

Identification of *Salmonella* sp. in Duck Eggs at Segiri Central Market in Samarinda

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ABSTRACT

Duck eggs are widely consumed due to their high nutritional content, but improper handling and storage can increase the risk of microbial contamination. This study aimed to identify *Salmonella* sp. and evaluate the microbiological quality of duck eggs based on the Total Plate Count (TPC) according to shell condition. A quantitative descriptive study with a laboratory observational design was conducted on 27 duck egg samples from 9 vendors at the Segiri Central Market in Samarinda, consisting of one clean, one dirty, and one cracked egg from each vendor. *Salmonella* sp. was identified using BPW, SSA, and biochemical tests, while TPC was determined using the pour plate method on PCA medium. The data were analysed using descriptive statistics. The results showed that 1 sample (3.7%) tested positive for *Salmonella* sp., and 7 samples (25.9%) exceeded the limit set by BPOM Regulation No. 13 of 2019.

INTRODUCTION

Duck eggs are commonly consumed as a source of animal protein and are widely distributed through traditional markets. During production, transportation, storage, and retail handling, eggs may become contaminated by microorganisms from the environment, equipment, surfaces, water, animals, or human handling. Pathogenic microorganisms of concern include *Salmonella* spp., which are important foodborne pathogens associated with contaminated animal-derived foods.

The eggshell and its associated cuticle provide an important physical barrier against microbial penetration. However, contamination may occur when the protective structure is damaged or when microorganisms adhere to the eggshell surface. Cracks or other structural damage may provide potential entry points for microorganisms, whereas contamination of intact shells may still occur through poor handling and environmental exposure. Therefore, evaluation of eggshell condition can provide useful descriptive information concerning the microbiological characteristics of eggs sold at retail markets.

Salmonella is a Gram-negative member of the family Enterobacteriaceae and is an important cause of foodborne infection. Contaminated eggs may serve as a vehicle for transmission when they are consumed without adequate cooking or are handled improperly. Detection of *Salmonella* therefore provides specific information concerning the presence of an important foodborne pathogen, whereas Total Plate Count (TPC) provides a general measure of viable aerobic microbial load. TPC cannot be used to specifically identify *Salmonella* and should therefore be interpreted separately from pathogen-specific testing.

Previous studies have reported the occurrence of *Salmonella* and other bacteria in eggs sold through traditional markets. However, information concerning the microbiological characteristics of duck eggs sold at Segiri Central Market, Samarinda, particularly according to eggshell condition, remains limited.

Therefore, this study was conducted to detect *Salmonella* sp. and describe TPC values in duck eggs according to clean, dirty, and cracked eggshell conditions. The objective of this study was to detect the presence of *Salmonella* sp. and describe the TPC values of duck eggs sold at Segiri Central Market, Samarinda, based on eggshell condition.

LITERATURE REVIEW

Market

Markets are a vital element in the economy and social life of a community as venues for buying and selling, with wholesale markets serving as hubs for the distribution of commodities in large quantities, thereby assisting wholesalers and fostering price transparency (Yulianto et al. 2022). Markets can be based on the types of goods traded, namely consumer and non-consumer markets (Rustini *et al.* 2025), management systems are divided into traditional and modern markets (Ilmi *et al.* 2022) and environmental health regulations that distinguish between healthy and unhealthy markets in accordance with Indonesian Ministry of Health Regulation No. 519/Menkes/SK/VI/2008.

Environmental conditions and vendors practices in handling foodstuffs are the primary sources of contamination by pathogenic bacteria such as *Salmonella* sp., *Escherichia coli*, *Staphylococcus aureus*, and *Listeria monocytogenes*, which frequently contaminate fresh food products (Herwianti & Wijayanti, 2023). Thus, markets have the potential to serve as reservoirs for microorganisms that cause foodborne diseases. This bacterial contamination has serious implications for public health, ranging from diarrhea and typhoid to food poisoning, and poor sanitation can facilitate the spread of harmful microorganisms, making it a major risk factor for foodborne diseases in the community (Thohira & Rahman, 2021).

Duck Eggshell Condition and Microbiological Quality

Eggs are a source of animal protein that have long been consumed by the public. They come from poultry such as chickens, ducks, and geese. In the supply chain, eggs pass through several stages from producers, distributors, and wholesalers to retailers before reaching consumers. As a result, the eggs received by consumers are typically more than 7 days old (Pingkan *et al.* 2022). The longer the storage period, the more the physical quality of the eggs tends to decline, as indicated by a decrease in weight and egg white height, as well as an increase in pH, all of which are signs of changes in the egg's internal quality.

Duck eggs, in particular, are rich in nutrients such as protein, fat, vitamins, minerals, and bioactive components like albumin, which contains the antimicrobial substance lysozyme. However, this protective property is not fully effective against all pathogens. The porous structure of the eggshell and the cuticle layer act as the primary barriers against microbial entry. However, if the cuticle is damaged or the shell is cracked, the protective function of the eggshell may be reduced and microorganisms may have greater opportunity to enter the egg (Fu *et al.* 2023). Therefore, clean, dirty, and cracked eggs may have different microbiological conditions depending on their handling and storage. The porous structure of duck eggshells may also allow microorganisms to enter under certain conditions (Mutaimah, 2021).

Bacterial contamination of duck eggs can occur via the trans-shell route where bacteria from the environment adhere to and penetrate a damaged shell or via the trans-ovarian route where bacterial infections, such as *Salmonella enteritidis* occur in the avian reproductive system before the shell forms (Velina *et al.* 2019). Unhygienic handling practices at the farm and retail levels such as leaving eggs exposed, mixing clean and dirty eggs, and using unhygienic containers and washing water further increase the risk of contamination (Sa'adah *et al.*, 2024). Some bacteria commonly found on eggs include *Salmonella* sp., *Escherichia coli*, *Staphylococcus aureus*, other *Enterobacteriaceae* (*Klebsiella* sp., *Proteus* sp., *Pseudomonas* sp.), and *Listeria monocytogenes*.

Pathogenic bacterial contamination in duck eggs poses serious health risks, especially when consumed undercooked. *Salmonella* sp. can cause salmonellosis with symptoms ranging from diarrhea, abdominal cramps, and fever to systemic infections in severe cases, while pathogenic *E. coli* causes gastrointestinal disorders, and *Staphylococcus aureus* produces enterotoxins that

can cause food poisoning, and some of these toxins may remain active even after the bacteria have been killed during cooking. Therefore, microbiological quality testing of eggs must include measurement of Total Plate Count (TPC) as an indicator of general microbial load, as well as specific testing for pathogens such as *Salmonella* sp. (Thaha *et al.* 2024).

***Salmonella* spp. as Foodborne Pathogens**

Bacteria are unicellular prokaryotic microorganisms capable of living in almost any habitat whether as parasites, free-living organisms, or symbionts due to their high adaptability. Based on their pathogenicity, bacteria are classified into pathogenic bacteria which cause infections, such as *Salmonella* sp., *Staphylococcus aureus*, and certain strains of *E. coli* and non-pathogenic bacteria, which generally serve as part of the normal flora, though they can become opportunistic when immunity is compromised (Fhitryani *et al.* 2017). *Salmonella* sp. itself is a Gram-negative zoonotic bacterium and one of the leading causes of foodborne illnesses such as salmonellosis, which can contaminate animal products and persist in the digestive tract, soil, water, and insects which serve as vectors for its transmission. Taxonomically, this bacterium belongs to the family Enterobacteriaceae, genus *Salmonella* (Hintono, 2022), with a rod-shaped morphology, motile due to peritrichous flagella, non spore forming, facultatively anaerobic, and capable of growing within a temperature range of 5–47°C and a pH range of 4.0–9.0, although it will die at 56°C or at salt concentrations above 9% (Nissa *et al.* 2023)

In terms of pathogenicity, *Salmonella* sp. infects through fimbriae and adhesins for initial colonization, followed by Type III secretion systems (TTSS-1 and TTSS-2) that inject effector proteins into intestinal epithelial cells, thereby triggering cellular invasion, while the lipopolysaccharide (LPS) in its cell wall triggers an inflammatory response via pro-inflammatory cytokines. These bacteria are also capable of surviving within macrophage phagosomes and possess virulence plasmids that facilitate systemic infection (Wardiani *et al.* 2025). Clinical symptoms of salmonellosis include diarrhea, fever, nausea, vomiting, abdominal pain, and dehydration, with an incubation period of 6–72 hours after consumption of contaminated food, although the infection is generally self-limiting, it can progress to bacteremia or serious systemic infection, particularly in vulnerable groups such as children, the elderly, and immunocompromised individuals (Wardiani *et al.* 2025).

Total Plate Count as an Indicator of Food Hygiene

Total Plate Count is a quantitative method for counting colonies formed by live microbial cells that grow into colonies on agar medium after incubation. The advantages of the TPC method lie in its simplicity, low cost, and ease of implementation using basic laboratory equipment, making it efficient for routine monitoring and useful as a sanitation indicator in the food production chain (Fatayati *et al.* 2023). However, this method also has limitations. It is not specific to certain types of microorganisms and therefore cannot identify the presence of specific pathogenic bacteria such as *Salmonella* sp. or *L. monocytogenes*. It may also

underestimate the microbial population because a single colony may originate from more than one bacterial cell forming a chain or cluster (Fatayati. 2023).

In practice, the TPC method requires that each viable single cell be able to grow into a single colony, using the commonly employed pour plate or spread plate techniques. Practical requirements include separate colonies for easy counting, an optimal colony count of 30–300 per plate to maintain accuracy, and observable colony size if colonies are too dense or fused; the result is reported as too many to count (TMTC) (Elkogajevani *et al.* 2025). In Indonesia, the maximum limit for microbial contamination, including TPC, is regulated by BPOM Regulation No. 13 of 2019. A TPC value exceeding the applicable limit indicates that the sample does not meet the microbiological standard (BPOM, 2019).

For *Salmonella* sp. detection, samples were subjected to pre-enrichment in Buffered Peptone Water (BPW), followed by selective culture on *Salmonella*-*Shigella* Agar (SSA). Suspected colonies were subsequently subjected to biochemical confirmation using Triple Sugar Iron Agar (TSIA), Sulfide Indole Motility (SIM), Simmons Citrate Agar (SCA), Methyl Red (MR), Voges-Proskauer (VP), and the phenylalanine/phenylpyruvate test according to the laboratory procedure. The first stage is pre-enrichment using Buffered Peptone Water (BPW) to revive bacterial cells that have been stressed by storage; the sample is incubated for 18 hours at 37°C until the medium appears cloudy. The second stage involves selective plating on *Salmonella Shigella* Agar (SSA), where *Salmonella* will grow as clear colonies with a black spot in the center due to H₂S production, while the growth of Gram-positive bacteria and other non-*Salmonella* bacteria is inhibited. The final step is a biochemical confirmation using six media TSIA (red slant, yellow butt. H₂S-positive because it ferments only glucose, not lactose or sucrose), SCA (a color change from green to blue indicates citrate positivity), SIM (H₂S-positive/black, indole-negative due to the absence of the enzyme tryptophanase, motility-positive), MR (positive/red because glucose fermentation produces strong acid), VP (negative because it does not produce acetone), and PAA (negative because it does not produce phenylpyruvate). The combined results of these six tests are sufficient to confirm the presence of *Salmonella* sp. in the tested sample.

For the TPC test, Plate Count Agar (PCA) medium is used, which is non-selective and supports the growth of various types of microorganisms without distinguishing between them. The resulting colonies are round, small to medium in size, and range in color from milky white to cream. To be counted and considered valid, colonies must be clearly separated from one another and not clustered together, with a count falling within the range of 30–300 colonies per plate according to standard counting procedures.

Conceptual Framework

Based on this literature review, this study employs a conceptual framework that examines *Salmonella* sp. contamination and microbial contamination levels through Total Plate Count (TPC) testing of duck eggs based on shell condition (clean, dirty, and cracked) using culture methods on selective

media and biochemical tests to determine the presence or absence of *Salmonella* sp. and the microbiological acceptability of the egg samples.

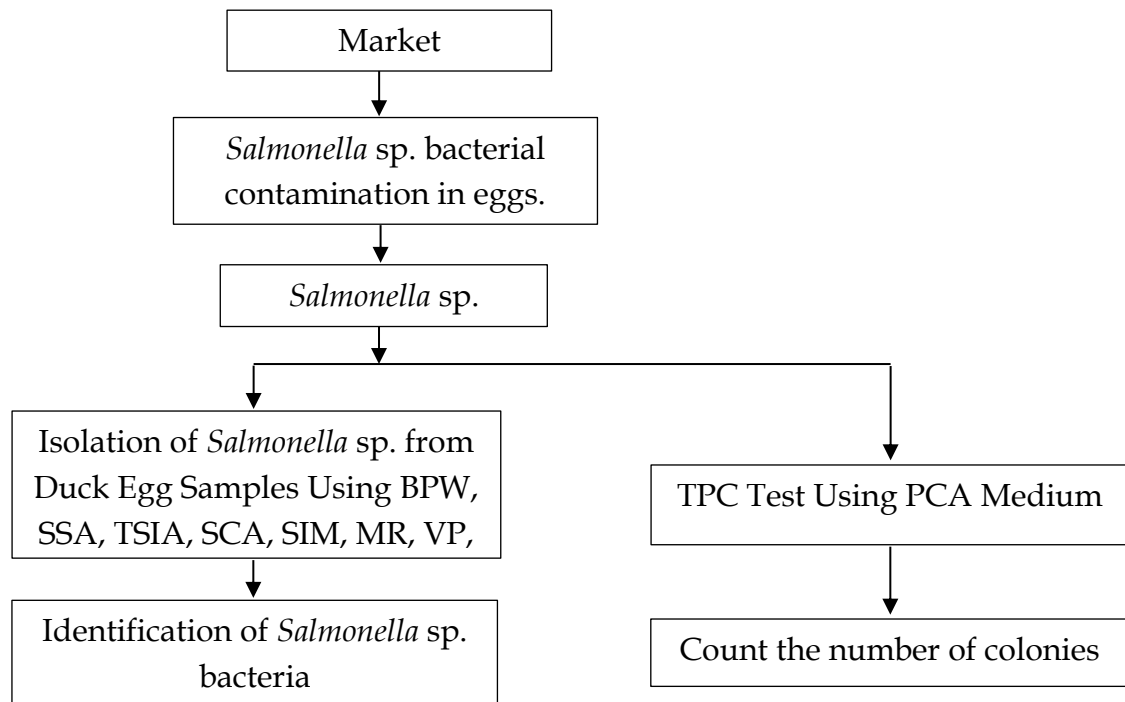


Figure 1. Conceptual Framework

METHODOLOGY

This study is a quantitative descriptive study with a laboratory observational design. It is quantitative because the data are numerical, namely the number of *Salmonella*-positive samples and the number of bacterial colonies (CFU/g), which were compared with the limit in BPOM Regulation No. 13 of 2019. It is descriptive because the study only describes the condition of the duck eggs as they were found at the market, without giving any treatment to the samples and without testing a hypothesis. The data were therefore analysed using descriptive statistics only. The study was conducted at Segiri Central Market in Samarinda City to collect duck egg samples, and at Medical Laboratory Technology Laboratory of the Health Polytechnic of the Ministry of Health of East Kalimantan to examine the samples, from October 6–11, 2025.

The study population consisted of all duck eggs sold by 9 vendors at Segiri Central Market in Samarinda. A total of 27 duck egg samples were obtained from nine vendors. Three eggs were obtained from each vendor, representing three predefined eggshell conditions: clean, dirty, and cracked. The eggs were selected using purposive sampling based on shell condition. At each vendor, one egg for each condition was chosen randomly from the eggs displayed for sale that met the criteria. The shell condition was assessed visually at the vendor's stall before purchase, clean eggs had no visible dirt or crack, dirty eggs had visible dirt without a crack, and cracked eggs had at least one visible crack. Thus, each eggshell condition group consisted of nine samples.

Data Analysis

The data were analysed using descriptive statistics. The results were presented as frequency and percentage for the detection of *Salmonella* sp., and as minimum and maximum values for TPC (CFU/g) in each eggshell condition. The TPC results were also grouped as meeting or not meeting the limit in BPOM Regulation No. 13 of 2019. No inferential statistical test was performed.

Total Plate Count (TPC) Examination

The Total Plate Count (TPC) examination was performed to determine the total number of viable microorganisms in duck egg samples. The samples were first opened aseptically and the egg contents were homogenized between the egg white and yolk. Serial dilutions were then prepared from the homogenized samples. The dilution series used in this study ranged from 10^{-1} to 10^{-4} . The diluted samples were inoculated onto Plate Count Agar (PCA) using the pour plate method and incubated at 37°C for 24 hours. After incubation, colonies that were clearly separated and suitable for counting were counted using a colony counter. Plates with excessive colony growth were recorded as Too Many To Count (TMTC). TMTC means the number of colonies was above the countable range, so it has no exact CFU/g value. TMTC samples were therefore not given a number and were not compared with the exact CFU/g values of other samples. They were classified as not meeting the BPOM limit because their counts were above it. The TPC results were expressed as colony-forming units per gram (CFU/g) and were recorded for each sample based on the eggshell condition. The calculation was based on the number of colonies and the dilution factor used for the countable plate. The TPC results were then described according to the three eggshell conditions: clean, dirty, and cracked. The percentage of *Salmonella*-positive samples was calculated using the following formula.

$$P = f \times N \times 100\%$$

Note: f is the number of samples with positive results, and N is the total number of samples.

RESEARCH RESULT

This study used a descriptive observational design with a laboratory-based microbiological examination. The study was conducted at Segiri Central Market, Samarinda, for sample collection and at the D3 Medical Laboratory Technology Laboratory of the Health Polytechnic of the Ministry of Health of East Kalimantan for laboratory examination. Sample collection and laboratory examinations were conducted from 6 to 11 October 2025.

Identification of *Salmonella* sp.

Table 1 Results of *Salmonella* sp. Identification on Selective Media

No	Eggshell Criteria	Positive <i>Salmonella</i> sp. (N)	(%)	Negative <i>Salmonella</i> sp. (N)	(%)	Total (N)	(%)
1	Clean	0	0	9	33.3	9	33.3
2	Dirty	0	0	9	33.3	9	33.3

3	Cracked	1	3.7	8	29.6	9	33.3
Total		1	3.7	26	96.3	27	100

Source: Primary data

Based on Table 1, of the 27 egg samples tested, a positive result for *Salmonella* sp. was found in only 1 of the 9 cracked eggshell samples. Meanwhile, all 9 dirty eggshell samples and all 9 clean eggshell samples showed negative results for *Salmonella* sp.

Total Plate Count (TPC)

Table 2 Total Plate Count Value of Duck Eggs

No	Eggshell Criteria	Minimum TPC Value (CFU/g)	Maximum TPC Value (CFU/g)	Total (N)
1	Clean	0	2.22×10^6	9
2	Dirty	0	3.0×10^5	9
3	Cracked	0	7.0×10^5	9
Total				27

Source: Primary data

Based on Table 2, the minimum TPC value across all eggshell conditions was 0 CFU/g. The highest countable TPC value was found in the clean eggshell group at 2.22×10^6 CFU/g, followed by the cracked eggshell group at 7.0×10^5 CFU/g and the dirty eggshell group at 3.0×10^5 CFU/g. Several samples in the dirty and cracked eggshell groups showed TMTC results. Because TMTC has no exact value, these samples were not compared with the values in the table, and the table does not show the highest microbial counts of the dirty and cracked groups. The results show that TPC values varied among samples, and the visible condition of the eggshell alone could not be used to describe the microbial load of the eggs.

Table 3 Total Plate Count Value of Duck Eggs Based on BPOM Regulation No. 13 of 2019

No	Eggshell Criteria	Meets BPOM Standard (N)	(%)	Does Not Meet BPOM Standard (N)	(%)	Total (N)	(%)
1	Clean	8	29.6	1	3.7	9	33.3
2	Dirty	7	25.9	2	7.4	9	33.3
3	Cracked	5	18.5	4	14.8	9	33.3
Total		20	74.1	7	25.9	27	100

Source: Primary data

Based on Table 3, 7 of the 27 samples did not meet the standard, with bacterial counts exceeding the threshold of 1×10^4 CFU/g set by BPOM Regulation No. 13 of 2019. Of these 7 non-compliant samples, 1 came from the clean eggshell group, 2 from the dirty eggshell group, and 4 from the cracked eggshell group. Meanwhile, 20 samples met the standard, consisting of 8 clean eggshell samples, 7 dirty eggshell samples, and 5 cracked eggshell samples.

DISCUSSION

This study identified the presence of *Salmonella* sp. and measured the TPC in duck egg samples using selective culture media and biochemical confirmation tests. A total of 27 duck egg samples were collected from 9 vendors at Segiri Central Market in Samarinda, categorized by eggshell condition (clean, dirty, and cracked), based on the assumption that eggshell condition influences the vulnerability of eggs to microbial contamination, including *Salmonella* sp.

Identification of Salmonella sp. on Culture Media and Biochemical Tests

The examination found *Salmonella* sp. in 1 of the 27 duck egg samples (3.7%). The positive sample came from the cracked-eggshell group, while all samples in the clean and dirty groups were negative. This result shows that *Salmonella* sp. was still found among the duck eggs examined at Segiri Central Market.

The positive result in a cracked egg may be related to damage to the eggshell, which can reduce its function as a physical barrier. A crack may make it easier for microorganisms from the surrounding environment to come into contact with the inside of the egg. Similar findings have also been reported in previous studies that found *Salmonella* contamination in eggs with damaged shells.

However, the finding of one positive sample in the cracked group does not mean that cracked eggshells were proven to have a higher risk of *Salmonella* contamination. This study was descriptive and only included nine samples in each eggshell-condition group. No statistical test was performed to determine an association between eggshell condition and *Salmonella* detection. Therefore, the result should be viewed as a finding from the examined samples rather than evidence of a statistical relationship.

The negative results found in all clean and dirty eggs also do not mean that these types of eggs are always free from *Salmonella*. Microbial contamination can be affected by several conditions, such as the source of the eggs, storage time, handling, environmental exposure, and eggshell integrity. These factors were not measured quantitatively in this study.

Total Plate Count (TPC) Test Using the Pour Plate Method

The TPC values varied among the examined duck egg samples. The highest countable value was 2.22×10^6 CFU/g in a clean-eggshell sample, followed by 7.0×10^5 CFU/g in the cracked group and 3.0×10^5 CFU/g in the dirty group. However, some dirty and cracked samples were TMTC, so the three groups cannot be ranked by their highest count. A clearer comparison is the number of samples that did not meet the BPOM limit: 1 of 9 clean eggs, 2 of 9 dirty eggs, and 4 of 9 cracked eggs.

This finding is important because visible eggshell condition alone cannot be used to determine the microbial load of an egg. A clean-appearing eggshell may still have a high microbial count as a result of contamination during production, transportation, storage, or handling. Conversely, a dirty or cracked egg may show variable microbial counts depending on the degree and timing of contamination and subsequent storage conditions.

The presence of a *Salmonella*-positive sample and variation in TPC also demonstrate that TPC and pathogen-specific detection provide different types of microbiological information. TPC reflects the general viable microbial load detected under the test conditions, whereas detection of *Salmonella* specifically addresses the presence of an important foodborne pathogen. Therefore, a high TPC cannot be interpreted as evidence of *Salmonella* contamination, and a low TPC cannot be interpreted as evidence that *Salmonella* is absent.

Several samples showed TMTC results during TPC examination. These results indicate that the number of colonies exceeded the practical counting range under the test conditions and therefore could not be reliably expressed as a numerical value. This should be considered when comparing TPC results among eggshell-condition groups.

Observations of the market environment described conditions such as humidity, standing water, open storage, and exposure of eggs to surrounding surfaces. These conditions may represent potential sources of environmental microbial contamination. However, because these factors were not measured using a structured observation instrument or analyzed statistically, they should be considered potential explanatory factors rather than study variables.

Technical factors, including sample homogenization, dilution procedures, inoculation, incubation, and colony counting, may also influence TPC results. Therefore, future studies should apply standardized sampling and laboratory procedures with adequate replication and quality-control measures.

CONCLUSIONS

Among the 27 duck egg samples examined at Segiri Central Market, Samarinda, one sample (3.7%) was positive for *Salmonella* sp., while 26 samples (96.3%) were negative. The positive sample originated from the cracked-eggshell group. TPC values varied among the examined samples and eggshell conditions, with the highest countable value observed in a clean-eggshell sample, while some dirty and cracked samples were TMTC. These findings demonstrate the presence of microbiological contamination among duck eggs sold at the study site. Because this study used a descriptive design and did not perform inferential statistical analysis, the findings do not establish a statistically significant association between eggshell condition and microbial contamination. Further studies with larger sample sizes, standardized sampling procedures, quantitative assessment of environmental and handling factors, and appropriate inferential statistical analysis are needed.

RECOMMENDATIONS

Future studies should include a larger number of duck egg samples and vendors and should apply clearly defined sampling procedures. Eggshell condition should be operationalized using objective criteria, including the degree of cracking and degree of surface contamination. Other relevant variables, such as storage duration, storage temperature, source of eggs, handling practices, and environmental sanitation, should also be assessed. Further microbiological examinations may include other foodborne bacteria, such as *Escherichia coli*, *Staphylococcus aureus*, and other relevant Enterobacteriaceae, to provide a more

comprehensive assessment of the microbiological quality of duck eggs. Consumers should handle eggs hygienically, avoid consuming raw or inadequately cooked eggs, and maintain appropriate storage conditions.

ADVANCED RESEARCH

Further research is recommended to use more specific sample characteristics, such as the degree of eggshell cracking, the level of eggshell dirtiness, and the storage period of duck eggs. Future studies may also include other microbiological parameters, such as *Escherichia coli* and other bacteria that may contaminate duck eggs. In addition, environmental factors such as storage conditions, handling practices, and sanitation at the point of sale could be examined quantitatively to provide a more complete description of factors related to microbial contamination. Studies involving a larger number of samples and more than one market are also recommended to provide broader information on the microbiological quality of duck eggs.

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