

A Microbiological Analysis of Egg Shell Bacteria

Simran Verma¹, Neetu Kukreja Wadhwa², Divya Bajaj², Richa Sharma³, Ekadashi Rajni³, and Anjali Priyadarshani^{1*} 

¹Department of Zoology, Kirori Mal College, University of Delhi, Delhi, India

²Department of Zoology, Hindu College, University of Delhi, Delhi, India

³Department of Microbiology, Mahatma Gandhi Medical College, Jaipur, India

*Correspondence: anjali18kumar@kmc.du.ac.in

ABSTRACT

Food-borne diseases are a major public health problem affecting developed as well as developing countries. Inaccurately treated eggs are implicated as one of its causes. Bacterial resistance to antibiotics is growing on a global level, necessitating the development of novel antibiotics. One of the most obvious reasons for Antimicrobial Resistance (AMR) in human beings is the consumption of contaminated food with microbes. The present study aims to isolate, identify, and characterise the food-borne pathogens from chicken eggs. This study has been designed to observe the possibility of transmission of pathogenic bacteria from the eggs available in the market to the community. Different types of bacteria found on egg shell surface have been identified and their antimicrobial susceptibility pattern has been determined. *E. coli* and *Staphylococcus* spp. were isolated from the chicken egg shell samples. Prevalence of *E. coli* on the outer egg shell surface was 84%, whereas for the inner egg shell this value was 21%. The prevalence of *Staphylococcus* sp. was 77% and 15% on the outer and inner egg shell surfaces respectively. The bacterial isolates showed considerable resistance to the commonly used antibiotics. *E. coli* isolates showed resistance to amoxicillin, ampicillin, tetracycline and cephalexin while *Staphylococci* showed resistance to ampicillin and cephalexin. Chicken eggs are a potential source of infection to the community. When consumed, these eggs may serve as a vehicle of transmission of infection and antimicrobial resistance. This is an important fact that needs to be explored and understood while developing policies for combating the consequent pandemic of AMR.

Keywords: Food-borne disease, chicken egg, antimicrobial resistance, microbial isolation, pathogen

1. INTRODUCTION

The increase in the incidences of food-borne illnesses over the past decade has been attributed to changing diets, commercial food services and methods of distributing food. Bacteria, viruses and parasites are common food-borne agents implicated in such diseases. Most bacteria may not harm healthy adults, however, some of them thrive and multiply in the body causing infections. The term food-borne diseases (including food-borne intoxications and food-borne infections) include illnesses acquired through consumption of contaminated food and may be referred to as food poisoning. Worldwide, food-borne diseases are a major health burden leading to high morbidity and mortality (WHO, 2023). Estimates of the global burden of food-borne diseases shows that almost 1 in 10 people are affected every year by consumption of contaminated food and 4,20,000 die as a result. Children under 5 years of age are reported to be at high risk, with 1,25,000 children dying from food-borne diseases every year (Kirk et al., 2017; Chowdhury, 2023). CDC (2022) report estimates that every year around 48 million people get affected from a food-borne illness, 128,000 are hospitalised, and 3,000 die. Food contamination is thus one of the major threats to food safety across the world (WHO, 2023).

Pathogens like *E. coli* and *Salmonella* easily find their way to the food chain through poultry, dairy and even drinking water. Lack of proper hygiene and faulty rearing practices foster bacterial growth that may get transferred to the food items as well. Contamination can also take place during handling, processing and transit. Poultry products have been reported to harbor microorganisms like *Campylobacter*, *Salmonella* sp., *Listeria monocytogenes*, *Staphylococcus* sp. and *E. coli* (Moats, 1980; Punom et al., 2020; Kim & Cheigh, 2021). Eggs carrying *Salmonella* look morphologically normal but can result in severe food poisoning (Davies & Breslin, 2003). Some studies have reported the penetration of bacteria across several membranes passing the contamination to the entire egg. For instance, *Pseudomonas* is a bacterial genus known to penetrate into egg shells of poor quality (Lorenz et al., 1952; Board et al., 1964; AL-Ashmawy et al., 2013). Microbes also degrade the quality of eggs and bring a sharp decline in the growth and performance of birds. Thus, poultry products, especially eggs, can act as a vector for these microbes and cause illness in humans (Ahmed et al., 2021; Alders et al., 2018; Rouger, 2017).

Antibiotics are instrumental in the prevention and treatment of infections caused by bacteria. Poultry set-ups use various vaccines and antibiotics to enhance the food production and growth of farm animals, keeping infections at bay. However, excessive use of antibiotics can induce emergence of antibiotic resistance in bacteria. Antibiotic resistance is a natural phenomenon but misuse of antibiotics in these animals accelerates the selection and proliferation of resistant strains, making it one of the biggest threats to the health of humans and animals globally (Silver & Bostian, 1993; Soni et al., 2023; Okorie-Kanu et al., 2016). It is therefore important to evaluate the bacterial load in the food products we are consuming as a step towards the prevention of food-borne diseases and combating the menace of growing AMR.

The current study aims to investigate chicken egg samples obtained from different sources and to isolate and identify the bacteria present on its surface using standard microbiological techniques. Antibiotic Susceptibility Test (AST) was also performed to identify the bacterial species resistant to antibiotics that are commonly used in the poultry industry.

2. MATERIALS AND METHODS

2.1. Collection of eggs

Fresh, undamaged and visibly clean table eggs (n=200) without fecal contamination were procured from 7 different sampling locations in Delhi, India. Eggs from different sites were collected in sterile plastic boxes and handled with gloves to minimise any chances of contamination from the hands. Two eggs per site were further processed for bacteriological analysis.

2.2. Examination of egg porosity

An Egg porosity assay was performed to assess the possibility of trans-shell contamination. Methylene blue dye (LobaChemie, India) was taken as a visual indicator for penetration of foreign substances into intact eggs. Egg porosity was checked by dipping the eggs (in triplicate) in a solution of 0.1 % methylene blue in absolute methyl alcohol for 20, 40 and 60 minutes respectively. Following incubation, eggs were washed in methyl alcohol to remove any dye solution. After the eggs were air-dried, they were checked for penetration of the stain on and under the eggshell surface.

2.3. Microbiological analysis of egg surface

The egg shell surface was examined for the presence of microbes, following the procedure described by Collins and Lyne (1970). All experiments were done in germ-free conditions in a laminar flow hood. The eggs were washed with 25 ml of nutrient broth (Sigma-Aldrich) to

obtain the surface rinsate both from the outer and inner surfaces. Undiluted and serially diluted surface rinsate (10^{-1} - 10^{-5}) was spread on the nutrient agar plates. Autoclaved nutrient broth was processed as a negative control along with surface rinsate plates. Plates were incubated at 37°C for 24 hours and each sample was processed in triplicate. Quadrant streaking was done for each colony after 24 hours incubation.

The eggshell surface (outer and inner surface) rinsate was used for bacteriological analysis. Two samples per site (total 14) were plated for total viable count (TVC), total coliform count (TCC) and total Staphylococcal Count (TSC).

2.4. Bacteriological analysis

The analysis was performed using different culture media like Nutrient Agar (NA), MacConkey Agar (MCA), Blood Agar (BA) and Mannitol Salt Agar (MSA). For this, overnight-grown bacterial cultures were streaked on different media and incubated at 37°C for 24 hours. Sterile nutrient broth was also processed as a negative control.

2.5. Identification of bacteria

The microorganisms were identified using standard microbiological techniques like a) colony morphology, b) staining characteristics, and c) biochemical tests including the coagulase test and the Indole test. Coagulase test was done to differentiate *Staphylococcus aureus* from other *Staphylococcus* sp. (CONS) (Sperber & Tatini, 1975). Indole test was conducted to identify *E. coli* sp. (Cowan & Steel 1960; Collins & Lyne 1970).

2.6. Total Viable Counts (TVC)/Total Coliform Count (TCC)/ Total Staphylococcal Counts (TSC)

Following incubation, the number of colonies on the plates exhibiting growth was counted. The TVC was obtained by multiplying the average number of colonies in a particular dilution by the dilution factor. It was expressed as the number of colony-forming units per ml (cfu/ml) of organism according to ISO, 1995. TCC and TSC were done using the same procedure on MacConkey Agar and Mannitol Salt Agar respectively (Damena et al., 2022). All counts were normalised to colony-forming units per square centimeter (cfu/cm²). All analysis was done in triplicates and count was expressed as cfu/ml.

2.7. Antibiotic Susceptibility Test (AST)

Antibiotic Susceptibility Test was performed according to the Clinical and Laboratory Standards Institute (CLSI) guidelines, using Kirby-Bauer modified disc-diffusion technique (Bauer et al., 1966). Antibiotic discs (Oxoid Ltd. UK) used were amoxicillin (25 µg/disc), tetracycline (30 µg/disc), gentamycin (10 µg/disc), ampicillin (30 µg/disc), ciprofloxacin (5 µg/disc), cephalixin (30 µg/disc) and vancomycin (10µ g/disc). Isolated pure bacterial colonies were emulsified in saline and their turbidity was compared with the standard turbidity of 0.5 McFarland. Selected antibiotic discs were picked using sterile forceps and placed on the inoculated Mueller-Hinton Agar plates. These plates were incubated at 37°C for 24 hours. Zones of inhibition were measured, and strains were classified as susceptible or resistant.

2.8. Data analysis

A total number of 200 eggs were used in this study. Bacterial counts were done on two eggs per site (total 14) and all microbiological tests were performed in triplicate. The data procured from the total viability count, coliform and staphylococcal count was analysed for percentage contamination of *E. coli* and *Staphylococcus* spp. on outer as well as inner shell surface. Standard error was calculated for assessing variation between the triplicates using Microsoft Excel 2010 (Redmond, WA).

3. RESULTS

3.1. Sample collection

Eggs from several different sampling locations in Delhi were collected. The locations and sample size are indicated in Table 1.

3.2. Egg porosity

The penetration of methylene blue was highest at 60 minutes, moderate at 40 minutes and no penetration at 20 minutes.

Table 1: Sampling location and sample size of cleidoic eggs taken in the study of microbial profile

Sampling Location	Sample size (No of eggs)
Rajouri Garden	38
Malkaganj	41
Shahdara	23
INA market	37
Preet Vihar	20
Dwarka	21
Sarojni Nagar	20
Total	200

3.3. Microbiological analysis of egg surface

Staphylococcus sp. was found to be the dominant bacterium in the category of gram-positive bacteria. There was only one isolate of *Staphylococcus aureus*, the rest being CONS. Amongst the Gram-negative bacteria, *E. coli* was found to be the predominant species found on the egg shell. The prevalence of *E. coli* on the outer egg shell surface was 84%, whereas for the inner egg shell, this value was 21%. Similarly, the prevalence of *Staphylococcus* sp. was 77% and 15% in the outer and inner egg shell surface respectively (Figure 1).

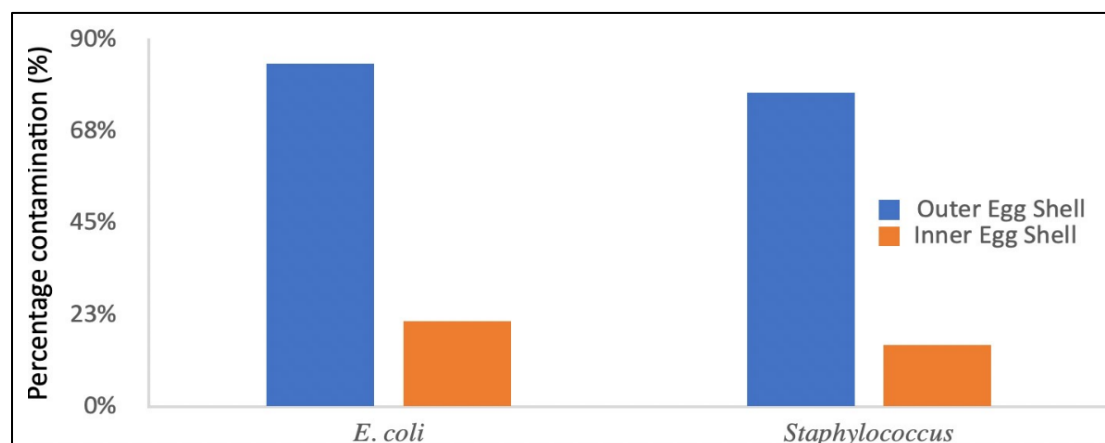


Figure 1: The total viable bacterial count detected on the egg shell surfaces. Two bacterial species were detected on the outer and inner surface of the chicken egg shell. The bacterial load was higher on the outer surface as compared to the inner shell surface. The count of *E. coli* was found to be significantly higher than *Staphylococcus* sp. both on the outer surface and the inner shell surface.

3.4. Colony morphology

E. coli appeared as greyish non-hemolytic colonies on blood agar and bright pink colonies on MacConkey Agar. (Figure 2A, 2B). Colonies of *Staphylococcus aureus* were creamish, beta hemolytic on Blood Agar and yellow colonies were found on Mannitol Salt Agar (Figure 3A, 3B). The morphological characteristics of these species on various media are summarised in Table 2.

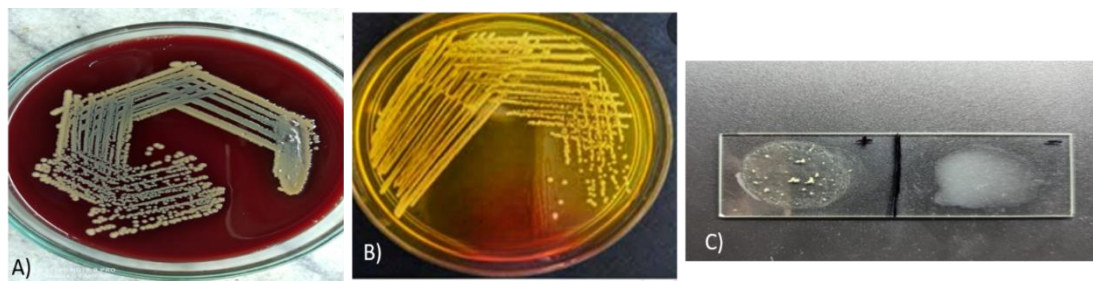


Figure 2: Characteristics of *E. coli*. A) *E. coli* on Blood Agar; B) *E. coli* on MacConkey Agar; C) Positive Indole test



Figure 3: Characteristics of *Staphylococcus* sp. A) *Staphylococcus* colonies on Blood Agar; B) *Staphylococcus* colonies on Mannitol Salt Agar; C) Coagulase test.

Table 2: Culture characteristics of *E. coli* and *Staphylococcus* spp. on various culture media used in the study. Different culture media like Nutrient Agar, MacConkey Agar, Blood Agar, and Mannitol Salt Agar were used and the bacteria isolates were cultured on them. The physical characteristics of culture growth were used to identify the organism.

Bacteria Isolated	Nutrient Agar	MacConkey Agar (MCA)	Blood Agar	Mannitol Salt Agar (MSA)
<i>E. coli</i>	Colourless, circular, smooth, colonies.	Bright pink-coloured, large mucoid colonies	Greyish, small, circular, non-hemolytic colonies	NA
<i>Staphylococcus</i> sp.	Large, circular, opaque colonies	Pale pink colored, opaque colonies	Creamish, round, pinhead size, beta hemolytic colonies	Yellow coloured colonies with yellow zone

3.5. Staining and biochemical characteristics

E. coli appeared as short plump rods, single, paired or arranged in beaded chain arrangement while *Staphylococci* were observed as gram positive cocci arranged in grape-like clusters as reported by similar studies (Muruhan et al., 2012). Coagulase test/Indole test: Clumping of

bacterial cells on the slide confirmed the isolates as *Staphylococcus aureus*. A positive red colour ring confirmed the isolates as *E. coli*. The response of bacterial isolates to Gram staining procedure and to different biochemical reactions are enlisted in Table 3.

Table 3: Summary of the response of bacterial isolates to biochemical tests. Biochemical tests like Gram staining, Coagulase test, and Indole test were used as confirmatory tests for identification of the isolated bacteria

S.No.	Test performed	<i>E. coli</i>	<i>Staphylococcus sp.</i>
1	Gram Staining	Negative	Positive
2	Coagulase test	NA	Positive bound coagulase test (found in a single isolate of <i>S. aureus</i>)
3	Indole test	Positive - red coloured ring	NA

3.6. Total Viable Counts (TVC)/Total Coliform Count (TCC)/ Total Staphylococcal Counts (TSC)

The average measures of TCC (cfu/ml) on the outer egg shell surface samples were 6.3×10^2 , 5.6×10^2 and 3.4×10^2 at different dilutions of 0.1, 0.01 and 0.001 respectively. The results for the inner shell surface were 1.26×10^2 cfu/ml, 0.87×10^2 cfu/ml and 0.44×10^2 cfu/ml at the corresponding three test dilutions.

Total Staphylococcal Count (TSC) was also measured for both the outer and inner egg shell surfaces in triplicate. The average measures of TSC on the outer egg shell surface samples were 4.3×10^2 , 2.96×10^2 and 1.4×10^2 at different dilutions of 0.1, 0.01 and 0.001 respectively. The results for the inner shell surface were 0.91×10^2 cfu/ml, 0.47×10^2 cfu/ml and 0.06×10^2 cfu/ml at the corresponding three test dilutions (Table 4).

Table 4: Microbial load on the eggshell surface. The Total Viability Count represented the overall microbial load on the outer and inner eggshell surfaces. Total Coliform Count (TCC) indicates the *E. coli* population and Total Staphylococcal Count indicates the Staphylococcal population. The TCC was significantly higher than TSC both on outer and inner eggshell surfaces.

Microbial Count	Dilution (ml)	Outer shell surface rinsate Mean \pm SE (cfu/ml)	Inner shell rinsate Mean \pm SE (cfu/ml)
Total Viability Count (TVC)	0.1	$7.4 \pm 0.7 \times 10^5$	$2.13 \pm 0.21 \times 10^5$
	0.01	$4.65 \pm 0.4 \times 10^5$	$2.06 \pm 0.22 \times 10^5$
	0.001	$2.22 \pm 0.21 \times 10^5$	$0.66 \pm 0.058 \times 10^5$
Total Coliform Count (TCC)	0.1	$6.3 \pm 0.62 \times 10^2$	$1.26 \pm 0.12 \times 10^2$
	0.01	$5.6 \pm 0.5 \times 10^2$	$0.87 \pm 0.79 \times 10^2$
	0.001	$3.4 \pm 0.3 \times 10^2$	$0.44 \pm 0.42 \times 10^2$
Total Staphylococcal Count (TSC)	0.1	$4.3 \pm 0.42 \times 10^2$	$0.91 \pm 0.92 \times 10^2$
	0.01	$2.96 \pm 0.3 \times 10^2$	$0.47 \pm 0.4 \times 10^2$
	0.001	$1.4 \pm 0.15 \times 10^2$	$0.06 \pm 0.05 \times 10^2$

3.7. Antibiotic Susceptibility Test (AST)

The Antibiotic Susceptibility Test showed highest sensitivity of both *E. coli* and *Staphylococcus* isolates to Ciprofloxacin. Further, both the species showed high sensitivity towards gentamycin. Though, *Staphylococcus* sp. were sensitive to ampicillin and tetracycline, the sensitivity of *E. coli* for these antibiotics was much lower. In the case of *E. coli*, the most effective antibiotic was ciprofloxacin with maximum zone of inhibition of 32 mm and the least effective antibiotic was tetracycline with 4 mm zone of inhibition (Figure 4). In the case of *Staphylococcus aureus* the most effective antibiotic was ciprofloxacin like in the previous case, with max zone of inhibition of 32 mm and least effective antibiotics were cephalixin and ampicillin with a zone of inhibition of 13 mm each (Figure 4).

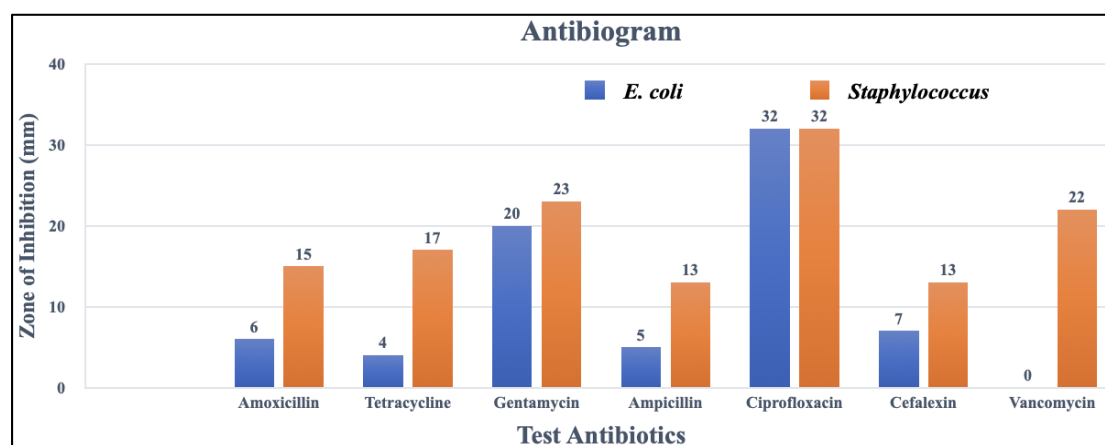


Figure 4: Antibiotic susceptibility profile of *E. coli* and *Staphylococcus* spp. The bacteria were allowed to grow in the presence of different antibiotics to identify the susceptibility of the bacteria towards these antibiotics.

4. DISCUSSION

Eggs are widely consumed as valuable source of proteins and other micronutrients. Contaminated eggs have been implicated in food borne illnesses (Abdullah, 2010; Ahmed et al., 2021). It is therefore imperative to minimise such food safety risks by devising ways to handle, store and transport eggs with least risk of microbial contamination. The current study was undertaken to analyse the chicken eggs for porosity and the bacterial flora present on eggshells procured from the local markets of Delhi, NCR.

Egg shells are mostly perceived as unsurpassable by the masses. Contamination occurring through eggs usually goes unrecognised as eggs and more specifically egg shells are not perceived as a source of contamination. Studies indicate passage of microorganisms and yeast species (under suction) through apertures present on the egg shell (Haines & Moran, 1940). It is hypothesised that similar suction pressure is generated during cooling of warm, freshly laid eggs. This pressure draws shell surface microbes towards its interior. In the current study, penetration of methylene blue dye verifies the porous nature of egg shells and thereby points to possibility of microbial entry through egg shells.

Bacterial contamination of eggs is not entirely avoidable. They are not laid in a sterile environment and may also get contaminated via vertical or horizontal transmission. Vertical transmission refers to introduction of pathogenic bacteria (e.g. *Salmonella*) from the infected reproductive tissues to eggs prior to shell formation and horizontal transmission occurs because of fecal contamination on the egg shell. Eggs are vulnerable to microbial contamination during handling and transportation too. The proliferation of microbes is

directly associated with the sanitation and treatment procedure employed (Damena et al., 2022). The eggs stored at room temperatures are reported to show elevated levels of food-borne microbial infections due to rapid proliferation at this temperature.

Several studies have examined the microbes present on the egg shell surface. Abdullah (2010) reported presence of *Staphylococcus*, *E. coli*, *Salmonella* and *Streptococcus* spp. AL-Ashmawy et al. (2013) reported the presence of *Pseudomonas* sp. in table eggs. Another study by Board et al. (1964) reported the presence of molds, particularly *Penicillium* sp., and other spore-forming bacteria on egg shells. Despite modern transportation and handling methods, these contaminating microbes are still found on egg surfaces. Furthermore, many of these microorganisms have become resistant to commonly used antibiotics.

Salmonella is an important cause of food poisoning in the United States. While most infections are associated with mild symptoms and are self-limiting, in some, it may be severe, leading to hospitalisations (Scallan et al., 2011). Certain group of people including the elderly, diabetics and immunocompromised are at a higher risk of severe infection (Lund & O'Brien, 2011). FDA has provided clear-cut safe handling guidelines to address this issue. A microbiological analysis of egg shells in our study has however, not revealed the presence of *Salmonella* sp. Microbiota in our study was constituted chiefly by *E. coli* and *S. aureus*. This highlights the geographical variation seen in the eggshell microbes.

Some studies have evaluated the complex interplay between the eggshell microbiota and the microbiota found consequently in the chicken gut (Maki et al., 2020). More detailed studies should be carried out to determine how egg shell microbial communities may be targeted to promote gut health in poultry, thereby mitigating food-borne illnesses.

The practice most commonly employed at households for disinfecting the egg is washing. However, washing of the eggs is not recommended as it may facilitate the entry of microorganisms through the pores along with water due to capillary action (Froning et al., 2002). Similarly, care should be taken while commercial egg processing is being done, to avoid any process that may lead to introduction of bacteria into the interior. Cuticle should not be damaged, and they should be dried immediately. It is strongly recommended that cracked eggs should be removed from sale as bacteria may enter through cracks and pores on shell of eggs. Washing of eggs should not be undertaken unless visibly soiled with fecal matter (Froning et al., 2002). If, however found so, they may be washed with household detergent and dried completely. Consumption of pasteurised eggs should be encouraged, and due attention should be given as to how they are stored during the time interval between purchase and consumption. They should ideally be kept refrigerated at 4°C or lower to discourage bacterial multiplication.

Animal husbandry employs antimicrobials extensively, often inappropriately, owing to increasing demand for meat/poultry products. Consequently, there is increase in the number of resistant bacterial strains occurring in chickens (Khaton et al., 2008; Pyzik & Marek, 2013). It is therefore imperative to assess the microbial species present on egg shell surface, and their susceptibility to various antibiotics. In the current study, *E. coli* isolates showed considerable resistance to commonly used antibiotics like tetracycline and ampicillin. These results are in sync with the studies carried out by Pyzik and Marek (2013) and Ema et al. (2018) who showed high resistance to amoxicillin. Likewise, Moellering et al. (1977), have reported resistance to gentamycin and ciprofloxacin. *Staphylococcus* sp. were found to be sensitive to ciprofloxacin, vancomycin, and gentamycin and relatively resistant to cephalixin and ampicillin, which was not completely in sync with the reports of Pyzik and Marek (2013), who reported resistance to gentamycin, ampicillin and vancomycin.

Through a meticulous and comprehensive analysis of the collected data, this research has provided valuable insights into the prevalence and potential implications of AMR in avian environments. The findings presented in this paper highlight the previously underestimated role of bird eggshells as carriers of antibiotic-resistant bacteria. This discovery has far-reaching implications for both wildlife and human health, emphasizing the need for heightened awareness and strategic interventions to address the emergence and dissemination of AMR. Understanding the dynamics of AMR in avian populations contributes not only to safeguarding the health of wildlife but also to protecting human health through the food chain and environmental interactions. By unraveling the factors driving the development of resistance and studying its consequences, we gain essential knowledge for devising effective strategies to combat AMR.

The World Health Organisation (2019) has confirmed that antimicrobial resistance in bacterial flora found on food items like eggs may significantly impact the human population. With the ever-increasing burden of multiple drug-resistant strains, the use of antibiotics needs to be minimal in poultry farms (Agyare et al., 2018). The hazard of antimicrobial resistance occurring in eggs is an example of how biomagnification could occur higher up in the food chain.

The documented patterns of antibiotic resistance in the isolated bacteria underline the urgency of collaborative efforts between researchers, ecologists, veterinarians, and policy-makers. Tackling the challenges posed by AMR requires a holistic approach that combines scientific research, targeted interventions, and regulatory measures to prevent its spread and minimise its impact.

5. CONCLUSION

It is a universally known fact that maximal consumption of antibiotics is in the animal husbandry sector. This produces an immense selection pressure leading to generation of multi-drug resistant bacteria. Needless to say, consumption of contaminated animal products would lead to transmission of these bacteria to human ecosystem, exaggerating the already mammoth issue of AMR. In our efforts to mitigate AMR, this route must be identified and addressed appropriately. In such a scenario, our study provides tangible evidence of bacterial contamination of egg shells. It provides the relevant authorities a direction for setting up basic norms for sale and purchase of eggs.

In essence, the insights obtained from this basic research underscore the critical need for continuous monitoring and collaborative research to counteract the escalating threat of antimicrobial resistance. By preserving the delicate balance between ecosystems, animals, and human well-being, we can aspire to a future in which the efficacy of antimicrobials is sustained, and the intricate interconnectedness of life is conserved.

6. STRENGTH OF THE STUDY

It is a universally known fact that maximal consumption of antibiotics is in the animal husbandry sector. This produces an immense selection pressure leading to generation of multi-drug resistant bacteria. Needless to say, consumption of contaminated animal products would lead to transmission of these bacteria to human ecosystem, exaggerating the already mammoth issue of AMR. In our efforts to mitigate AMR, this route must be identified and addressed appropriately. In such a scenario, this study provides tangible evidence of bacterial contamination of egg shells. It provides the relevant authorities a direction for setting up basic norms for sale and purchase of eggs. In essence, the insights obtained from this basic research underscore the critical need for continuous monitoring and collaborative research to

counteract the escalating threat of antimicrobial resistance. By preserving the delicate balance between ecosystems, animals, and human well-being, we can aspire to a future in which the efficacy of antimicrobials is sustained, and the intricate interconnectedness of life is conserved.

7. LIMITATIONS OF THE STUDY

Bacterial load on the inside of the egg was not evaluated. If done, it would have led to a better understanding of eggs contamination. Also, anaerobes, which could also be present on the eggshells were not evaluated. Further studies are needed which would include anaerobic culture in their scope and give a better understanding of the microbial communities present on eggshells.

8. IMPLICATIONS OF THE FINDINGS OF THIS STUDY

In this study, we found out that the eggs available in the market serve as reservoirs for different strains of pathogenic bacteria. The consumption of infected eggs with high microbial load can cause different food borne infections and intoxications which can be treated only by chemo-therapeutic agents. Medical treatment of these infections is complicated by the resistance to first-line antibiotics as these bacteria pass through the food chain and foster resistance against particular antibiotics. Thus, the use of antibiotics should be restricted to curtail the development of antibiotic resistance. The microbial population contaminating the eggs during handling and transportation is identified as a challenge to the egg industry. The study highlights the need to improve and standardise the egg handling and storage practices to minimise chances of microbial growth.

FUNDING

The authors have no other relevant affiliations or financial involvement with any organisation or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript.

CONFLICT OF INTEREST

The authors have no relevant financial or non-financial interests to disclose.

ACKNOWLEDGMENT

The authors are thankful to Principal, Kirori Mal College, University of Delhi, Prof. Dinesh Khattar, and Prof. Anju Srivastava, Principal, Hindu College for allowing us to conduct this research. We would also like to thank Prof. Anita K Verma, Kirori Mal College, University of Delhi for her continuous support and guidance.

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How to cite this article: Verma, S., Wadhwa, N. K., Bajaj, D., Sharma, R., Rajni, E., & Priyadarshani, A. (2023). A Microbiological Analysis of Egg Shell Bacteria. *Vantage: Journal of Thematic Analysis*, 4(2), 34-46.

DOI: <https://doi.org/10.52253/vjta.2023.v04i02.04>

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