Bacterial Contamination of Chicken Eggs from Poultry Farms and Retail Markets in the New Juaben Municipality, Ghana

Matthew Glover Addo¹, Manomba-Asamoah Raissa¹, Kingsley Badu¹ and Samuel Agordzo¹

¹Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Authors' contributions

This work was carried out in collaboration among all authors. Authors MGA and KB managed the conceptualization, supervision, validation, writing, review and editing. Author MAR did the data duration, investigation, methodology and writing. Author SA managed the analyses of the study and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/MRJI/2020/v30i730239

(1) Dr. Ana Cláudia Coelho, University of Trás-os-Montes and Alto Douro, Portugal.

Reviewers:

(1) Siddhant, Durgesh Nandini Degree College, India.
(2) M. Sabuncu, Dokuz Eylül University, Turkey.

Complete Peer review History: http://www.sdiarticle4.com/review-history/57488

Received 25 May 2020
Accepted 31 July 2020
Published 10 August 2020

ABSTRACT

This cross-sectional study seeks to investigate the bacterial contamination of poultry products (eggs) produced from selected farms and sold within the major markets in the New Juaben Municipality in the Eastern region of Ghana. A total of 100 eggs were sampled randomly from October to December, 2018 from five poultry farms and five retail markets in the municipality for microbial evaluation. The collected swabs of eggshells and its contents collected at various times of the day were cultured on suitable media and standard microbiological test were performed to identify the isolated organisms. The entire eggshell samples were positive for bacteria with only 13 (13%) having growth in the egg content. The genera of bacteria recorded are Staphylococcus, Escherichia, Klebsiella, Proteus and Citrobacter. The mean total viable count of bacteria from both shell and content sampled from poultry farms and retail markets were 13.2×10⁷ cfu/ml and 8.0×10⁷ cfu/ml (p>0.05) respectively. These were higher than the acceptable value of 10×10⁵ gm/cfu. The study also showed that the level of microbial contamination of the eggs was highest in the

*Corresponding author: E-mail: maddosci@yahoo.co.uk;
afternoon as compared to the morning and evening. The bacteria isolates and the sheer numbers from both the eggshells and the egg content confirm the poor hygienic conditions under which both the poultry farms and markets were kept. Even though serious human pathogens were not prevalent in this study, it is recommended that strict hygienic protocols be adhered to on the poultry farms and in the markets.

Keywords: Egg; microbial contamination; poultry farms; retail markets; bacteria; Ghana.

1. INTRODUCTION

The egg produced by chicken is undoubtedly an important source of nutrients including proteins, vitamins, zinc, phosphorus among others and it remains the single major source of cholesterol among the foods consumed in the USA [1]. In Ghana, poultry farmers keep the birds for either the eggs, meat or both. In order to ensure a continuous supply of high-quality eggs, several improvements have been made in enriching the omega3, lutein and folate components [2]. Apart from humans, microorganisms especially bacteria also find the egg highly nutritious thereby feeding on it. These microorganisms can survive on the shell of the egg and even cross the shell and membrane to feed on the yolk and other eggshell contents. Microbial contamination of poultry and poultry products such as the egg significantly impacts the industry by way of economic loss and at the same time results in infections and illnesses [3]. While Campylobacter is the major bacteria associated with the foodborne disease, Salmonella, on the other hand, is the most common bacterial cause of poultry and egg-related illnesses [4]. Apart from Salmonella enteritidis, other bacteria associated with the contamination of chicken and their eggs include Listeria monocytogenes, Campylobacter jejuni and Escherichia coli [5]. These bacteria are capable of contaminating both the eggshell and its content. Internal (shell content) contamination may occur before oviposition when the eggshell is not fully formed and the reproductive organs are infected. The eggshell contamination can result from contact of the eggshell with the colonized gut containing contaminated faeces before or during oviposition [6]. Under the intensive system of poultry keeping, eggs laid by the hen are collected in the morning, afternoon and evenings. Eggs collected in the morning spend several hours in the house from the previous evening after the day's collection up until the following morning before collection. It is therefore expected that eggs collected in the morning should have higher bacterial contamination as compared to those collected in the afternoon and evening [7]. The increase in human population and lack of good sanitation practices in the New Juaben Municipality in the Eastern region of Ghana has led to an increase in bacterial diseases, especially, Typhoid. Poultry farms in the municipality are also facing similar sanitation problems. This leaves the eggs produced by the poultry not safe for consumption if not well washed and thoroughly cooked. The objective of this study therefore, is to investigate the contamination of chicken eggs from poultry farms and retail markets in the New Juaben Municipality of Ghana.

2. MATERIALS AND METHODS

2.1 Sample Sites and Sample Collection

Samples were collected from five poultry farms (PF) and coded as; PF1, PF2, PF3, PF4 and PF5, as well as five retail markets (RM) at RM1, RM2, RM3, RM4 and RM5 (Table 1) together with interviews using structured questionnaires for assessing factors such as hygiene. In total, 100 eggs were randomly selected from the poultry farms and the retailers in the markets in the New Juaben Municipality of Ghana from October to December, 2018. Sampling of the eggs was conducted in the morning, afternoon and evening across the study sites. Each of the eggs was kept in a separate sterile plastic ziplock bag and transported on ice to the Microbiology laboratory of the Regional Hospital in Koforidua for processing within 2 hours.

2.2 Cultures for the Eggshell

The surfaces of each of the eggshells were swabbed using separate sterile cotton swabs sticks that were soaked in 0.1% peptone water. These swabs were inoculated into different tubes containing 5ml of 0.1% peptone water. These test tubes were labelled using coded names of the locations (farms and markets) as well as the time of collection. The tubes were then incubated at 37°C for 18-24 hours. A pool was made using each of the cotton swabs on well-labelled media (Blood Agar, Muller Hinton Agar, and
MacConkey Agar) and streaked. Subsequently, 1ml each of the samples incubated in the 0.1% peptone water was transferred into 9ml of selenite broth and incubated 18-24 hours. Using the streaking method, the selenite broth with its content was plated on separate Salmonella-Shigella (S-S) agar. The S-S agar plates were incubated at 37°C for 24 hours and observed for growth.

2.3 Cultures for the Eggshell Content

Before cracking the eggshells to assess their contents, 70% ethanol was used to disinfect the shells. The eggs were cracked-open gently with a sterile spatula and their contents (yolk and albumin) were carefully emptied into separate and well labelled sterile glass Petri-dishes. The contents of the Petri dishes were then homogenized with the aid of sterile cotton swab sticks. Pre-enrichment and subsequent enrichment techniques were repeated for the eggshell content as previously done for the eggshell.

2.4 Isolation and Identification of Microorganisms

After the 18-24hr incubation period, standard bacteriological techniques including morphology (shape, size, colour, and outline) of the colony-forming units, Gram’s staining and biochemical (Coagulase, Urease, Indole and Citrate) tests were performed to identify the isolated microorganisms.

2.5 Determination of Total Viable Count (TVC)

For us to enumerate the total viable organisms, serial dilutions of 10⁻¹ to 10⁻⁶ concentrations of each test sample were prepared using 1ml of the 0.1% peptone water containing dissolved swabs from the eggshell and eggshell content. This was followed by transferring 1ml of each serial dilution into tubes containing 9ml of molten agar. The tubes were gently wrapped in between the palm to obtain a homogenous mixture. The mixtures were immediately poured onto sterile glass Petri-dishes and incubated at 37°C for 24 hours. The plates showing the growth of colonies between 30-300 were selected and counted.

2.6 Data Analysis

The data obtained were entered into Microsoft Excel and analyzed using IBM SPSS statistics software version 20.0. Variations in microbial counts at different sites were analyzed using Analysis of Variance (ANOVA). The level of significance was determined at an alpha level of 0.05.

3. RESULTS

3.1 Isolation and Characterization of Microorganisms

3.1.1 Isolation of microorganisms

A total of one hundred eggs were sampled from both farms and retail markets. Bacteria of different genera were isolated from 13% of the eggshell contents whereas all the eggshells (100%) had bacteria isolated from them. In all, 110 bacterial isolates were isolated and these can be grouped into five (5) genera; Staphylococcus, Escherichia, Klebsiella, Proteus and Citrobacter (Table 2).

| Sampling locations | Code  | Retail markets | Code  |
|--------------------|-------|----------------|-------|
| Poultry farms      | Code  | Retail markets | Code  |
| Ben PF₁            | Jumapo| RM₁           |
| Akyeme PF₂         | Oyoko | RM₂           |
| Mark PF₃           | Agartha| RM₃         |
| Bempomaa PF₄       | Central| RM₄         |
| Waveland PF₅       | Adweso| RM₅           |

3.1.2 Biochemical characterization

Various biochemical tests such as catalase test, indole, urease, coagulase, citrate and glucose utilization were done to identify the suspected isolates present in the agar plates. All the suspected organisms were able to utilised glucose and also produce catalase but failed to utilised citrate. *Citrobacter diversus* (A6) showed variable reaction with the enzyme urease (Table 2).

3.2 Microorganisms Isolated from Eggshell Surfaces and Eggshell Contents

The eggs sampled from both the poultry farms and retail markets were contaminated with the microorganisms either on the eggshell or egg content. *Coagulase Negative Staphylococcus* was the most abundant and was predominantly
isolated from the eggshell surface 72.7% (n=80). *Staphylococcus aureus* 2.7% (n=3) and *Proteus mirabilis* 0.9% (n=1) were isolated from only the eggshell surface representing (Table 3).

### 3.3 Isolates from the Poultry Farms and the Retail Markets

Eggs obtained from all the poultry farms were contaminated with bacteria. *Staphylococcus* sp. was identified as the predominant microorganism contaminating eggshell surfaces in all the five farms particularly PF$_1$, PF$_2$ and PF$_5$ where it was single handedly contaminates the shell surfaces (Table 4). Apart from *Staphylococcus* sp., *Klebsiella* sp. (PF$_3$), *Escherichia coli*, *Proteus mirabilis* and *Citrobacter diversus* (PF$_4$) were also encountered on eggshell surface. Among them, *Citrobacter diversus* and *Proteus mirabilis* were the least abundant microorganism associated with the eggshell surfaces. Egg content was also contaminated by microorganisms. *Escherichia coli* was considered as most abundant bacteria from egg content, contaminating major farms (Table 4) while *Citrobacter* sp. being the least abundant. PF$_2$ was devoid of egg content contamination.

Microorganisms were isolated and characterized from the sampled eggs bought from the five selected retail markets. *Staphylococcus* sp. was dominant microflora, invading on egg shell surface in four (RM$_1$-RM$_4$) out of five retail market particularly RM$_2$, RM$_3$ and RM$_4$ where it was single handedly contaminates the shell surface (Table 5). Complete absence of *Staphylococcus* sp. was observed from RM$_5$. RM$_5$ market had *Escherichia coli*, *Citrobacter* sp. and *Klebsiella* sp. on the eggshell surface. Contamination in egg content was noticed only from RM$_2$ market. It was contaminated with *Klebsiella* sp.

### 3.4 Comparing the Bacterial Contamination between Poultry Farms and Retail Markets

Our study also compared the level of bacterial contamination on the eggs between the poultry farms and the retail markets. We obtained a total mean bacterial count of $13.2 \times 10^7$ cfu/ml and $8.0 \times 10^7$ cfu/ml (p > 0.05) from the farms and the markets respectively. These values represented the mean bacterial count from eggs sampled in the morning, afternoon and evening from the two sources (results not shown).

| Suspected organism | Characteristics | A1 | A2 | A3 | A4 | A5 | A6 | A7 |
|--------------------|----------------|----|----|----|----|----|----|----|
| Cultural           |                |    |    |    |    |    |    |    |
| Elevation          |                | Convex | Convex | Raised | Convex | Convex | Convex | Flat |
| Margin             |                | Entire | Entire | Entire | Entire | Serrated | Entire | Serrated |
| Colour             |                | Cream | Cream | Beige | Greyish | Cream | Cream | Cream |
| Shape              |                | Round | Round | Rod | Rod | Rod | Rod | Circular |
| Morphology         |                | + | + | - | - | - | - | - |
| Gram Stain         |                | - | - | - | - | - | - | - |
| Spore Stain        |                | Rod | Rod | Rod | Rod | Rod | Rod | Rod |
| Cell Type          |                | Single | Single | Single | Single | Single | Single | Single |
| Cell Arrangement   |                |    |    |    |    |    |    |    |
| Biochemical        |                |    |    |    |    |    |    |    |
| Catalase           |                | + | + | + | + | + | + | + |
| Indole             |                | - | - | + | + | + | + | - |
| Urease             |                | + | - | - | + | - | +/- | - |
| Coagulase          |                | - | - | - | - | - | - | - |
| Citrate            |                | + | - | - | - | - | + | + |
| Glucose            |                | + | + | + | + | + | + | + |
| Number n (%)       |                | 82 (74.5) | 3 (2.7) | 9 (8.1) | 9 (8.1) | 4 (3.6) | 2 (1.8) | 1 (0.9) |

Legend: + = positive, - = negative, +/- = variable

A1 - Coagulase Neg. Staphylococcus: A2 - Staphylococcus aureus: A3 - Escherichia coli: A4 - Klebsiella sp.: A5 - Citrobacter sp.: A6 - Citrobacter diversus: A7 - Proteus mirabilis
Table 3. Number of bacterial species isolated from both eggshell surface and eggshell content

| Isolate                | Number of Isolates from Eggshell content n (%) | Number of Isolates from Eggshell surface n (%) | Total Number of isolates n (%) |
|------------------------|-----------------------------------------------|-----------------------------------------------|-------------------------------|
| Coagulase Neg. Staphylococcus | 2 (1.8)                                       | 80 (72.7)                                     | 82 (74.5)                     |
| Staphylococcus aureus  | 0 (0.0)                                       | 3 (2.7)                                       | 3 (2.7)                       |
| Escherichia coli       | 5 (4.5)                                       | 4 (3.6)                                       | 9 (8.1)                       |
| Klebsiella sp.         | 4 (3.6)                                       | 5 (4.5)                                       | 9 (8.1)                       |
| Citrobacter sp.        | 1 (0.9)                                       | 3 (2.7)                                       | 4 (3.6)                       |
| Citrobacter diversus   | 1 (0.9)                                       | 1 (0.9)                                       | 2 (1.8)                       |
| Proteus mirabilis      | 0 (0.0)                                       | 1 (0.9)                                       | 1 (0.9)                       |
| **Total**              |                                               |                                               | 110                           |

Table 4. Distribution of the bacteria isolated from the five poultry farms

| Poultry farms | Eggshell surface | Number n (%) | Eggshell content | Number n (%) |
|---------------|------------------|--------------|------------------|--------------|
| PF1           | Staphylococcus   | 11 (10)      | Escherichia coli | 1 (0.9)      |
| PF2           | Staphylococcus   | 15 (13.6)    | Klebsiella sp.   | 2 (1.8)      |
| PF3           | Staphylococcus   | 3 (2.7)      | Staphylococcus   | 1 (0.9)      |
| PF4           | Staphylococcus   | 5 (4.5)      | Escherichia coli | 3 (2.7)      |
| PF5           | Staphylococcus   | 15 (13.6)    | Klebsiella sp.   | 1 (1.0)      |
|               | Proteus mirabilis| 1 (0.9)      | C. diversus      | 1 (0.9)      |
|               | Klebsiella sp.   | 1 (0.9)      |                  |              |
|               | Citrobacter sp.  | 3 (2.7)      |                  |              |
|               | Klebsiella sp.   | 1 (0.9)      |                  |              |
|               | Klebsiella sp.   | 1 (0.9)      |                  |              |

Table 5. Distribution of the bacterial isolates in the five retail markets

| Retail market | Eggshell surface | Number n (%) | Eggshell content | Number n (%) |
|---------------|------------------|--------------|------------------|--------------|
| RM1           | Staphylococcus   | 10 (9.0)     | -                | -            |
|               | Klebsiella sp.   | 1 (0.9)      | -                | -            |
| RM2           | Staphylococcus   | 6 (5.4)      | Klebsiella sp.   | 2 (1.8)      |
| RM3           | Staphylococcus   | 12 (10.9)    | -                | -            |
| RM4           | Staphylococcus   | 11 (10.0)    | -                | -            |
| RM5           | Escherichia coli | 1 (0.9)      | -                | -            |
|               | Citrobacter sp.  | 3 (2.7)      | -                | -            |
|               | Klebsiella sp.   | 1 (0.9)      | -                | -            |
|               | Klebsiella sp.   | 1 (0.9)      | -                | -            |

3.5 Bacterial Growth across Poultry Farms

The mean total viable count (TVC) for the eggs samples from each of the Poultry Farms are shown in Fig. 1. The result showed that the level of microbial contamination of the eggs was highest in the afternoon as compared to the morning and evening samples. In the morning, mean total viable count (TVC) recorded from the five farms (PF1, PF2, PF3, PF4, and PF5) were (8.64×10⁶: 5.23×10⁶) cfu/ml, (6.38×10⁶: 0.00×10⁶) cfu/ml, (5.56×10⁶: 4.67×10⁶) cfu/ml, (6.23×10⁶: 5.10×10⁶) cfu/ml and (6.56×10⁶: 5.50×10⁶) cfu/ml respectively for eggshell surfaces and eggshell contents (Fig. 1) while the afternoon samples recorded mean TVC of (8.56×10⁶: 5.85×10⁶) cfu/ml, (7.80×10⁶: 0.00×10⁶) cfu/ml, (6.48×10⁶: 3.17×10⁶) cfu/ml, (7.95×10⁶: 5.17×10⁶) cfu/ml and (7.2×10⁶: 4.40×10⁶) cfu/ml. The bacteriological examinations conducted on the eggs obtained in the evening revealed growth on only the eggshell surfaces from four farms. It was 7.74×10⁶, 7.49×10⁶, 6.03×10⁶ and 7.14×10⁶ g/cfu respectively for PF1, PF2, PF4 and PF5 (Fig. 1). PF3 however, recorded no bacterial growth on both the eggshell surface and eggshell content.
3.6 Bacterial Growth across Retail Markets

The morning eggs samples from three markets recorded bacterial growth on the shell surfaces only while those of RM1 and RM2, recorded bacterial growth on both the shell surface and the shell content \((6.90 \times 10^6:4.31 \times 10^6)\) and \((2.45 \times 10^6:1.93 \times 10^6)\) cfu/ml respectively (Fig. 2). The afternoon samples also resulted in the isolation of organisms only from the shell surfaces of the eggs obtained from the RM1, RM3, RM4 and RM5 with a mean total viable bacterial counts of \(1.74 \times 10^6\) cfu/ml, \(8.57 \times 10^6\) cfu/ml, \(7.23 \times 10^6\) cfu/ml and \(6.23 \times 10^6\) cfu/ml respectively. RM2 market however, recorded isolates from both the eggshell and its content, with a mean total viable count of \(1.74 \times 10^6\) g/cfu and \(5.24 \times 10^6\) g/cfu respectively (Fig. 2). The evening samples showed that, the eggs from three (RM6, RM3 and RM4) markets recorded bacterial count and these were isolated from the shell surfaces with a mean total viable count of \(4.0 \times 10^6\) cfu/ml, \(6.4 \times 10^6\) cfu/ml and \(7.4 \times 10^6\) cfu/ml respectively. None of the market showed bacterial growth in evening sampled egg content.

4. DISCUSSION

Freshly laid eggs are generally expected to be sterile [8]. Comprehensive studies, however, have indicated that microorganisms can be found on the eggshell and egg content [9]. Contamination of chicken eggs can occur in a number of ways. Prior to being laid, chicken eggs may become horizontally infected, constituting movement of bacteria into the developing egg, while the egg is still in the oviduct of the hen. Bacterial contamination can also occur through vertical infection during the laying process. Hens are a common carrier of a number of bacteria and many of which, like Salmonella, exist in the alimentary canals. Eggs can be contaminated by these bacteria as they are deposited through the cloaca, a structure which serves as the end of the reproductive, urinary, and intestinal tract. In this study, some level of bacterial contaminations were isolated on both the eggshell surfaces and in the eggshell contents.

The microbial isolates were mainly; coagulase-negative Staphylococcus (74.5%), Staphylococcus aureus (2.7%), Escherichia coli (8.2%), Klebsiella sp. (8.2%), Proteus mirabilis (0.9%), Citrobacter sp. (3.6%), and Citrobacter diversus (1.8%). Even though some studies have shown that Salmonella enteritidis is mainly associated with egg contamination [10], in this study, however, Salmonella sp. was not isolated from the eggs which is in accordance with the work of EL-Kholy et al. [11] in Egypt. This difference in prevalence may partly be due to differences in sample size and the randomly sampled eggs used between the different

![Fig. 1. Comparison of the bacterial load at different times of the day](image)
Fig. 2. Comparison of the bacterial load at different times of the day

studies. This may also be due to the fact that the eggs received from all the farms and the retail markets were free of salmonellosis. Our results is also supported by Ansah et al. [12] who reported the presence of Staphylococcus and Escherichia coli, in their studies conducted in the northern region of Ghana.

In a similar study conducted in Nigeria, Salihu et al. [13] also reported the isolation of Escherichia coli, Staphylococcus aureus, Klebsiella sp. and Citrobacter diversus from table egg. Generally, the isolation of coliforms is attributed to faecal contamination and poor hygienic conditions [14]. The isolation of E. coli, Klebsiella spp, and Citrobacter spp either on the eggshell surface or in the eggshell content from both retail market and poultry farms reveals the poor hygienic conditions under which these farms were kept. Mahdavi et al. [14] reports that, the isolation of coliforms is attributed to faecal contamination and poor hygienic conditions.

This is in agreement with the work of Musgrove et al. [15] who reported that Klebsiella sp. is one of the most frequently isolated Gram-negative bacteria found on eggs. The presence of Klebsiella spp. in this study, may attributed to poor hygiene conditions which can lead to significant public health concern. Under these conditions, consumers, especially children, and immunologically impaired individuals are at risk of developing diarrhoea, urinary tract infections, and other severe illnesses if the eggs are not washed well and cooked properly before consuming [10]. For example, Klebsiella pneumoniae is known to cause arthritis, meningitis, septicemia in neonates [16]. Proteus mirabilis is known to cause kidney stone disease upon altering the pH of urine to an alkaline state [17]. Citrobacter can cause a wide spectrum of infections in humans, such as infections in the urinary tract, respiratory tract, wounds, bone, peritoneum, endocardium, meninges, and bloodstream [18]. Among the various sites of infection, the urinary tract is the most common, followed by the abdomen, skin/soft tissues (including surgical site infection), and pneumonia [19]. In addition, the presence of Klebsiella sp. and Citrobacter sp. can lead to spoilage of the egg [12]. Bacterial contamination of the external and internal contents of the egg is influenced by several factors which are categorized into two as vertical and horizontal contamination [8]. Klebsiella spp. were isolated from the sampled eggs from both markets and poultry farms.

In this study, we determined the effect of time of egg collection on bacterial contamination of eggs. The time of the day in the collection of the eggs was found to be significantly associated with bacterial contamination. In most of the cases, even though not significant (p>0.05), the afternoon samples recorded the highest mean
microbial load on the eggshell for all the five farms and three markets. Mesophilic microorganisms grow best at their optimum temperature of 25°C-40°C and this explains why the microbial load is highest in the afternoon as compared to the morning and evening. It is in agreement with the finding of Theron et al. (2003) who observed much higher organism counts in both the egg contents and on the eggshells, which had been subjected to high temperature shocks [20].

5. CONCLUSION

Despite the high nutritional values of egg, contaminations with coliforms and other pathogenic bacteria may result in critical health complications. The bacteria isolates and the sheer numbers from both the eggshells and the egg content confirm the poor hygienic conditions under which both the poultry farms and markets were kept. Even though serious human pathogens were not prevalent in this study, it is recommended that strict hygienic protocols be adhered to on the poultry farms and in the markets. The findings of this study will help inform policy on the intervention measures used to address bacterial contamination in poultry farms and the retail markets.

ACKNOWLEDGEMENT

We are very thankful to the Technicians at the Microbiology Laboratory at the Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana for facilitating the Lab. Work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Meister KA. The role of eggs in the diet: Update. American Council on Science and Health; 2002.
2. Kusi LY, Agbeblewu S, Anim IK, Nyarku KM. The challenges and prospects of the commercial poultry industry in Ghana: A synthesis of literature. International Journal of Management Sciences. 2005;5(6):476-489.
3. Adesiyum A, Offiah N, Seepersadsingh N, Rodrigo S, Lashley V, Musai L, et al. Microbial health risk posed by table eggs in Trinidad. Epidemiol. Infect. 2005; 133:1049-1056.
4. Fardows J, Shamsuzzaman SM. Role of egg in food-born salmonellosis: A public health issue. Bangladesh Journal of Medical Microbiology. 2015;9(1):27-32.
5. Cox NA, Bailey JS, Mauldin JM, Blankenship LC. Presence and impact of Salmonella contamination in commercial broiler hatcheries. Poult. Sci. 1990;69: 1606-1609.
6. Gantois I, Ducatelle R, Pasmans F, Haesebrouck F, Gast R, Humphrey TJ, et al. Mechanisms of egg contamination by Salmonella Enteritidis. FEMS Microbiology Reviews. 2009;33(4):718-738.
7. Berrang ME, Frank JF, Buhr RJ, Bailey JS, Cox NA, Mauldin, JM. Microbiology of sanitized broiler hatching eggs through the egg production period. The Journal of Applied Poultry Research. 1997;6(3):298–305. DOI: 10.1093/japr/6.3.298
8. Svobodová J, Tůmová E. Factors affecting microbial contamination of market eggs: A review. Scientia Agriculturae Bohemica. 2014;45(4):226-237.
9. De Reu K, Grijspeerdt K, Messens W, Heyndrickx M, Uyttendaele M, Debevere J, et al. Eggshell factors influencing eggshell penetration and whole egg contamination by different bacteria, including Salmonella enteritidis. International Journal of Food Microbiology. 2006;112:253-260.
10. Ghasemian SH, Jalali M, Hosseini A, Narimani T, Sharifzadeh A, Raheimi E. The prevalence of bacterial contamination of table eggs from retail markets by Salmonella spp., Listeria monocytogenes, Campylobacter jejuni and Escherichia coli in Shahrekord, Iran. Jundishapur Journal of Microbiology. 2011;4(4):249-253.
11. El-Kholy AM, Saadia H, EL-Shinawy SH, Seliem H, Zeinhom MMA. Potential risk of some pathogens in table eggs. Journal of Veterinary Medical Research. 2020;27(1). Accepted.
12. Ansah T, Dzoagbe GSK, Teye GA, Adday S, Danquah JK. Microbial quality of table eggs sold on selected markets in the Tamale municipality in the Northern Region of Ghana. Livestock Research for Rural Development. 2009;8:128.
13. Salihu MD, Garba B, Isah Y. Evaluation of microbial contents of table eggs at retail outlets in Sokoto metropolis, Nigeria.
14. Mahdavi M, Jalali M, Safaei HG, Shamloo E. Microbial quality and prevalence of Salmonella and Listeria in eggs. International Journal of Environmental Health Engineering. 2012;1(1):48. Available: http://www.ijehe.org/text.asp?

15. Musgrove MT. Effects of processing on the microbiology of commercial shell of eggs. PhD Thesis, U.S. Department of Agriculture. University of Georgia, Athens; 2004.

16. Ghorashi Z, Nezami N, Hoseinpour-feizi H, Ghorashi S, Tabrizi JS. Arthritis, osteomyelitis, septicemia and meningitis caused by Klebsiella in a low-birth-weight newborn: a case report. Journal of Medical Case Reports. 2011;5:241.

17. Norsworthy AN, Pearson MM. From catheter to kidney stone: The uropathogenic lifestyle of Proteus mirabilis. Trends in Microbiology. 2017;25(4):304-315.

18. Lipsky BA, Hook EW III, Smith AA, Plorde JJ. Citrobacter infections in humans: Experience at the Seattle Veterans administration medical center and a review of the literature. Reviews of Infectious Diseases. 1980;2(5):746-760.

19. Samonis G, Karageorgopoulos DE, Kolteridis DP, Matthaiou DK, Sidiropoulou V, Maraki S, Falagas ME. Citrobacter infections in a general hospital: characteristics and outcomes. European Journal of Clinical Microbiology & Infectious Diseases. 2009;28(1):61-68.

20. Theron H, Venter P, Lues JFR. Bacterial growth on chicken eggs in various storage environments. Food Research International. 2003;36:969–975.

© 2020 Addo et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/57488