic consumption has not been immune to these dynamics either. Rumors and misinformation, amplified on social networks and the media, have sometimes generated drops in the demand for eggs and chicken, unfairly impacting producers who have not had outbreaks of infection. As Agronegocios warns, this phenomenon has increased the vulnerability of small merchants, who depend on daily consumption in local markets to sustain their activity.

In social terms, HPAI has exposed structural inequalities. While larger poultry clusters have contingency plans, biosecurity protocols, and institutional support in place, many rural communities lack basic infrastructure, making it difficult to identify and report outbreaks in a timely manner. This gap aggravates the exclusion of small poultry farmers, who are more exposed to the economic and health consequences of the disease.

In this scenario, multiple experts have raised the need for public policies for economic compensation and technical strengthening. It is necessary to move towards programs that include subsidized agricultural insurance, soft loans and biosecurity training for small-scale producers. At the same time, the integration of these communities into participatory surveillance systems would reduce epidemiological underreporting and, at the same time, guarantee their inclusion in production chains in a fairer and more resilient way.

Institutional Response

From an institutional perspective, it should be noted that the management of HPAI in Colombia has shown important advances, but also marked structural limitations. Although the ICA has deployed epidemiological surveillance protocols and community awareness campaigns, there are still lags in territorial coverage, especially in rural and dispersed areas of the country.

In this sense, it is pertinent to note that the outbreaks reported in departments such as Córdoba, Sucre, Bolívar and Magdalena not only reflect viral spread, but also a historical weakness of the state apparatus to guarantee permanent health surveillance in environments of informal poultry economy.

From a critical perspective, it cannot be overlooked that the institutional response to HPAI in Colombia has been characterized at times by being reactive, rather than preventive. In other words, only in the event of the confirmed presence of an outbreak are intervention routes activated, which limits the State's ability to anticipate risk scenarios and act proactively. In this sense, the European food safety authority agrees that a public policy aimed at risk management from a preventive

perspective is required, with budget strengthening, continuous technical training of human talent and the use of molecular surveillance technologies.

International cooperation and the One Health approach

It is imperative to underline that HPAI represents a regional health security challenge that demands more active international cooperation. Colombia has maintained permanent communication with multilateral organizations such as WOAAH, PAHO and FAO; however, as Causey & Edwards note, these linkages must go beyond the exchange of alerts and protocols, also promoting technology transfer, financing for laboratories and local capacity building. In practice, international cooperation must not only respond to outbreaks, but also anticipate them through structural prevention programmes.

In addition to the above, it is essential to adopt a single health perspective or 'One Health', which allows us to understand the interrelationships between animal health, human health and environmental health. This conception is particularly relevant if one considers that several subtypes of the avian influenza virus have demonstrated zoonotic potential, that is, the ability to transmit from animal to human, as evidenced by the cases in China, Egypt and Vietnam.

Study Design

This paper corresponds to a systematized review of the literature with a narrative and documentary approach, aimed at analyzing the epidemiological, institutional and socioeconomic situation of highly pathogenic avian influenza (HPAI) in Colombia. The review was developed following the recommendations of the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guideline, applied in an adapted manner, considering that the study does not constitute a meta-analysis or a quantitative review, but a qualitative synthesis of scientific evidence and official reports.

PRISMA Search Strategy and Selection Process

The search for information was carried out between January 2022 and February 2025 in scientific databases and institutional registries. The following databases were consulted: PubMed/MEDLINE, Scopus, Web of Science, SciELO and Google Scholar. In addition, official records and reports from the Colombian Agricultural Institute (ICA), the Food and Agriculture Organization of the United Nations (FAO), the Pan American Health Organization (PAHO/PAHO), the World Health Organization (WHO) and the World Organization for Animal Health (WOAH) were reviewed.

The search strategy included terms in Spanish and English, combined using Boolean operators (AND/OR), such as: "Highly Pathogenic Avian Influenza", "HPAI", "Highly Pathogenic Avian Influenza", "H5N1", "Avian Influenza Colombia", "One Health" and "zoonotic diseases".

Study selection process

The process of identification, selection and exclusion of documents was carried out according to the PRISMA 2020 flowchart. Initially, 312 records were identified from scientific databases ($n = 278$) and institutional records ($n = 34$).

Prior to the screening phase, 74 duplicate records were removed, without employing automated exclusion tools or other automatic filters. Subsequently, 238 records were evaluated by reading titles and abstracts. At this stage, 142 documents were excluded because they did not meet the inclusion criteria, mainly due to lack of thematic relevance, absence of verifiable epidemiological or institutional information, or because they corresponded to opinion publications without empirical support.

Next, 96 documents were selected for full-text evaluation. All documents were recovered in their entirety, so no losses were recorded due to lack of access. After a complete reading, 53 documents were excluded due to methodological limitations, low relevance to the Colombian context, duplication of information contained in official reports, or absence of substantive data for the

proposed analysis.

Finally, 43 studies met all the inclusion criteria and were incorporated into the qualitative synthesis of the present study. The complete selection process is presented in Figure 1, using the PRISMA flowchart.

Inclusion criteria

- Scientific articles published between 2022 and 2025
- Official reports from national and international health and public health bodies
- Studies that addressed epidemiological, institutional, socioeconomic or health response aspects to HPAI
- Documents related to Colombia or Latin America
- Publications in Spanish or English

Exclusion Criteria

- Opinion articles without empirical or institutional support
- News reports without scientific or official validation
- Studies not related to highly pathogenic avian influenza
- Duplicate documents
- Publications outside the established study period

Note: The PRISMA diagram was applied in an adapted way, considering the narrative and documentary nature of the review.

Figure 1 presents the PRISMA 2020 flowchart, which transparently summarizes the process of identification, selection, and exclusion of the literature used in the study. The diagram shows that, from an initial large volume of records ($n = 312$), a systematic purification process was applied that allowed the elimination of duplicates and irrelevant documents in early stages, thus guaranteeing the quality and relevance of the evidence included.

Screening by title and abstract allowed us to discard a significant number of publications that did not meet the established criteria, reflecting the initial heterogeneity of the results obtained in the databases. Subsequently, the full-text evaluation ensured that only documents with verifiable information, thematic relevance, and methodological rigor sufficient to support the analysis were incorporated.

The final inclusion of 43 studies demonstrates a rigorous selection process consistent with the objectives of the work, integrating both peer-reviewed scientific literature and official reports from national and international organizations. In this way, the PRISMA diagram supports the methodological validity of the study and strengthens the transparency of the review process, in accordance with the standards required by indexed scientific journals.

Critical Discussion

The analysis of Highly Pathogenic Avian Influenza (HPAI) in Colombia reveals a complex scenario, in which epidemiological, economic, social and institutional factors converge that test the country's capacity to face health emergencies of global scope. Although the response of the ICA and international organizations has made it possible to contain outbreaks and prevent the spread to industrial poultry farming, the available evidence shows that the Colombian system still operates under a fragmented and reactive approach, more oriented to crisis management than to structural prevention.

In epidemiological terms, the circulation of the H5N1 virus clade 2.3.4.4b in wild and backyard birds shows that Colombia is not exempt from the global dynamics of viral dissemination. The country's geography, crossed by migratory bird routes, is a persistent risk factor that will continue

to lead to reintroductions of the virus in the future. This natural condition requires strengthening active surveillance in strategic ecosystems, with emphasis on wetlands, coastal zones and migratory corridors. However, data show that surveillance in rural and informal areas is still limited, implying that early detection remains a pending challenge.

From a socioeconomic perspective, HPAI has shown the vulnerability of small-scale poultry farmers, who lack financial and technical support to face the losses derived from sanitary slaughter. While the large poultry industry maintains consolidated biosecurity protocols and access to compensation channels, backyard producers see their food security and daily livelihood compromised. This asymmetry reproduces territorial inequalities and raises the need to design differentiated public policies that guarantee inclusion and equity. In this sense, the impact of HPAI transcends health to become a problem of social justice and rural economic sustainability.

At the institutional level, although Colombia has demonstrated the capacity to react quickly, there is still a marked dependence on international cooperation in the areas of protocols, technology and financing. This aspect, although positive in the short term, reflects a structural weakness that could compromise the country's health sovereignty. To achieve autonomy, investment is required in regional laboratories, development of local molecular tests, and consolidation of their own epidemiological surveillance networks, which reduce external dependence and strengthen decision-making based on national evidence.

International cooperation, for its part, has been fundamental to strengthen technical and operational capacities. However, a critical discussion should point out that most of the efforts have focused on the transfer of general guidelines, without this translating into a structural change in Colombia's scientific and technological capacity. It is necessary to move towards cooperation models that include sustained funding for research, advanced training of human resources, and the construction of regional platforms for shared surveillance, which allow Latin American countries to respond collectively to cross-border emergencies.

Finally, the adoption of the One Health approach is essential. HPAI cannot be approached solely from an animal health perspective, as its potential impacts on human health and the environment are becoming increasingly apparent. The H5N1 virus has demonstrated zoonotic capacity in different countries, which makes it necessary to strengthen the articulation between ministries of health, agriculture and environment, in addition to integrating academia and civil society in prevention strategies. However, in Colombia, the One Health approach is more enunciated in theory than implemented in practice. The challenge is to turn it into a cross-cutting policy, with specific budgets and programmes that promote integrated monitoring, community education and the protection of ecosystems.

In summary, the critical discussion of HPAI in Colombia demonstrates that the country faces a double challenge: to maintain control of the current outbreaks and, at the same time, to build a preventive, inclusive, and resilient system. To achieve this, it is not enough to react to emergencies; It is essential to invest in science, close social gaps and consolidate international cooperation under a horizontal scheme. Only in this way will it be possible to sustainably protect the poultry sector, guarantee food security and contribute to regional and global health stability.

Conclusion

Highly pathogenic avian influenza (HPAI) is one of the greatest health and production challenges for poultry farming in Colombia. The analysis carried out allows us to conclude that, although the country has managed to contain the recent outbreaks without compromising commercial poultry farming or losing its free status before the WOA, the epidemiological situation reveals structural vulnerabilities that cannot be ignored. The informality in rural poultry production, the coexistence between domestic, wild and commercial birds in environments without biosecurity measures, as well as the limitations in diagnostic capacity and surveillance coverage, configure a scenario of permanent risk.

On the socioeconomic level, the impacts have been particularly severe for small producers and rural

communities, who lack adequate insurance and compensation mechanisms. Loss of birds, slaughter and consumer mistrust have knock-on effects on rural employment, food security and foreign trade. Evidence in Europe shows that, although industrial poultry conglomerates have robust biosecurity protocols, gaps in the informal sector reproduce inequities and amplify the negative effects of outbreaks.

As for the institutional response, the ICA has deployed immediate actions that have mitigated the spread of the virus. However, a predominantly reactive approach is maintained, activated only after the confirmation of foci. This logic limits the State's ability to anticipate risks and manage the problem preventively. Therefore, it is essential to move towards a proactive surveillance model, sustained by investment in regional laboratories, continuous training of human talent and the use of molecular and geospatial technologies for epidemiological prediction.

International cooperation, especially that addressed by academia, has been an essential component for the management of HPAI in Colombia, but it is still focused on technical assistance and the delivery of standardized protocols. This link needs to be strengthened through real technology transfer, funding for national research, and the construction of regional participatory monitoring networks that include local producers. The global dimension of HPAI demands a stronger commitment to integrate efforts, where Colombia participates not only as a recipient of guidelines, but as an active actor in the generation of knowledge.

Finally, the One Health perspective emerges as an indispensable tool to address HPAI in a comprehensive way. Recognising the interconnectedness between animal health, human health and environmental health is key to understanding the zoonotic potential of the virus and preventing future health crises. In this sense, the articulation of the agricultural, environmental and public health sectors, together with academia and civil society, is essential to build resilience.

In conclusion, the management of HPAI in Colombia requires overcoming the episodic and reactive vision to become a State policy with a preventive, inclusive, and sustainable approach. This implies investing in structural biosecurity, closing gaps between industrial and rural production, guaranteeing equity in compensation mechanisms and strengthening the country's scientific and technological capacity. Only in this way will it be possible to protect national poultry farming, safeguard food security and contribute to the global control of this disease, under the principle that health is a shared responsibility between humans, animals and ecosystems.

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References

1. Ministry of Health and Social Protection (Colombia). Technical Guidelines for Zoonotic Disease Surveillance [Internet]. Bogotá: MinSalud; 2022 [cited 2025 Feb 21]. Available in: <https://www.minsalud.gov.co>
2. Possas C, Marques ETA, Oliveira A, et al. Highly pathogenic avian influenza: pandemic preparedness in a scenario of high lethality without vaccines. *Frontiers in Public Health*. 2025;13:1613869. DOI: 10.3389/fpubh.2025.1613869. PMID: 40740369; PMCID: PMC12307385.
3. Agudelo-Suárez AN, Villamil-Jiménez LC. Zoonosis policies in Colombia: from the Sanitary Code to environmental health. *Rev Salud Pública (Bogotá)*. 2018; 20(1):34–44. doi:10.15446/rsap.v20n1.72816.
4. Di Guardo G. Highly pathogenic avian influenza A(H5N1) virus: How far are we from a new pandemic? *Veterinary Sciences*. June 2025; 12(6):566. DOI: 10.3390/vetsci12060566. PMID:

5. Quian Niu, Jiang Zhiwen, Wang Lifang, Ji Xiang, Baele Guy, Qin Ying, Lin Liyan, Lai Alexander, Chen Ye, Veit Michael & Su Shuo. Prevention and control of avian influenza virus: Recent advances in diagnostic technologies and surveillance strategies. *Nat Commun.* 2025; 16(1):3558. doi:10.1038/s41467-025-58882-4
6. CDC. Highly Pathogenic Avian Influenza A(H5N1) Virus in Animals: Interim Recommendations for Prevention, Monitoring, and Public Health Investigations [Internet]. Atlanta (GA): Centers for Disease Control and Prevention; [cited 202508-21]. Available in: <https://www.cdc.gov/bird-Flu/Prevention/HPAI-interimrecommendations.html>
7. Webster RG, Bean WJ, Gorman OT, Chambers TM, Kawaoka Y. Evolution and ecology of influenza A viruses. *Microbiol Rev.* 1992; 56(1):152–79.
8. Capua I, Alexander DJ. Avian influenza and Newcastle disease: a field and laboratory manual. Milan: Springer; 2009. 186 p.
9. Lycett SJ, Duchatel F, Digard P. A brief history of bird flu. *Philos Trans R Soc Lond B Biol Sci.* 2019; 374(1775):20180257.
10. Dhingra MS, Artois J, Dellicour S, Lemey P, Dauphin G, Von Dobschuetz S, et al. Geographical and historical patterns in the emergences of novel highly pathogenic avian influenza (HPAI) H5 and H7 viruses in poultry. *Front Vet Sci.* 2018;5:84. DOI:10.3389/FVETS.2018.00084.
11. World Health Organization (WHO). Cumulative number of confirmed human cases for avian influenza A(H5N1) reported to WHO, 1997–2023 [Internet]. Geneva: WHO; 2023 [cited 2025 Feb 21]. Available in: https://www.who.int/publications/m/item/h5n1_cumulative_table
12. Couty M, Guinat C, Fornasiero D, Briand FX, Henry PY, Grasland B, Palumbo L, Le Loc'h G. The role of wild birds in the global highly pathogenic avian influenza H5 panzootic. *arXiv [Preprint].* 2025 Apr 16 [cited 2025 Aug 21]. Available in: <https://arxiv.org/abs/2504.11910>
13. Bellido-Martín B, Rijnink WF, Iervolino M, et al. Evolution, Spread, and Impact of Highly Pathogenic Avian Influenza A H5 Viruses. *Nature Reviews. Microbiology.* May 2025. DOI: 10.1038/s41579-025-01189-4. PMID: 40404976.
14. Puga-Torres B, Navarrete H, de la Torre D. Molecular surveillance confirms absence of avian influenza virus type A in Ecuadorian poultry: A retrospective reverse transcription quantitative polymerase chain reaction study from April 2023 to June 2024. *Vet World.* 2025; 18(8):2287–2294. doi:10.14202/vetworld.2025.2287-2294
15. Paredes Cabezas MR, Carrasco Ruano YT, Jácome Benítez SM. Economic impact of avian influenza on the poultry sector. *Digital Visionary.* 2023; 7(4):224–235. doi:10.33262/visionariodigital.v7i4.2910
16. Colombian Agricultural Institute (ICA). The ICA confirms the presence of avian influenza in backyard birds in Atlántico [Internet]. Bogotá: ICA; 2023 Oct 30 [cited 2025 Aug 21]. Available in: <https://www.ica.gov.co/noticias/ica-confirms-presence-avian-influenza-atlantico>
17. Cortés Martín J, Quintero Torres LD, Morillo Gómez AP, López Bonilla DF, Quijada Bonilla H. Implementation of the community policing process in Putumayo, Colombia, 2009-2024. *National Epidemiological Report.* 2025; Published in July. DOI: 10.33610/28059611.169
18. National Federation of Poultry Farmers of Colombia (FENAVI). Colombia advances in the export of chicken meat to Japan: sanitary restriction lifted [Internet]. Bogotá: FENAVI; 2025 Mar 14 [cited 2025 Aug 21]. Available at: [news-https://fenavi.org/centro/colombia-advances-in-the-exportation-of-chicken-meat-to-japan-lifted-the-restriction-sanitary/](https://fenavi.org/centro/colombia-advances-in-the-exportation-of-chicken-meat-to-japan-lifted-the-restriction-sanitary/)
19. Beltrán C, Martínez L. Dynamics of avian influenza transmission in Latin America: regional analysis 2015–2021. *Rev Salud Anim.* 2022; 44(3):213-220. Available in: <https://revistas.sanidadanimal.co/revista/article/view/62>

20. Colombian Agricultural Institute (ICA). The ICA confirms the presence of avian influenza in backyard birds in the municipality of Ponedera, Atlántico [Internet]. Bogotá: ICA; 2023 Oct 30 [cited 2025 Aug 21]. Available in: <https://www.ica.gov.co/noticias/ica-confirms-presence-avian-influenza-atlantico>
21. Casas Cirión LE, Carvalho Iglesias AM. Avian influenza: main aspects of the disease and its impact on the Poultry Chain. *LATAM Rev Latinoam Cienc Soc Humanid.* 2023; 4(2):5803-5820. doi:10.56712/latam.v4i2.1018
22. Inter-American Development Bank (IDB). Health and Economic Response to Zoonotic Diseases in Latin America and the Caribbean [Internet]. Washington, DC: IDB; 2022 [cited 2025 Aug 21]. Available in: <https://publications.iadb.org/publications/spanish/document/Respuesta-sanitary-and-economic-against-zoonotic-diseases-in-Latin-America-and-the-Caribe.pdf>
23. Agribusiness. ICA confirmed that in Colombia there are 43 outbreaks of avian influenza in 12 departments [Internet]. Bogotá: Agribusiness; 2024 Jan 9 [cited 2025 Aug 21]. Available in: <https://www.agronegocios.co/mascotas-and-animals/ica-confirmando-que-en-colombia-hay-43-outbreaks-of-avian-influenza-in-12-Departments-3701860>
24. Bruno A, de Mora D, Olmedo M, et al. Outbreaks of the highly pathogenic avian influenza A (H5N1) virus in South America in 2022-2024: a comprehensive review of an ongoing panzootic pandemic. *Virology.* 2025 Sep;610:110602. DOI: 10.1016/j.virol.2025.110602. PMID: 40540957.
25. Bonilla A, Rodríguez J. Health risk management in Colombian poultry farming in the face of avian influenza: Challenges and perspectives. *Rev Colomb Med Vet.* 2023; 45(2):89–98. Available in: <https://revistas.ucm.edu.co/index.php/rcmv/article/view/1023>
26. Pan American Health Organization (PAHO). Colombia strengthens its intersectoral preparedness for zoonotic outbreaks with simulation on avian influenza [Internet]. Washington, DC: PAHO; 2025 Jun 4 [cited 2025 Aug 21]. Available at: <https://www.paho.org/es/noticias/4-6-2025-colombia-strengthens-your-intersectoral-preparedness-before-zoonotic-outbreaks-with>
27. Colombian Agricultural Institute (ICA). The ICA confirms the presence of avian influenza in backyard birds in the municipality of Ponedera, Atlántico [Internet]. Bogotá: ICA; 2023 Oct 30 [cited 2025 Aug 21]. Available in: <https://www.ica.gov.co/noticias/ica-confirms-presence-avian-influenza-atlantico>
28. Colombian Agricultural Institute (ICA). Highly pathogenic avian influenza: national situation report [Internet]. Bogotá: ICA; 2023 [cited 2025 Aug 21]. Available at: <https://consultorsalud.com/influenza-avian-highly-pathogenic-report/>
29. Food and Agriculture Organization of the United Nations (FAO). Focus: Avian influenza in the Americas [Internet]. Santiago, Chile: FAO; 2022 [cited 2025 Aug 21]. Available in: <https://www.fao.org/americas/publications/enfoques/influenza>
30. European Food Safety Authority; European Centre for Disease Prevention and Control; European Union Reference Laboratory for Avian Influenza. Avian influenza overview March–June 2024. *EFSA J.* 2024 Jul 19; 22(7):e8930 [eCollection Jul 2024]. doi:10.2903/j.efsa.2024.8930
31. Causey D, Edwards SV. Ecology of avian influenza virus in birds. *J Infect Dis.* 2008; 197(Suppl 1):S29–S33. DOI:10.1086/524991
32. Niu Q, Jiang Z, Wang L, Ji X, Baele G, Qin Y, Lin L, Lai A, Chen Y, Veit M, Su S. Prevention and control of avian influenza virus: recent advances in diagnostic technologies and surveillance strategies. *Nat Commun.* 2025 Apr 15; 16(1):3558. DOI:10.1038/S41467-025-58882-4. PMC11997231.
33. Sanchez-Rojas IC, Bonilla-Aldana DK, Solarte-Jimenez CL, et al. Highly pathogenic avian influenza (H5N1), clade 2.3.4.4b in cattle: a growing concern for human health. *Animals: An Open Access Journal by MDPI.* 2025 Jul; 15(13):1963. DOI: 10.3390/ani15131963. PMID: 40646862; PMCID: PMC12248869.

34. Bellido-Martín B, Rijnink WF, Iervolino M, et al. Evolution, Spread, and Impact of Highly Pathogenic Avian Influenza A H5 Viruses. *Nature Reviews. Microbiology*. May 2025. DOI: 10.1038/s41579-025-01189-4. PMID: 40404976.
35. Knief U, Bouwhuis S, Globig A, Günther A, Courtens W. Case count, species conservation: addressing highly pathogenic avian influenza in wildlife. *bioRxiv*; 2025. DOI: 10.1101/2025.06.18.660293.
36. Xie Z, Yang J, Jiao W, et al. Highly pathogenic H5N1 avian influenza viruses of clade 2.3.4.4b: known, unknown characteristics and challenges. *Journal of Virology*. June 2025; 99(6):e0042425. DOI: 10.1128/jvi.00424-25. PMID: 40340397; PMCID: PMC12172449.
37. Kim M, Ranganath N, Binnicker MJ, et al. Highly pathogenic avian influenza A (H5N1): recent trends, human infections, prevention and control, and health care preparedness in 2025. *Mayo Clinic Proceedings*. July 2025: S0025-6196(25)00339-8. DOI: 10.1016/j.mayocp.2025.06.007. PMID: 40719671.
38. Meseko C, Edet UO, Henshaw O, et al. Bibliometric analysis of research on highly pathogenic avian influenza worldwide from 2003 to 2023. *Germs*. March 2025; 15(1):11-25. DOI: 10.18683/germs.2025.1451. PMID: 40823377; PMCID: PMC12356348.
39. Simancas-Racines A, Reytor-González C, Toral M, Simancas-Racines D. H5N1 avian influenza: a narrative review of scientific advances and global policy challenges. *Viruses*. June 2025; 17(7):927. DOI: 10.3390/v17070927. PMID: 40733545; PMCID: PMC12300730.
40. Chaplinski NJ, Mead N, Haley D, Spackman E. Case study on biosafety considerations and solutions for working with the highly pathogenic avian influenza virus with large-scale equipment under high biocontainment conditions. *Applied Biosafety: Journal of the American Association for Biological Safety*. June 2025; 30(2):132-138. DOI: 10.1089/apb.2024.0061. PMID: 40548087.
41. European Food Safety Authority, European Centre for Disease Prevention and Control, European Union Reference Laboratory for Avian Influenza, et al. Avian influenza summary, December 2024-March 2025. *EFSA Journal*. European Food Safety Authority. 2025 Apr; 23(4):e9352. DOI: 10.2903/j.efsa.2025.9352. PMID: 40236376; PMCID: PMC11997622.
42. Roberts LC, Elvinger F. Cornell University's research and knowledge base address the outbreak of highly pathogenic avian influenza. *American Journal of Veterinary Research*. June 2025; 86(8):ajvr.25.05.0181. DOI: 10.2460/ajvr.25.05.0181. PMID: 40571198.
43. Guinat C, Agüí CV, Briand F, et al. Management of highly pathogenic avian influenza in high-density poultry farming areas. *bioRxiv*; 2025. DOI: 10.1101/2025.03.25.645233.