@LIMENTECH CIENCIA Y TECNOLOGÍA ALIMENTARIA
ISSN Impreso 1692-7125/ ISSN Electrónico 2711-3035. Volumen 23 No. 2, p. 182 - 200, año 2025
Facultad de Ingenierías y Arquitectura
Universidad de Pamplona

Prevalence And Levels Of *Salmonella* In Commercial Shell Eggs From Santander, Colombia

Prevalencia Y Niveles De Salmonella En Huevos Con Cáscara Comerciales De Santander, Colombia.

Parra Aparicio Gina [1*], Ortega Toro Rodrigo[2], Clavijo Olmos Claudia[3]‡*, Castillo, Alejandro[4]‡

[1]Universidad de Santander, Facultad de Ciencias Exactas Naturales y agropecuarias, Programa Microbiologìa Industrial. Grupo de Investigación Microbiota –. Calle 70 No. 50-210 Campus lagos del Cacique. Bucaramanga, Santander. Colombia.*
**Correo electrónico gi.parra@mail.udes.edu.co*
https://orcid.org/0000-0003-0060-5352
[2] Universidad de Cartagena, Faculty of Engineering. Food Packaging and Shelf Life research group (FP&SL). PhD. Programa de Ingeniería de Alimentos. Avenida del Consulado calle 30 No. 48-152 Cartagena de Indias 130015 Cartagena. Colombia: Correo electrónico rortegap1@unicartagena.edu.co.
https://orcid.org/0000-0003-0815-5317.
[3] Universidad de Pamplona,Facultad de Ciencias básicas, programa de Microbiologia. Grupo de investigación GIMBIO- Km 1 Via Bucaramanga campus universitario, Pamplona.Colombia; Correo electrónico Clau.clavijo@unipamplona.edu.co.*
*https://orcid.org/*0009-001-4896-9721
[4] Texas A&M University, Food Science and Technology Department. Texas A&M AgriLife Research Group, College Station, TX 77843, USA; Correo electrónico a-castillo@tamu.edu

Recibido: junio 15 de 2025; Aprobado: noviembre 02 de 2025; Publicado: diciembre 15 de 2025

ABSTRACT

Salmonellosis remains one of the leading foodborne diseases worldwide, and eggs are recognized as an important vehicle of *Salmonella,* particularly *Salmonella enterica* subsp. *enterica* serovar Enteritidis. This study aimed to determine the prevalence and load of *Salmonella* in commercial shell eggs produced in Santander, Colombia. A total of 360 egg samples were collected from six provinces over a three-month period.

Eggshells and internal contents were analyzed separately following ISO 6579-1:2017, with biochemical and serological confirmation of isolates. *Salmonella* was detected in five samples, resulting in an overall prevalence of 1.4%. Four positive samples were found on eggshells and one in egg contents, originating from two farms. One isolate was presumptively identified as *S.* Enteritidis, corresponding to a prevalence of 0.3%. Quantification using the most probable number method showed an average concentration of 0.052 MPN/g. The detection of *Salmonella* indicates a potential public health risk, particularly when eggs are consumed raw or undercooked. These findings establish baseline data on the presence of *Salmonella*. in commercial eggs from Santander and highlight the importance of maintaining microbiological surveillance and strengthening biosecurity and sanitary control measures to ensure egg safety.

Key words: *Food safety; prevalence; Salmonella* Enteritidis*; Salmonella; shell eggs.*

RESUMEN

La salmonelosis es una de las principales enfermedades transmitidas por alimentos a nivel mundial, y los huevos son reconocidos como un vehículo de *Salmonella* especialmente *Salmonella enterica* subsp. *enterica* serovar Enteritidis. El objetivo de este estudio fue determinar la prevalencia y la carga de *Salmonella* en huevos comerciales producidos en el departamento de Santander, Colombia. Se recolectaron 360 muestras de huevos provenientes de seis provincias durante un período de tres meses. Las cáscaras y los contenidos internos se analizaron por separado siguiendo el método ISO

@LIMENTECH CIENCIA Y TECNOLOGÍA ALIMENTARIA
ISSN Impreso 1692-7125/ ISSN Electrónico 2711-3035. Volumen 23 No. 2, p. 182 - 200, año 2025
Facultad de Ingenierías y Arquitectura
Universidad de Pamplona

6579-1:2017, con confirmación bioquímica y serológica de los aislamientos. *Salmonella* se detectó en cinco muestras, correspondiente a una prevalencia de 1,4 %. Cuatro muestras positivas se encontraron en la cáscara y una en el contenido del huevo, provenientes de dos granjas. Un aislamiento fue identificado presuntivamente como *S.* Enteritidis, con prevalencia de 0,3 %. La cuantificación mediante el método del número más probable mostró promedio de 0,052 NMP/g. Aunque la prevalencia y las cargas bacterianas fueron bajas, la detección de *Salmonella* evidencia un potencial riesgo para la salud pública, especialmente cuando los huevos se consumen crudos o poco cocidos. Los resultados obtenidos establecen una línea base sobre la presencia de *Salmonella* en huevos comerciales de Santander y resaltan la importancia de mantener la vigilancia microbiológica y fortalecer las medidas de bioseguridad y control sanitario para garantizar la inocuidad del producto.

Palabras clave: *cáscara de huevo, prevalencia, Salmonella* Enteritidis, *Salmonella, inocuidad alimentaria*

*Autor a quien debe dirigirse la correspondencia Gina Parra E-mail: patriciaginha@yahoo.es

‡ Créditos compartidos equitativamente entre autores Castillo y Clavijo como Co-Directores del proyecto

INTRODUCTION

Salmonellosis is a major foodborne disease of global public health concern and remains one of the leading causes of bacterial gastroenteritis worldwide. Non-typhoidal *Salmonella* is commonly associated with the consumption of contaminated foods of animal origin, particularly poultry products and shell eggs (CDC, 2020; FDA, 2022; OMS, 2018). In the United States, *Salmonella* enterica serovars Enteritidis and *S.* Typhimurium account for a substantial proportion of human salmonellosis cases and are frequently linked to eggs and egg products (USDA, 2023).

Shell eggs may become contaminated with *Salmonella* Enteritidis through several transmission routes. Vertical transmission occurs when the pathogen colonizes the

reproductive organs of laying hens, allowing contamination of egg contents prior to shell formation. Horizontal transmission may occur during oviposition or post-lay handling, as eggs pass through the cloaca and become exposed to fecal material, dust, water, equipment, or handlers. Under favorable conditions of temperature, humidity, and storage time, *Salmonella* may penetrate the eggshell and reach the internal contents, increasing the risk of human exposure (Kaiser & Lamont, 2001).

Eggs are widely consumed worldwide due to their affordability and high nutritional value, providing high-quality protein, vitamins, and essential minerals. However, the consumption of raw or undercooked eggs, as well as egg-based products that do not undergo sufficient heat treatment—such as mayonnaise, salad dressings, desserts, and beverages—has frequently been associated with outbreaks of salmonellosis (ICMSF, 2016). Consequently, shell eggs remain a critical control point within food safety systems.

Colombia is one of the main egg-producing countries in Latin America, and the department of Santander represents an important contributor to national production. In 2023, egg production in Santander reached approximately 3.878 billion units (FENAVI, 2024). Nationally, egg production totaled 16.864 billion units during the same year (FENAVI, 2024). Nevertheless, the sector experienced a production decrease of approximately 4.6% in 2022, reaching levels similar to those reported in 2020, largely due to increased production costs associated with key feed inputs such as corn and soybean (Bolsa Mercantil, 2024).

Shell eggs are a food of high biological value, yet their handling and origin can jeopardize public health*;" The monitoring of hygienic-sanitary conditions is critical not only in primary production but also in the food services where these raw materials are processed, as deficiencies in the environment can enhance the transmission of pathogens*" (Castillo-Luquez et al., 2023). In Colombia, the prevalence of foodborne diseases is closely linked to*;"food security in vulnerable populations, where access to safe food is a fundamental pillar in preventing malnutrition diagnoses***"** (Mora-Aguirre, et al., 2024a; Mora-Aguirre et al., 2024b; Pino Meléndez, et al., 2024; Pineda-Zambrano, et al., 2020).

Globally, egg consumption has increased by approximately 12%. Regarding international trade, the Netherlands ranks as the leading exporter with 21.7% of global exports, followed by the United States with 11.7% (Bolsa Mercantil, 2024). In Colombia, approximately 98% of poultry farms correspond to small-scale family production systems with limited technological development, while only 2% are highly technified. Egg-laying production accounts for approximately 39% of poultry activities, primarily concentrated in the departments of Cundinamarca and Santander, followed by Valle del Cauca, Antioquia, and Quindío.

Eggs are considered one of the most regulated animal-derived food products in international trade due to strict sanitary and safety requirements. According to the Food and Agriculture Organization, global egg production has doubled since the 1960s, reflecting its growing importance as an accessible and nutritionally valuable food source (FAO, 2023; Parada, et al., 2020). Eggs are also considered one of the most affordable sources of high-quality protein available in the market. In Colombia, the average consumption is estimated at approximately 291 eggs per person per year (Castellanos, et al., 2023; Soto & Caballero, 2021; Agronegocios, 2020; Padilla-Frías, et al.,2018).

Public health authorities, including the Centers for Disease Control and Prevention, the Pan American Health Organization, and the Colombian Ministry of Health and Social Protection, have classified eggs as a high-risk food for public health due to their association with salmonellosis transmission (CDC, 2020; Resolution 0719 of 2015). Salmonellosis remains a significant global health problem, causing approximately 2.2 million deaths worldwide, with children representing the most vulnerable population (OMS, 2018). In the United States alone, the CDC estimates approximately 1.35 million cases of salmonellosis annually, resulting in about 420 deaths (FDA, 2023).

The National institutions such as the National Federation of Poultry Producers (FENAVI) and the Colombian Agricultural Institute (ICA) are currently working toward strengthening these standards (Moreno, 2019).

Salmonella is one of the most important pathogens responsible for foodborne diseases. The genus includes more than 2,400 serotypes, among which *Salmonella* Enteritidis and *Salmonella* Typhimurium are the most frequently associated with human

infections, accounting for nearly 50% of reported cases in the United States (USDA, 2019).

According to the World Health Organization, foodborne diseases affect approximately one in ten people worldwide each year, causing around 420,000 deaths annually. Children under five years of age represent nearly one-third of these fatalities (WHO, 2025). Non-typhoidal *Salmonella.* is one of the principal etiological agents responsible for these illnesses. Furthermore, *Salmonella* is recognized as one of the four leading causes of diarrheal diseases worldwide (Peña-Rivera, et al., 2023; Peñaloza & Hernández, 2018; OMS, 2018). The bacterium is highly resilient and can survive for several weeks in dry environments and for months in water.

In the United States, the Food and Drug Administration has estimated that approximately 79,000 foodborne illness cases are associated with the consumption of contaminated eggs each year, resulting in approximately 30 deaths (FDA, 2017). In Europe, *Salmonella* is responsible for nearly one-third of reported foodborne outbreaks. In 2023, salmonellosis ranked as the second most frequently reported foodborne disease in the United States, but it remained the leading cause of foodborne hospitalizations and deaths (FDA, 2023).

In Colombia, the National Institute of Health reported 719 foodborne disease outbreaks during 2023 associated with contaminated food and water. Among the identified etiological agents were *Escherichia coli* (5.4%), *Staphylococcus aureus* (3.9%), *Salmonella* (1.5%), and *Bacillus cereus* (1.3%). Most outbreaks occurred in households (49.7%), followed by educational institutions (13.9%) and restaurants (10.7%). The most affected age groups were individuals between 20 and 49 years (42.1%), adolescents between 10 and 19 years (27.1%), and children aged 1 to 4 years (11.6%) (INS, 2024).

Previous studies conducted in Colombia have also demonstrated the presence of *Salmonella* in egg samples. For example, (Castañeda et al., 2017) detected *Salmonella* in 9 (9.4%) of eggs collected from four localities in Bogotá, whith 5 isolates found in the internal egg contents and 4 on the eggshell surface.

Therefore, the objective of this study was to determine the prevalence and concentration of *Salmonella* in commercial shell eggs produced in Santander, Colombia. The

findings provide baseline information to support food safety risk management, improve control programs in the egg production chain, and protect public health.

MATERIALS AND METHODS

Study area and sample collection. The study was conducted in the department of Santander, Colombia, a major egg-producing region at the national level. According to official records from the Colombian Agricultural Institute (ICA), Santander has both registered commercial laying-hen farms operating under biosecurity programs and unregistered farms for which no official census is available.

A total of 360 commercial shell eggs were collected from six of the seven provinces of Santander (Guanentá, Comunera, Yariguíes, García Rovira, Metropolitana, and Vélez). Samples were obtained from six commercial farms, which were coded as farms A through F to ensure confidentiality, as recommended by the National Poultry Federation of Colombia (FENAVI).

Eggs were collected over a three-month period between November 15, 2022, and March 2023, with nonconsecutive sampling days. Eggs originated from flocks aged approximately 29 to 80 weeks and were collected from houses using either manual or automatic egg collection systems. Samples were taken primarily from the morning lay (5:00 to 6:00 a.m.) and, in some cases, from the evening lay (5:00 to 6:00 p.m.). For each farm and sampling month, 20 eggs were randomly selected from three trays, resulting in approximately 60 eggs per farm and a total sample size of 360 eggs.

Sample preparation. Eggshells and internal contents were analyzed separately. Eggs were aseptically cracked using sterile spatulas, and the shells were separated from the combined albumen and yolk. Each fraction was placed into sterile bags. From each sample, 25 g were used for microbiological analysis, while the remaining portions were stored at refrigeration temperature as retain samples for subsequent quantification when applicable.

Detection of *Salmonella.* The presence or absence of *Salmonella* was determined according to ISO 6579-1:2017, in compliance with Colombian Technical Standard NTC 1240 (2011) and Resolution 1407 (2022). Detection consisted of pre-enrichment,

selective enrichment, isolation on selective agar media, and biochemical and serological confirmation.

For pre-enrichment, 25 g of sample were added to 225 mL of buffered peptone water (Oxoid, UK) and incubated at 37°C for 18 h. Following pre-enrichment, 0.1 mL of culture was transferred to 10 mL of Rappaport–Vassiliadis soya broth (RVS; Merck, Germany) and incubated at 41.5°C ± 1°C for 24 h ± 3 h. In parallel, 1 mL of pre-enrichment culture was transferred to 10 mL of Müller–Kauffmann tetrathionate-novobiocin broth (MKTTn; Merck) and incubated at 37°C ± 1°C for 24 h ± 3 h.

Selective isolation was performed by streaking enriched cultures onto xylose lysine deoxycholate (XLD) agar and Hektoen enteric agar (Oxoid). Plates were incubated at 37°C ± 1°C for 24 h ± 3 h. Presumptive *Salmonella* colonies were selected based on typical morphology: red colonies with or without black centers on XLD agar and blue-green colonies with or without black centers on Hektoen agar.

Biochemical and serological confirmation

At least three presumptive colonies per plate were subjected to biochemical identification using the API 20E system (bioMérieux, France), following the manufacturer's instructions. Results were interpreted using the API 20E database software. Additional biochemical tests, including oxidase activity and carbohydrate fermentation, were used to exclude non-*Salmonella* isolates.

Serological confirmation was performed by slide agglutination using commercial O (somatic) and H (flagellar) antisera (Thermo Scientific™, USA; Oxoid). Confirmed reactions were interpreted according to the Kauffmann–White scheme. A reference strain of *Salmonella* Enteritidis (ATCC 13067) was used as a positive control.

Quantification of *Salmonella spp.*

Samples confirmed positive for *Salmonella spp.* were subjected to quantitative analysis using the most probable number (MPN) method, following the Food Safety and Inspection Service (FSIS–USDA) Microbiology Laboratory Guidebook, Appendix 2.05d. Analyses were performed in triplicate with a 95% confidence level.

A homogenized sample (65 ± 2 g) was mixed with 585 mL of RVS broth and processed in a stomacher for 2 min. Serial dilutions corresponding to 10 g, 1 g, and 0.1 g were

prepared and inoculated into three tubes per dilution. Tubes were incubated at 41°C for 24 h, and growth was assessed by turbidity. Positive tubes were confirmed by plating on XLD agar and by biochemical tests using triple sugar iron (TSI) and lysine iron agar (LIA). MPN values were calculated using FSIS–USDA reference tables.

RESULTS AND DISCUSSION

Prevalence of *Salmonella* in shell egg samples

A total of 360 commercial shell eggs were analyzed to determine the presence of *Salmonella* Eggshells and internal contents (albumen–yolk) were evaluated separately. *Salmonella* was detected in five samples, resulting in an overall prevalence of 1.39%. Of the positive samples, four corresponded to eggshells (1.11%) and one to egg contents (0.27%) (Table 1).

Table 1. Presence of *Salmonella* in shell eggs collected from six commercial farms in Santander, Colombia

Farm	Egg shell samples analyzed	Egg shell positive (n)	Egg shell prevalence (%)	Egg content samples analyzed	Egg content positive (n)	Egg content prevalence (%)
A	60	1	1.7	60	1	1.7
B	60	0	0.0	60	0	0.0
C	60	3	5.0	60	0	0.0
D	60	0	0.0	60	0	0.0
E	60	0	0.0	60	0	0.0
F	60	0	0.0	60	0	0.0
Total	**360**	**4**	**1.1**	**360**	**1**	**0.3**

The present study provides baseline data on the prevalence and concentration of *Salmonella* in commercial shell eggs produced in Santander, Colombia. The overall prevalence of 1.4% observed in this study is relatively low compared with reports from other regions in Latin America, where prevalence values ranging from 2.4% to more than 15% have been documented in shell eggs and egg contents (Freije et al., 2019; Rumão et al., 2020; Guier et al., 2022). These differences may reflect variability in biosecurity practices, flock management,

environmental conditions, and regulatory oversight across production systems.

Positive samples were identified in eggs collected from two farms (A and C), whereas no *Salmonella spp.* was detected in samples from farms B, D, E, or F. Farm C showed the highest prevalence on eggshells (5.0%), while farm A presented *Salmonella spp.* in both eggshell and internal content samples, each with a prevalence of 1.7%.

The detection of *Salmonella* primarily on eggshells rather than in internal contents suggests that post-lay contamination and environmental exposure are likely the dominant routes of contamination in the studied farms. Similar findings have been reported in studies conducted in Colombia and other countries, where eggshell contamination was more frequent than internal contamination (Ramírez et al., 2015; Castañeda et al., 2017).

Factors such as contact with fecal material, contaminated surfaces, dust, and handling practices during collection and storage may facilitate shell contamination, while subsequent bacterial penetration into the egg contents can occur under conditions of high humidity, elevated temperature, and extended storage time.

Presumptive identification of *Salmonella* Enteritidis. Biochemical identification using the API 20E system confirmed five *Salmonella* isolates. One isolate from farm C was identified as *Salmonella* Gallinarum and was excluded from further analysis. The remaining four isolates were confirmed as *Salmonella* by biochemical testing.

Serological analysis revealed that one isolate reacted positively with both O (somatic) and H (flagellar) antisera and was presumptively identified as *Salmonella* enterica serovar Enteritidis. This result corresponds to a prevalence of 0.27% among the total egg samples analyzed (Table 2).

Table 2. Prevalence of presumptive *Salmonella* Enteritidis in commercial shell eggs

Sample type	Total samples	Presumptive *S.* Enteritidis (n)	Prevalence (%)	95% CI (%)
Shell eggs	360	1	0.3	0.93

Only one isolate was presumptively identified as *Salmonella enterica* serovar Enteritidis, representing a prevalence of 0.3%. Although low, the presence of this serovar is of particular concern due to its strong

association with egg-related outbreaks of salmonellosis worldwide.

International surveillance data from the United States and the European Union consistently identify *S.* Enteritidis as one of the leading causes of egg-associated salmonellosis, even in countries with established control programs (CDC, 2023; Stilz et al., 2022). Therefore, the detection of this serovar in commercial eggs from Santander, even at low prevalence, highlights the need for continued vigilance.

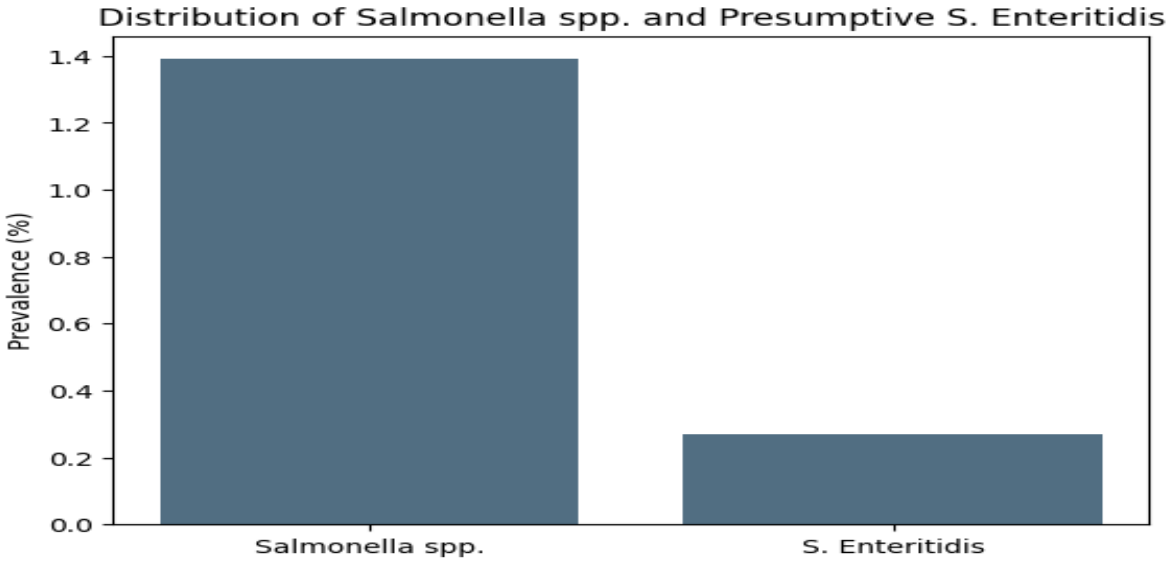

Figure 1. Distribution of *Salmonella* and presumptive *S*. Enteritidis among positive samples.

In addition, Xu et al. (2022) conducted a study to corroborate the relationship between the virulence of *Salmonella enterica* serovar Enteritidis and egg yolk as an inoculation medium, administering the bacterium to mice, which resulted in a high mortality rate.

Therefore, it is crucial to implement sanitary control measures in egg-producing farms in Santander and throughout Colombia, especially those that have not been registered with governmental authorities.

Quantification of *Salmonella* by MPN

Quantitative analysis was conducted on samples confirmed positive for *Salmonella* using the most probable number (MPN)

method. The average concentration of *Salmonella* among positive samples was 0.052 MPN/g. Samples from farm A showed an average of 0.042 MPN/g, whereas samples from farm C presented a higher average concentration of 0.067 MPN/g (Table 3).

Table 3. Quantification of *Salmonella* in positive shell egg samples by the MPN method

Farm	10	1	0,1	Reported positive values	Estimated NMP/g	95% Confidence Limit
AM1	1/3	1/3	0/3	110	0.074	0.42
AM1	1/3	0/3	0/3	100	0.036	0.18
AM1	0/3	0/3	0/3	000	<0.03	0.095
AM2	1/3	0/3	0/3	100	0.036	0.18
AM2	0/3	0/3	0/3	000	<0.03	0.095
AM2	0/3	0/3	0/3	000	<0.03	0.095
AM1	1/3	0/3	0/3	100	0.036	0.18
AM1	0/3	0/3	0/3	000	<0.03	0.095
AM1	0/3	0/3	0/3	000	<0.03	0.095
CM1	1/3	1/3	0/3	110	0.074	0.2
CM1	0/3	0/3	0/3	000	<0.03	0.095
CM1	0/3	0/3	0/3	000	<0.03	0.095
CM2	2/3	0/3	0/3	200	0.092	0.38
CM2	0/3	0/3	0/3	000	<0.03	0.095
CM2	0/3	0/3	0/3	000	<0.03	0.095
CM3	1/3	0/3	0/3	100	0.036	0.18
CM3	0/3	0/3	0/3	000	<0.03	0.095
CM3	1/3	0/3	0/3	100	0.036	0.18
Media					0.052	0.15

Across all positive samples, detectable *Salmonella* levels were observed in approximately 33% of the replicates, indicating low but measurable contamination levels. The average *Salmonella* concentration of 0.052 MPN/g observed in this study indicates low-level contamination. Nevertheless, low bacterial loads do not eliminate public health risk, particularly when eggs are consumed raw or undercooked or

are used as ingredients in foods that do not receive adequate heat treatment. Previous risk assessments have demonstrated that even small numbers of *Salmonella* cells can lead to illness, depending on host susceptibility and consumption patterns (ICMSF, 2016). This is especially relevant in regions where traditional foods and beverages prepared with raw eggs are commonly consumed.

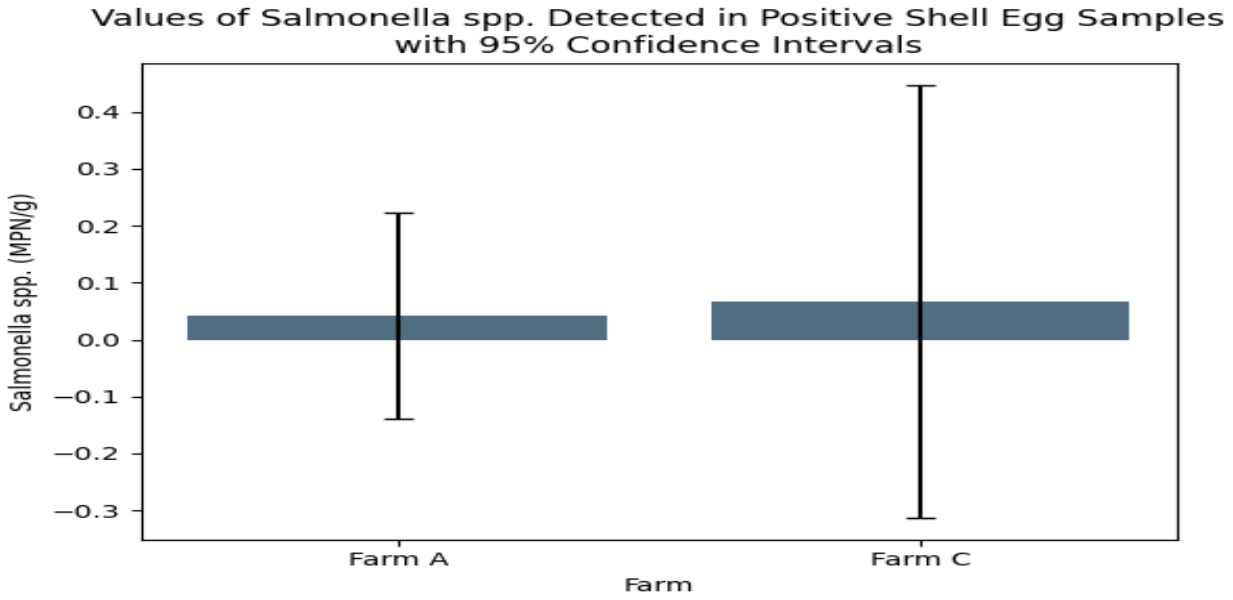

Figure 2. Mean values of *Salmonella* detected in positive shell egg samples from farms A and C, expressed as most probable number (MPN/g). Error bars represent 95% confidence intervals

Compared with international reports, the lower prevalence and bacterial loads observed in Santander may reflect the impact of biosecurity programs, vaccination strategies, and monitoring activities promoted by national authorities and poultry industry organizations. Similar reductions in egg-associated *Salmonella* prevalence have been documented in countries that implemented mandatory control programs targeting *S.* Enteritidis at the farm level (FAO, 2023). Still, with the numbers of eggs being sent to the market every day, 1.4% prevalence represents a large number of contaminated eggs in the market, involving a large number of consumers potentially being exposed to *Salmonella* on eggs. However, the presence of unregistered or informal egg-

producing farms represents a critical gap in the food safety system and may contribute disproportionately to consumer exposure, as these operations may lack adequate sanitary controls and official oversight.

The findings of this study underscore the importance of maintaining and strengthening microbiological surveillance throughout the egg production and distribution chain. Establishing regional baseline data is essential for tracking trends over time, supporting quantitative microbial risk assessment, and evaluating the effectiveness of control measures. Moreover, harmonization with international standards and surveillance frameworks can enhance the competitiveness of the Colombian egg industry while protecting public health.

CONCLUSION

This study establishes baseline data on the prevalence and concentration of *Salmonella* in commercial shell eggs produced in Santander, Colombia. The overall prevalence was low (1.39%), and only one isolate was presumptively identified as *Salmonella* enterica serovar Enteritidis (0.27%). Quantitative analysis revealed low bacterial loads, with an average concentration of 0.052 MPN/g among positive samples.

Despite the low prevalence observed, the detection of *Salmonella* spp and S. Enteritidis confirms that commercial shell eggs remain a potential vehicle for foodborne transmission, particularly when consumed raw or undercooked. These findings highlight the importance of sustained microbiological surveillance, strict biosecurity measures, and effective control programs throughout the egg production chain.

This research was funded by the Universidad de Santander, Colombia, and Texas A&M University, Food Science and Technology Doctorate, Universidad de Pamplona, Colombia, and was supported by the Secretariat of Health of Santander, Colombia.

AUTHOR CONTRIBUTIONS

The authors declare no conflict of interest

REFERENCES

Agronegocios. (2020, 29 de diciembre). *Consumo de huevo en Colombia tuvo un crecimiento de 11,6% en el año de la pandemia*. https://www.agronegocios.co/agricultura/consumo-de-huevo-en-colombia-tuvo-un-crecimiento-de-116-en-el-ano-de-la-pandemia-3127013

Bolsa Mercantil de Colombia. (2024). *Análisis del producto: Sector avícola*. https://www.bolsamercantil.com.co/sites/default/files/2024-05/Informe_sector_avicola_final.pdf

Castañeda, R., Pulido, A., Mendoza, M., Carrascal, A., & Sandoval, K. (2017). Detección e identificación de *Salmonella* spp. en huevos para consumo humano provenientes de diferentes localidades de Bogotá, Colombia. *Infectio*, *21*(3), 147–153. https://doi.org/10.22354/in.v21i3.672

Castellanos-González Leónides, Vera-Peña Mariam S. Calderón-Gutiérrez Jefferson A. (2023) Enfermedades fúngicas en mora (*Rubus* spp.) en los municipios de Pamplona Y Pamplonita Norte De Santander" Revista @limentech, Ciencia y Tecnología Alimentaria. ISSN Impreso 1692-7125 ISSN Electrónico 2711-3035. Volumen 21 N° 1. Pp: 69 -84. https://doi.org/10.24054/limentech.v21i2.2628

Castillo-Luquez, G., León-Peña, M., Filott-Tamará, M., & García-Toscano, Y. (2023). Evaluación de condiciones higiénico-sanitarias en el servicio de alimentación de un centro educativo en la ciudad de Barranquilla en el periodo 2010-2022. *@limentech, Ciencia y Tecnología Alimentaria*, *21*(2), 124–137. https://doi.org/10.24054/limentech.v21i2.2662

Centers for Disease Control and Prevention. (2020). *Salmonella and eggs*. https://www.cdc.gov/foodsafety/communication/salmonella-and-eggs.html

Centers for Disease Control and Prevention. (2023). *La Salmonella y los alimentos*. https://www.cdc.gov/foodsafety/es/communication/salmonella-and-food-sp.html

Federación Nacional de Avicultores de Colombia. (2024). *Información estadística: Producción de huevos*.

https://fenavi.org/estadisticas/produccion-huevos-p/

Food and Agriculture Organization & World Health Organization. (2005). *Comisión del Codex Alimentarius: Manual de procedimiento*. https://www.fao.org/3/y5817s/y5817s.pdf

Food and Agriculture Organization of the United Nations. (2023). *Carne, huevos y leche son fuente esencial de nutrientes, en especial para los más vulnerables*. https://www.fao.org/newsroom/detail/meat-eggs-and-milk-essential-source-of-nutrients-new-fao-report-says-250423/es

Food and Drug Administration. (2017/2022). *Seguridad con los huevos*. https://www.fda.gov/food/buy-store-serve-safe-food/seguridad-con-los-huevos

Food and Drug Administration. (2023). *Conozca los datos sobre la Salmonella*. https://www.fda.gov/animal-veterinary/animal-health-literacy/conozca-los-datos-sobre-la-salmonella

Freije, J., Comba, E., Caffer, M., Alcain, A., & Pidone, C. (2019). Aislamiento de *Salmonella* spp. a partir de huevos de gallina comercializados en la ciudad de Casilda, Santa Fe, Argentina. *Revista FAVE - Sección Ciencias Veterinarias*, *18*(1), 23–25. https://doi.org/10.14409/favecv.v18i1.8277

Guier, M., Davidovich-Young, G., Wong-González, E., & Cubero-Castillo, E. (2022). Calidad microbiológica y fisicoquímica y sabor de huevos de gallina de producción convencional o pastoreo. *Agronomía Mesoamericana*, *33*(1), Artículo 46140. https://doi.org/10.15517/am.v33i1.46140

Instituto Colombiano de Normas Técnicas y Certificación. (2011). *Norma Técnica Colombiana NTC 1240: Huevos de gallina frescos para consumo*.

Instituto Nacional de Salud. (2024). *Boletín epidemiológico semanal, semana 3*. https://www.ins.gov.co/buscador-eventos/BoletinEpidemiologico/2024_Bolet%C3%ADn_epidemiologico_semana_3.pdf

International Commission on Microbiological Specifications for Foods. (2016). *Microorganisms in foods 8: Use of data for*

assessing process control and product acceptance. Springer.

International Organization for Standardization. (2017). *ISO 6579-1:2017 Microbiology of the food chain—Horizontal method for the detection, enumeration and serotyping of Salmonella—Part 1: Detection of Salmonella spp.* Geneva, Switzerland.

Kaiser, M., & Lamont, S. (2001). Genetic line differences in survival and pathogen load in young layer chicks after *Salmonella enterica* serovar Enteritidis exposure. *Poultry Science*, *80*(8), 1105–1108. https://doi.org/10.1093/ps/80.8.1105

Ministerio de Salud y Protección Social. (2015). *Resolución 0719 de 2015: Clasificación de alimentos para consumo humano*. https://www.invima.gov.co/documents/20143/344791/resoluci%C3%B3n0719de2015anexot%C3%A9cnico.pdf

Mora-Aguirre, C. P., Mancilla-Cabezas, A. F., & Osorio-Torres, C. A. (2024a). Influencia de las condiciones laborales en la prevalencia de exceso de peso en taxistas, Cali Colombia. *@limentech, Ciencia y Tecnología Alimentaria*, *22*(1), 266–281. https://doi.org/10.24054/limentech.v22i1.3175

Mora-Aguirre, C. P., Sandoval-Zapata, A. S., Tombe-Cantor, C. D., & Zúñiga-Fory, I. (2024b). Seguridad alimentaria en niños con diagnóstico de desnutrición aguda, Cali: estudio de prevalencia. *@limentech, Ciencia y Tecnología Alimentaria*, *22*(1), 84–97. https://doi.org/10.24054/limentech.v22i1.2864

Moreno, G. (2019, 13 de enero). *Al campo: Los colombianos consumimos 290 huevos al año*. Caracol Radio. https://caracol.com.co/programa/2019/01/13/al_campo/1547388159_692239.html

Padilla-Frías, K. Granados-Conde, Cl. León - Méndez, G. Arrieta, Y. y Torrenegra - Alarcón, M. (2018). Evaluación de la influencia de la temperatura en procesos de secado. Revista @limentech. 14(1), 107-117. https://doi.org/10.24054/16927125.v1.n1.2018.3935

Parada, M., Caballero, L., M., & Rivera, M. (2020). Selección y entrenamiento de jueces en cata de café. *@limentech,*

Ciencia Y Tecnología Alimentaria, *18* (2), 104–124. https://doi.org/10.24054/limentech.v18i2.3213

Peña-Rivera, M. P., Smith-Martínez, L. M., Carmona-Hernández, Y. D. C., & Franco-Anaya, P. A. (2023). Calidad microbiológica y condiciones sanitarias de almacenamiento del agua de lluvia recolectada: desde techos de viviendas para consumo humano en San Cayetano, Bolívar. *@limentech, Ciencia y Tecnología Alimentaria*, *21*(3, Suplemento Especial), 5–20. https://doi.org/10.24054/limentech.v21i3.2725

Peñaloza, R., & Hernández, M. (2018). Conservación de la uchuva (*Physalis peruviana* L.) mediante la aplicación de recubrimiento comestible a base de gel de aloe *barbadensis miller.* Revista @limentech, Ciencia y Tecnología Alimentaria, 16(2), 50-67. https://doi.org/10.24054/16927125.v16.i2.2018.3228

Pineda-Zambrano, M. C., Pineda, D., Labarca, J. L., & González-García, H. (2020). Caracterización y comportamiento biológico de una cepa nativa de Trichoderma harzianum Rifai del Sur del Lago de Maracaibo, Venezuela. *Ciencia y Tecnología Agropecuaria,* 5(1), 9–15. https://doi.org/10.24054/cyta.v5i1.788

Pino Meléndez, V. E., Cobos Mora, F. J., Troya Guerrero, G., & Reyes Villón, H. (2024). Avances en la evaluación de microorganismos como agentes biocontroladores de patógenos causantes de enfermedades en el cultivo de arroz. *Ciencia y Tecnología Agropecuaria,* 9(1), 27–35. https://doi.org/10.24054/cyta.v9i1.2955

Ramírez, R., Rincón, A., & Vargas, J. (2015). *Salmonella* Enteritidis en huevos de gallina comercializados en Tunja, Colombia. *Salud & Sociedad UPTC*, *2*(1). https://doi.org/10.19053/19092407.3496

Rey-Rodríguez, J. F., Cobos-Rodríguez, D. L., & Prada-Álvarez, Y. G. (2023). Evaluación del efecto tecnológico de la albúmina de huevo en polvo como estabilizante en un helado de crema. *@limentech, Ciencia y Tecnología Alimentaria*, *21*(1), 48–68. https://doi.org/10.24054/limentech.v21i1.2307

Rumão, J., Brito, D., Reinehr, C., Conceição, A., & Frazão, R. (2020). *Salmonella* spp. and microbial quality indicators in eggs marketed in Brazil. *Research, Society and Development*, *9*(8), e480986175. https://doi.org/10.33448/rsd-v9i8.6175

Soto-Toloza, E. P., & Caballero-Pérez, L. A. (2021). Evaluación de la calidad de café en taza de una muestra comercial de la región frente a una muestra comercial de alta calidad tipo exportación. *@limentech, Ciencia y Tecnología Alimentaria*, *19*(1), 17–35. https://doi.org/10.24054/limentech.v19i1.1408

Stilz, C., Cavallo, S., Garman, K., & Dunn, J. (2022). *Salmonella* Enteritidis outbreaks associated with egg-producing farms not regulated by FDA's egg safety rule. *Foodborne Pathogens and Disease*, *19*(8), 529–534. https://doi.org/10.1089/fpd.2022.0025

United States Department of Agriculture. (2023). *Releases proposed regulatory framework to reduce Salmonella infections linked to poultry products*. https://www.fsis.usda.gov/news-events/news-press-releases/usda-releases-proposed-regulatory-framework-reduce-salmonella

World Health Organization. (2018). *Food safety*. https://www.who.int/es/news-room/fact-sheets/detail/food-safety

World Health Organization. (2025). *Estimating the burden of foodborne diseases*. https://www.who.int/activities/estimating-the-burden-of-foodborne-diseases

Xu, Y., Abdelhamid, A., Sabag-Daigle, A., Sovic, M., Ahmer, B., & Yousef, A. (2022). The role of egg yolk in modulating the virulence of *Salmonella enterica* serovar Enteritidis. *Frontiers in Cellular and Infection Microbiology*, *12*, 903979. https://doi.org/10.3389/fcimb.2022.903979.