Antibiograms and risk factors of *Salmonella* isolates from laying hens and eggs in Jimma Town, South Western Ethiopia

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**Abstract**

**Objectives:** *Salmonella* is the most important causes of foodborne illness especially from poultry and poultry products. So the aim of this study was to carryout phenotypic characterization, antimicrobials susceptibility pattern and risk factors of *Salmonella* isolates from farms and markets eggs, cloacae swabs of chickens and stool of egg collectors. A cross-sectional study was conducted from January 2018 to September 2018. Samples were, processed; *Salmonella* was isolated, phenotypically identified by OmniLog and antimicrobials susceptibility were carried out.

**Result:** Over all; 11 (2.65%) of *Salmonella enterica* were phenotypically characterized out of 415 samples from farms egg content (n = 83), farms eggshell (n = 83), cloacae (n = 83), market eggshell (n = 83) and market egg contents (n = 83) with 2.4%, 0%, 2.4%, 4.8% and 3.6% prevalence, respectively. Out of isolates, 8 (72.72%) displayed multidrug resistance. All isolates showed susceptibility to Gentamicin, Kanamycin and Streptomycin. Lack of separating cracked eggs, washing hand, eggs stay longer unsold, and mixing excreta with feed were associated risk factors for *Salmonella* presence (P-value < 0.05). The presence of drug resistant *Salmonella enterica* within egg/chicken can pose serious health problem. Good hygienic practices are important to reduce risk factors of *Salmonella* contamination.

**Keywords:** Antibiogram, Egg, Chicken, Salmonella

**Introduction**

*Salmonella* is one of the major causes of foodborne disease outbreaks globally [1]. Outbreaks due to *Salmonella* have been associated with a wide variety of foods, like; meat, chicken and egg [2, 3].

Infections can occur via ingestion of contaminated meat, eggs, raw and milk. Contamination of these foods can occur during production, processing and distribution [4]. Eggshells and egg contents can be contaminated by this bacterium during egg formation in the hen reproductive system or from environmental including fecal contact. Several outbreaks of salmonellosis have been reported where the eggs is the source of human infection [5–7].

The World Health Organization reports that, the incidence and severity of cases of salmonellosis have increased significantly [8, 9]. Some studies reported varying level of *Salmonella* prevalence (0.2–69%) in poultry [10, 11]. Bayu and his collaborators [12] report 4.69% prevalence of *Salmonella* species from egg. There was report of 41.9% prevalence of *Salmonella* from chicken farm in Jimma town [4]. Additionally antimicrobial resistance of *Salmonella* was also reported [13].

However, an egg is an important source of food; there is no report on infection/contamination status, antimicrobial susceptibility of *Salmonella* from chicken, farm and market egg in this study area. Therefore this study was designed to carry out phenotypic characterization, antimicrobial susceptibility and risk factors of *Salmonella* isolates from chicken and eggs in Jimma town.
Main text

Methods

Study area

Study was conduct in Jimma town which is situated in south western Ethiopia. Jimma town is located at latitude of 07°41'' N and longitude of 36°50'' E, and at an elevation average of 1780 m above sea level [14].

Study design

Cross-sectional study design was conduct from January 2018 to September 2018 on egg and cloacae swab of chicken. The number of eggs sample were estimated based on previous reports using Thrusfield formula [15].

Accordingly, 4.69% [12] expected prevalence was taken with 5% desired absolute precision and 95% confidence interval. Samples size was separately calculated for eggs sampled from markets and farms.

Calculated sample size was \( \approx 69 \) for each. This was increased by 20% and 83 eggs were sampled from each (market and farm). From 166 total eggs, 83 eggs contents and 83 eggshell of market eggs samples and 83 eggs content and 83 eggshell of farm egg samples were analyzed separately. Similarly, 83 cloacae swab samples were collected from chicken those laid sample of egg at farm. Overall, 415 samples were tested for Salmonella detection.

Samples from poultry farms were collected using proportional allocation sampling method and allocated samples were collected randomly. Samples of egg from markets were randomly collected. Structured questionnaire was administered to egg collectors and egg sellers at the markets to assess factors favoring contamination of egg with Salmonella.

Sample collection and transportation

Sample of egg from farms were collected as soon as egg is laid using sterile glove. Cloacae swabs were collected according to [16] and swabs were placed in sterile tube containing 10 ml of Buffered Peptone Water (BPW). Samples of egg from markets were collected using sterile glove. Each sample was coded, packaged separately in an ice box and transported to analyze laboratory.

Sample processing

Sterile cotton tipped swab was soaked in BPW and external egg was rubbed. Swab was inoculated in 10 ml of BPW. Eggshell was washed and immersed in 70% alcohol. Eggs were cracked and 25 g of egg content was added into flask. 225 ml of trypticase soy broth (TSB) was added on the egg content in the same flask, mixed and incubated according to [17].

Salmonella isolation and identification

Salmonella isolation was performed as recommended by [18]. Briefly, 1 ml of BPW mixture of eggshells, cloacae swabs and 1 ml from incubated TSB with egg content mixture were transferred to 10 ml Selenite cysteine broth (SCB) and incubated. A loop full from incubated SCB was streaked on XLD and BGA and incubated. Plate was examined for the presence of Salmonella [19].

Salmonella suspected isolates on BGA and XLD were tested via biochemical test according to [20, 21]. Isolates producing an alkaline slant with acid butt on TSI and H2S production or no H2S production, urea hydrolysis negative and indole negative, citrate utilization positive, decarboxylate lysine positive and motile were assumed as Salmonella species.

Salmonella isolates confirmed by biochemical test were taken to Biolog OmniLog test. This was by growing Salmonella isolates on Biolog Universal Growth Agar. Cell suspensions was made and pipette into 96 well of Biolog Plates and incubated [22]. The incubated microplates were inserted into Biolog OmniLog reader and analyzed. Result was read from computer software [23].

Antibiogram of Salmonella isolates

Phenotypically confirmed Salmonella isolates were subjected to 12 antimicrobial discs by agar diffusion method [24]. Culture of isolates were compared with 0.5 McFarland turbidity standards and swabbed on Mueller–Hinton Agar [4]. Antimicrobial discs were placed on Mueller–Hinton Agar and incubated. For each antimicrobial, inhibition zone was measured.

Associated risk factors

Structured questionnaire was pretested and administered to interviewee (farm managers, egg collectors and egg sellers at the market) to assess potential factors favoring contamination of egg with Salmonella species. The structured questionnaire survey at farm was includes; number of chicken in each farm, chicken keeping system, availability of disinfection bath at the entrance of the farm, eggs collection methods, feeding methods, while farm workers washing their hand after use of toilet, use of protective cloth, cleaning of stained/dirty/eggs, entrance of other people into farm, washing egg collection material/container, separating of cracked eggs from undamaged eggs, treatment of poultry with antibiotic medication, mixing of chicken excreta with fodder and eggs. The structured questionnaire survey at market was include; maximum number of days the unsold egg stays at market, using storage/frigid for unsold egg, cleanliness of egg...
containers, mixing eggs bought from different farmers, and separating cracked eggs.

Data collection, management and analysis
Data collected from laboratory investigation and questionnaire survey were stored. In univariable logistic regression, all independent variables with P-value < 0.25 were taken to multivariable logistic regression. Independent variables with P < 0.05 in multivariable logistic regression were considered as significant.

Result
Phenotypically characterized Salmonella isolates
Overall, 11 (2.65%) out of 415 samples; Salmonella enterica were phenotypically characterized from farm egg content (n = 83), farm eggshell (n = 83), cloacae swab (n = 83), market eggshell (n = 83) and market egg content (n = 83) at a rate of 2.4%, 0%, 2.4%, 4.8% and 3.6% respectively.

Antibiogram of Salmonella enterica
The degree of resistance Salmonella enterica ranges from 9.09 to 90.09% was observed to five antimicrobials. Of the isolates, 8 (72.72%) were multidrug resistance. Isolates susceptible to Neomycin, Ciprofloxacin, Chloramphenicol, Trimethoprim, and Tetracycline, were observed. None of the isolates resistance to Gentamicin, Kanamycin and Streptomycin was observed (Table 1).

Risk factors of Salmonella at farm and market’s egg
Risk factors for Salmonella contamination at farm and at market were analyzed. Hand washing before and after use of toilet, separation of cracked eggs and excreta mix with feed are factors associated with Salmonella contamination (P < 0.05) at farm (Table 2).

The rate of Salmonella isolate is significantly associated (P < 0.05) with duration of unsold egg stays and separation of cracked eggs from intact one (Table 3).

Discussion
In the present study, Salmonella enterica was phenotypically characterized using OmniLog test. In this study, the overall prevalence (2.98%) of Salmonella enterica corroborates with the previous report of [25] 2.25%, and [26] 3.3% prevalence’s. However, higher prevalence of 4.64% [4], 4.69 [12], 13.88%, and 41.9% [11] were reported. Differences in prevalence rates in various studies may be due to geographic and seasonal variation, animal management practices [2] and hygienic conditions [27].

In this study, out of 13 Salmonella enterica; one from farm egg content and one from cloacae swab was isolated from the same chicken that might indicate as the infection of gastrointestinal gut may reason for infection of reproductive organ [28]. This could be a means for transovarial transmission of this bacterium from chicken to egg.

In the present study, occurrence of 2.41% Salmonella enterica species from cloacae swabs in some farms may be linked to the hygienic status of poultry production [29, 30]. The prevalence of Salmonella enterica species from farm egg contents in the present study was in line with 2.9% prevalence report [31]. But it shows lower prevalence when compared with 3.84% [32], 4.64% [4] and 4.69 [12]. This may be due to inadequate storage conditions of egg [33]. But in this study, eggs were collected as soon as egg laid that might minimize the exposure of egg contamination [34, 35].

In this study some of Salmonella enterica species from shell and contents of market egg were isolated from the same egg. This suggest as both eggs part can

| Antimicrobial          | Disc potency (μg) | Resistant (%) | Intermediate (%) | Susceptible (%) |
|------------------------|-------------------|---------------|------------------|-----------------|
| Ceftriaxone            | 30                | 63.63         | 36.36            | 100             |
| Gentamicin             | 10                | 100           |                  |                 |
| Kanamycin              | 30                | 100           |                  |                 |
| Streptomycin           | 10                | 100           |                  |                 |
| Neomycin               | 30                | 9.09          | 81.81            | 9.10            |
| Ciprofloxacin          | 5                 | 9.09          | 90.91            |                 |
| Chloramphenicol        | 30                | 9.09          | 90.91            |                 |
| Sulphonamides          | 30                | 90.09         | 9.09             |                 |
| Trimethoprim           | 5                 | 54.54         | 46.46            |                 |
| Tetracycline           | 30                | 9.09          | 90.91            |                 |
| Ampicillin             | 10                | 90.09         | 9.09             |                 |
| Oxytetracycline        | 30                | 36.36         | 63.63            |                 |
Table 2  Risk factors for *Salmonella enterica* at farm

| Variable                        | Frequency (%) | Univariable | Multivariable |
|--------------------------------|--------------|-------------|---------------|
|                                |              | COR (95% CI)| P-value       | AOR (95% CI)  | P-value |
| Number chicken                 |              |             |               |               |         |
| 63                             | 10 (3.7)     | 0 (0–0.032) | 0.999         |               |         |
| 106                            | 20 (7.4)     | 0 (0–0.058) | 0.998         |               |         |
| 328                            | 55 (20.4)    | 1.754 (0.006–514) | 0.846 |         |         |
| 1150                           | 185 (68.5)   | 1.00        |               |               |         |
| Chicken kept system            |              |             |               |               |         |
| Cage                           | 185 (68.5)   | 3.534 (0.05–2.3) | 0.702 |         |         |
| Open                           | 85 (31.5)    | 1.00        |               |               |         |
| Fodder method                  |              |             |               |               |         |
| Manual                         | 70 (100)     | 1.00        |               |               |         |
| Egg collecting method          |              |             |               |               |         |
| Manual                         | 270 (100)    | 1.00        |               |               |         |
| Wash hand after use of toilet  |              | 1.00        |               |               |         |
| Yes                            | 106 (39.3)   | 21.4 (1.285–337) | 0.033 | 0.066 (0.005–0.809) | 0.034 |
| No                             | 164 (60.7)   | 1.00        |               |               |         |
| Disinfection bath              |              |             |               |               |         |
| Yes                            | 137 (50.7)   | 0.63 (0.025–15.5) | 0.775 |         |         |
| No                             | 133 (49.3)   | 1.00        |               |               |         |
| Separating cracked eggs        |              |             |               |               |         |
| Yes                            | 119 (44.1)   | 28.4 (1.28–629.4) | 0.034 | 0.062 (0.005–0.802) | 0.033 |
| No                             | 151 (55.9)   | 1.00        |               |               |         |
| Dirty eggs clean               |              |             |               |               |         |
| Yes                            | 56 (20.7)    | 9.57 (0.025–15.5) | 0.162 | 0.164 (0.021–1.276) | 0.084 |
| No                             | 214 (79.3)   | 1.00        |               |               |         |
| Wear special wear              |              |             |               |               |         |
| Yes                            | 79 (29.3)    | 0.75 (0.030–18.7) | 0.861 |         |         |
| No                             | 191 (70.7)   | 1.00        |               |               |         |
| Other people enter farm        |              |             |               |               |         |
| Yes                            | 139 (51.5)   | 0.2 (0.05–10.32) | 0.451 |         |         |
| No                             | 131 (48.5)   | 1.00        |               |               |         |
| Excreta mix with feed          |              |             |               |               |         |
| Yes                            | 225 (83.3)   | 0.1 (0.003–3.1) | 0.190 | 19.87 (2.234–176.79) | 0.007 |
| No                             | 45 (16.7)    | 1.00        |               |               |         |
| Washing egg container          |              |             |               |               |         |
| Yes                            | 159 (58.9)   | 0.5 (0.032–8.2) | 0.635 |         |         |
| No                             | 111 (41.1)   | 1.00        |               |               |         |
| Excreta mix with the eggs      |              |             |               |               |         |
| No                             | 134 (49.6)   | 0.23 (0.016–3.12) | 0.266 |         |         |
| Yes                            | 136 (40.4)   | 1.00        |               |               |         |
| Treated with medication        |              |             |               |               |         |
| Yes                            | 24 (8.9)     | 20.67 (0.612–0.700) | 0.092 | 0.082 (0.004–1.497) | 0.09  |
| No                             | 246 (91.1)   | 1.00        |               |               |         |
be contaminated with *Salmonella* from the environment [34, 35].

In this study, occurrence of 3.6% and 4.82% *Salmonella enterica* from content and shell respectively, out of analyzed sample of market’s eggs, may be due to the difference in handling/hygienic status of egg at the markets [27, 36]. This finding is in line with the studies of [32, 37].

There are reports showed drug resistances of *Salmonella* [6, 16, 32, 38]. In the current study, resistance of *Salmonella enterica* to antimicrobials is concurs with previous reports [10, 39, 40]. Multi-drug resistance observed in this study is consistent with the findings of [41, 42]. This may be due to the bacteria accumulate multiple genes; each coding for resistance [43, 44].

In this study, none of *Salmonella enterica* were resistant to Gentamicin, Kanamycin and Streptomycin is in line with [45, 46] studies. Contrary to these [4, 40], was report 100% resistance of *Salmonella* to Streptomycin. Resistivity of *Salmonella enterica* can be linked to various factors including inappropriate medication and frequent use of antibiotics [31].

In this study, importance of separating cracked egg from the intact, might be due to cracked egg promotes the gross of bacteria [28]. Similarly, mixing excreta with feed influenced the prevalence of *Salmonella* contaminates in the feed [34]. Washing hand before and after use of toilet has reduced risk for egg contamination in this study may linked with keeping hygienic status of egg collectors can minimize bacterial contamination [27].

Unsold egg stays for long time has increased risk for egg contamination may be associated with lack of appropriate use of storage and transportation [47]. However, our result suggests that establishment of good hygienic practices in poultry farm and on markets eggs are essential to reduce the contamination of *salmonella*.

**Limitation**
The isolates were not molecularly characterized due to lack of resource.

**Abbreviations**
BGA: Brilliant Green Agar; BUG: Biolog Universal Growth; XLD: Xylose Lysine Deoxycholate.

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**Authors’ contributions**
DT, ES, TT and BD were participated in the conception of the research idea, Methodology and, ML and AO carried out the laboratory work of OmniLog test. All authors read and approved the final manuscript.

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**Availability of data and materials**
The data sets developed and analyzed during the current study are available from the first author or from the corresponding authors upon request.

| Table 3 Risk factors for Salmonella enterica at market |
|--------------------------------------------------------|
| Variable | Frequency (%) | Univariable | Multivariable |
|          |              | COR (95% CI) | P-value | AOR (95% CI) | P-value |
| Maximum days unsold egg stays (days) |          |              |         |             |         |
| > 5      | 99 (59.6) | 0.02 (0.001–0.38) | 0.009 | 50.87 (2.65–976) | 0.009 |
| 3–5      | 40 (24.1) | 0.0 (0.0–0.01) | 0.997 |
| 1–2      | 27 (16.3) | 1.00 |
| Unsold egg store |          |              |         |             |         |
| No       | 2 (1.2)  | 3.6 (0.0–0.08) | 1.0 |
| Yes      | 16 (498.8) | 1.00 |
| Containers clean |          |              |         |             |         |
| Yes      | 56 (33.7) | 5.5 (0.4–75) | 0.2 | 0.18 (0.013–2.455) | 0.198 |
| No       | 110 (66.3) | 1.00 |
| Mix eggs bought |          |              |         |             |         |
| No       | 63 (38) | 9.5 (0.5–17.7) | 0.129 | 0.106 (0.006–1.92) | 0.129 |
| Yes      | 103 (62) | 1.00 |
| Separate cracked eggs |          |              |         |             |         |
| Yes      | 22 (13.3) | 17.97 (1.17–28) | 0.038 | 0.055 (0.004–0.85) | 0.038 |
| No       | 144 (86.7) | 1.00 |
Ethics approval and consent to participate
Ethical clearance was obtained from Jimma University, College of Agriculture and Veterinary Medicine. All participants were informed about the aim of research. Additionally, written consent was obtained from all participants and Jimma town administration office.

Consent to publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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References
1. Shawkat H, Tahoun A, El-Gohary AEGA, El-Abasy M, El-Khayat F, Gillepsie T, El-Adawy H. Epidemiological, molecular characterization and antibiotic resistance of Salmonella enterica serovars isolated from chicken farms in Egypt. Gut Pathog. 2017;9:8.
2. Naik VK, Shaky S, Patyal A, Gade NE. Isolation and molecular characterization of Salmonella spp. from chevon and chicken meat collected from different districts of Chhattisgarh, India. Vet World. 2015;8:702.
3. Feasey NA, Dougan G, Kingsley RA, Heyderman RS, Gordon MA. Invasive non-typhoidal Salmonella disease an emerging and neglected tropical disease in Africa. Lancet. 2012;379:2489–99.
4. Kebede A, Keral J, Alemayehu H, Habte Mariam S. Isolation, identification, and antibiotic susceptibility testing of Salmonella from slaughtered bovines and ovines in Addis Ababa Abattoir Enterprise Ethiopia. Int J Bacteriol. 2016;8:421.
5. Moosavi MH, Esmaili S, Amiri FB, Mostafavi E, Salehi TZ. Detection of Salmonella spp. in commercial eggs in Iran. Iran J Microbiol. 2015;7:50.
6. Mohammed HI, Ibrahim AE. Isolation and identification of Salmonella from the environment of traditional poultry farms in Khartoum North. 2012;7:1239–1245.
7. Bhunia AK. Foodborne microbial pathogens: mechanisms and pathogenesis. New York: Springer; 2018.
8. De Knept LV, Pires SM, Hald T. Attributing foodborne salmonellosis in humans to animal reservoirs in the European Union using a multi-country stochastic model. Epidemiol Infect. 2015;143:1175–86.
9. Organization, WH. Antimicrobial resistance: global report on surveillance. Geneva World Health Organization; 2014.
10. Bezzerra WGA, Silva ING, Vasconcellos RH, Machado DN, de Souza Lopes E, Lima SVG, de Castro Teixeira RS, Lima JB, Oliveira FR, Maciel WC. Isolation and antimicrobial resistance of Escherichia coli and Salmonella Enterica Subsp Enterica in broiler chickens. Acta Sci Agric. 2016;44:1–7.
11. Indu A, Addis M. A survey on Salmonella infection among chicken flocks in Jimma town, Ethiopia. Afr J Microbiol Res. 2013;7:1239–45.
12. Bayu Z, Asrade B, Kebede N, Siay Z, Bayu Y. Identification and characterization of salmonella species in whole egg purchased from local markets in Addis Ababa, Ethiopia. J Vet Med Anim Health. 2013;5:133–7.
13. Endrias Z. Prevalence, distribution and antimicrobial resistance profile of Salmonella isolated from food items and personnel in Ethiopia, Addis Ababa University. 2004.
14. Duguma B, Kechero Y, Jannsens GPJ. Survey of major diseases affecting dairy cattle in Jimma town, Oromia, Ethiopia. Glob Vet. 2012;7:862–6.
15. Thrusfield M. Veterinary epidemiology. 3rd ed. Blackwell Science Ltd: London. 2005. p. 228–45.
16. Garcia C, Soriano JM, Benitez V, Catala-Gregori P. Assessment of Salmonella spp. in feces, cloacal swabs, and eggs (eggshell and content separately) from a laying hen farm. Poult Sci. 2011;90:1581–5.
17. Muallem AK. Occurrence of Salmonellato spp. in hens eggs and their environment in selected farms in Gaza strip. Doctoral dissertation, Islamic University-Gaza. 2008.
18. Standardization, I.O.F. Microbiology of food and animal feeding stuffs Horizontal method for the detection of Salmonella spp. vol. 6579. ISO. 2002. p. 62.
19. International Organization for Standardization. ISO-6579. Microbiology—general guidance on methods for the detection of Salmonella. 2002. p. 27.
20. Özkalp B. Isolation and identification of salmonellas from different samples Dange. Foodborne Pathog. 2012;2:1–7.
21. Andrews WH, Jacobson A, Hammack T. Bacteriological analytical manual (BAM). Chapter 5 Salmonella. 2011.
22. Wragg P, Randall L, Whatmore AM. Comparison of Biolog GEN III MicroStation semi-automated bacterial identification system with matrix-assisted laser desorption ionization-time of flight mass spectrometry and 16S ribosomal RNA gene sequencing for the identification of bacteria of veterinary interest. J Microbiol Methods. 2014;105:16–21.
23. Oselska MA, Jagodziński PP. Long non-coding RNA as potential biomarkers in non-small-cell lung cancer: what do we know so far? Biomed Pharmacother. 2018;101:322–33.
24. Matsumura PM, Hyman JM, Jeffrey SR, Mareisch MJ, Thorpe TC, Barron WG. Device and method for microbial antibiotic susceptibility testing. 2000.
25. Lambe KJ, Verma AK, Jain U, Bist B. Bacteriological quality of chevon and pork in Mathura City. J Vet Public Health. 2009;7(2):141–3.
26. Dabaasa A, Bacha K. The prevalence and antibiotic resistance of Salmonella and Shigella isolated from Abattay, Jimma Town, Southwestern Ethiopia. In: Conference of Jimma University. 2011. p. 169.
27. Elson R, Little CL, Mitchell RT. Salmonella and raw shell eggs: results of a cross-sectional study of contamination rates and egg safety practices in the United Kingdom catering sector. J Food Prot. 2005;68:256–64.
28. Gantois I, Ducatelle R, Pasmans F, Haesebrouck F, Gast R. Mechanisms of egg-contamination by Salmonella enteritidis. FEMS Microbiol Rev. 2009;33:3718–38.
29. Foley SL, Lynne AM, Nyakay R. Salmonella challenges: prevalence in swine and poultry and potential pathogenicity of such isolates. J Anim Sci. 2008;86:149–62.
30. Velge F, Cloeckaert A, Barrow P. Emergence of Salmonella epidemics: the problems related to Salmonella enterica serotype Enteritidis and multiple antibiotic resistances in other major serotypes. Vet Res. 2005;36:267–88.
31. Tessema K, Bedu H, Epo M, Hiko A. Prevalence and antibiotic resistance of Salmonella species isolated from chicken eggs by standard bacteriological method. J Vet Sci Technol. 2017;8:421. https://doi.org/10.4172/2157-7579.1000421.
32. Singh S, Yadav AS, Singh SM, Bharti P. Prevalence of Salmonella in chicken eggs collected from poultry farms and marketing channels and their antimicrobial resistance. Food Res Int. 2010;43:2027–30.
33. Humphrey T, Baskerville A, Mawer S, Rowe B, Hooper S. Salmonella enteritidis phage type 4 from the contents of intact eggs: a study involving naturally infected hens. Epidemiol Infect. 1989;103:415–23.
34. Aguiles TM. How egg quality impacts the health of day-one-chicks? Poult Sci. 2014;2:1–3.
35. Lopez LD, Rosos R, Cressey PJ, Horn B, Lee J. Foodborne disease in New Zealand. Wellington: Ministry for Primary Industries; 2016.
36. Andrews WH. Salmonella: bacteriological analytical manual. Gaithersburg: Food Drug Administration; 1993. p. 5-01.
37. Suresh T, Hatha AAM, Sreenivasan D, Sangeetha N, Lashmanaperumal samy P. Prevalence and antimicrobial resistance of Salmonella enterica serovar Typhimurium in different districts of Chhattisgarh, India. Vet World. 2015;8:706.
38. Tassew A. Isolation, identification, antimicrobial profile and molecular characterization of enterohaemorrhagic isolated from ruminants slaughtered at debre zeytella export abattoir and Addis Ababa abattoirs enterprise. 2015.
39. Garedew L, Hagos Z, Addis Z, Tesfaye R, Zegeye B. Prevalence and antimicrobial butcher shops in Gondar town, Ethiopia. Antimicrob Resist Infect Control. 2015;4:015-0062.
40. Reda AA, Seyoum B, Yimam J, Fiseha S, Jean-Michel V. Antibiotic susceptibility patterns of Salmonella and Shigella isolates in Harar Eastern Ethiopia. J Infect Dis Immun. 2011;3:134–9.
41. Tsegaye S, Beyene W, Tesfaye B, Tesfaye S, Feleke A. Prevalence and antimicrobial susceptibility pattern of Salmonella species from exotic chicken eggs in Alage, Ziway and Shashemene, Ethiopia. Afr J Basic Appl Sci. 2016;8:180–4.
42. Mouttotou N, Ahmad S, Kamran Z, Koutoulis KC. Prevalence, risks and antibiotic resistance of *Salmonella* in poultry production chain. 2017.

43. Perron GG, Bell G, Quessy S. Parallel evolution of multidrug-resistance in *Salmonella enterica* isolated. FEMS Microbial Lett. 2008;281:17–22.

44. Dominic H, Barbara R, Aniko P, Michael R, Peter B, Scott B, Mark E, Barbara T, Colin M, Shawn D, Colin H. Antibiotic susceptibilities of *Pseudomonas aeruginosa* isolates derived from patients with cystic fibrosis under aerobic, anaerobic and biofilm conditions. J Clin Microbiol. 2005;43:5085–90.

45. Brown K, Li W, Kaur P. Role of aromatic and negatively charged residues of DrrB in multisubstrate specificity conferred by the DrrAB system of *Streptomyces peucetius*. Biochemistry. 2017;56:1921–31.

46. Musgrove MT, Jones DR, Northcutt JK, Cox NA, Harrison MA, Fedorka-Cray PJ, Ladely SR. Antimicrobial resistance in *Salmonella* and *Escherichia coli* isolated from commercial shell eggs. Poult Sci. 2006;85:1665–9.

47. Bekele B, Ashenafi M. Distribution of drug resistance among enterococci and salmonella from poultry and cattle in Ethiopia. Trop Anim Health Prod. 2010;4:857–64.

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