KJVS
Korean Journal of Veterinary Service
https://doi.org/10.7853/kjvs.2023.46.3.211
pISSN: 1225-6552 eISSN: 2287-7630
Korean J Vet Serv 2023;46(3):211-218

ORIGINAL ARTICLE

Prevalence and antimicrobial resistance of *Salmonella* spp. isolated from duck farms in Jeollanam-do Province, South Korea

Sin-Wook Park[1†], Keon Kim[1†], Chang-Yun Je[1], Chang-Hyeon Choi[1], Sang-Gyue Choi[2], Jong-Soo Lim[3], Ok-Mi Jeong[4], Guk-Hyun Suh[1]*, Chang-Min Lee[1]*

[1]Department of Veterinary Internal Medicine, College of Veterinary Medicine and BK21 FOUR Program for Creative Veterinary Science Research Center, Chonnam National University, Gwangju 61186, Korea
[2]Jeollanamdo Agricultural Research & Extension Service (Livestock Research Institute), Gangjin 59213, Korea
[3]Jeollanamdo Veterinary Service Laboratory, Gangjin 59213, Korea
[4]Veterinary Drugs & Biologics Division, Animal and Plant Quarantine Agency, Gimcheon 39660, Korea

Received July 5, 2023
Revised July 28, 2023
Accepted August 16, 2023

Corresponding author:
Guk-Hyun Suh
E-mail: ghsuh@jnu.ac.kr
https://orcid.org/0000-0003-0910-3340

Chang-Min Lee
E-mail: cmlee1122@chonnam.ac.kr
https://orcid.org/0000-0002-7867-1053
[†]These first two authors contributed equally to this work.

This study was carried out to investigate the prevalence and antimicrobial resistance of *Salmonella* serotypes in duck farms of Jeollanam-do Province, South Korea. A total of 1112 samples (breeder ducks, 286; broiler ducks, 826) were collected from 196 duck farms (breeder duck farms, 25; broiler duck farms, 171) between January 2018 and November 2019. The total prevalence of *Salmonella* serotypes was 45.4% (89/196) in the duck farms, with no significant difference between prevalence in breeder and broiler duck farms (48% and 45%, respectively; $P>0.05$). The most prevalent serotype among the 127 *Salmonella* isolates was *Salmonella* Typhimurium (20.5%) followed by *Salmonella* Albany (17.3%), *Salmonella* Hadar (15.7%), and *Salmonella* Enteritidis (11.8%). Maximum resistance was observed against penicillin (78.74%), followed by tetracycline (68.50%), and kanamycin (65.35%). Of the 127 isolates, 117 (92.13%) were resistant to ≥3 antimicrobials and 2 to all 18 antimicrobials. Our results demonstrate the presence of *Salmonella* strains and their resistance to multiple antimicrobials, thus indicating a public health concern in South Korea. The emergence of *Salmonella* stains that are resistant to multiple drugs highlight the need for careful use of antimicrobials in duck farms.

Key Words: Duck samples, Multidrug resistance, Public health, Salmonellosis

INTRODUCTION

Salmonellae are gram-negative, rod-shaped, non-sporing, non-capsulated organisms belonging to the family Enterobacteriaceae (Mondal et al, 2008). They are predominantly associated with infections in both animals and humans and identified as zoonotic pathogens (Cha et al, 2013). *Salmonella* cause clinical disease in ducks and are transmitted to humans through food (Mondal et al, 2008). In ducks, salmonellosis occurs either in acute or subclinical form; adult ducks commonly develop a nonlethal chronic condition or become carriers of the disease (Henry, 2000; Lu et al, 2011). The probability of zoonotic transmission to humans through the food chain is high because of the horizontal and vertical transmission of *Salmonella* in ducks, and the disease may be subclinical or remain asymptomatic without causing any modifications (Jibril et al, 2020; Tariq et al, 2022).

Poultry products, such as meat and eggs, derived from asymptomatic animals are the main sources of infection in humans (Gast et al, 2014). According to the Centers for Disease Control and Prevention, *Salmonella* alone accounts for 1.3 million infections each year in the United States, causing symptoms of diarrhea, fever, and abdominal pain (Tariq et al, 2022). In Korea, approximately 413 outbreaks of salmonellosis, impacting 16475 patients were reported from 2002 to 2021 (Oh et al, 2023). Therefore, reducing *Salmonella* outbreaks in poultry farms is essential for enhancing food safety in the broiler meat industry.

Over the past decades, antimicrobial agents have come to be regarded as an important option for treating and managing *Salmonella* and other pathogens (Kuang et al, 2015). Nonetheless, their extensive use has led to the emergence and global dissemination of antimicrobial-resistant and even multidrug-resistant *Salmonella* strains, which pose a significant threat to global public health (Gong et al, 2013; Lai et al, 2014). In veterinary medicine, the regular use of antimicrobials contributes to antimicrobial resistance of human pathogens, which is increasingly becoming a cause for concern (McEwen, 2012).

According to the Korean Statistical Information Service, Jeollanam-do is South Korea's largest duck farming province, accounting for >50% of duck production occurring in approximately 270 duck farms. Information regarding the prevalence and characteristics of *Salmonella* spp. in duck farms in Jeollanam-do Province is limited. Therefore, the aim of this study was to assess the prevalence of *Salmonella* spp. in this area to ascertain their antimicrobial-resistance profiles.

MATERIALS AND METHODS

Sample collection

A total of 1112 samples (breeder ducks, 286; broiler ducks, 826) were gathered from 196 duck farms in Jeollanam-do Province (breeder duck farms, 25; broiler duck farms, 171) between January 2018 and November 2019. The samples were collected from duck carcasses (broiler duck farms, 98), cloacal cavities (broiler duck farms, 278), feces (breeder duck farms, 286; broiler duck farms, 336), and living environment (broiler duck farms, 114) such as water, soil, feed, and manure. They were obtained from diseased ducks or randomly from the living environment using sterilized cotton swabs, placed in separate containers, and transported to the laboratory and examined.

Isolation and serotyping of *Salmonella* spp.

Buffered peptone water (Oxoid, UK) was added to the test sample to produce 1:10 dilution and incubated at 37℃ for 6~8 h. After pre-enrichment, 0.1 mL of the broth was added to 10 mL Rappaport-Vassiliadis (RV) enrichment broth (Oxoid, UK) that was prepared according to the manufacturer's instructions. The RV broth was incubated at 42℃ for 18~24 h and streaked onto Rambach agar (Difco). Loopfuls of the enriched broths were streaked onto plates of XLT 4 agar (Oxoid) and incubated at 37℃ for 24 h. *Salmonella* colonies showed up as black or black-centered colonies with a yellow or pink periphery. Presumptive *Salmonella* colonies were selected, inoculated into nutrient agar, and incubated at 37℃ for 24 h to facilitate growth. All strains were serotyped using matrix-assisted laser desorption/ionization-time of flight mass spectrometry (MALDI-TOF MS; Bruker, Germany) according to the manufacturer's instructions.

Antimicrobial susceptibility testing

The disk diffusion test was conducted to examine antimicrobial resistance of all *Salmonella* isolates. The following 18 antimicrobials were used: amoxicillin/clavulanic acid (30 μg), ampicillin (10 μg), apramycin (30 μg), cephalexin (30 μg), ceftiofur (30 μg), ciprofloxacin (5 μg), doxycycline (30 ug), enrofloxacin (5 μg), florfenicol (30 μg), flumequine (30 μg), gentamicin (10 μg), kanamycin (30 μg), neomycin (30 μg), oxytetracycline (30 μg), penicillin (10 μg), spectinomycin (100 μg), sulfamethoxazole/trimethoprim (23.75/1.25 μg), and tetracycline (30 μg). The inhibition zone diameters were evaluated based on the Clinical and Laboratory Standards Institute guidelines (Jorgensen et al, 2007). Isolates resistant to ≥3 categories of antimicrobials were considered multidrug-resistant (MDR) strains.

https://doi.org/10.7853/kjvs.2023.46.3.211

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows, version 29 (IBM Corp., Armonk, NY, USA). The chi-square test was used to analyze the association between prevalence of isolates and type of duck (breeder/broiler). Statistical significance was considered as $P<0.05$ for all the tests.

RESULTS

Prevalence of *Salmonella* in ducks

The prevalence of *Salmonella* spp. in this study was 45.4% (89/196) and *Salmonella* spp. were isolated in 127 of 1112 samples (11.4%). The number of isolates detected in the 286 breeder and 826 broiler duck samples were 15 (5.2%) and 112 (13.6%), respectively. In the broiler duck samples, *Salmonella* spp. were isolated in carcasses (12/127), cloacal cavities (22/127), feces (86/127) and living environment (7/127). The prevalence of *Salmonella* spp. in breeder duck farms was 48% (12/25) and that in broiler duck farms was 45.0% (77/171). There was no significant difference between *Salmonella* spp. prevalence in breeder and broiler duck farms ($P>0.05$).

In broiler duck farms, 108 flocks were infected with *Salmonella* spp. when they were 1 week old (96.4%) and 2 flocks each when they 2 (1.8%) and 3 weeks old (1.8%). In breeder duck farms, the median age of flocks with *Salmonella* was 9 weeks (range, 6~26 weeks).

Bacteria isolation and serotyping

The 127 *Salmonella* isolates belonged to 14 different serovars. The predominant serovars were *Salmonella* Typhimurium (26/127), *Salmonella* Albany (22/127), *Salmonella* Hadar (20/127), and *Salmonella* Enteritidis (15/127). Other isolated serovars were *Salmonella* Muenster (4/127), *Salmonella* Agona (3/127), *Salmonella* London (3/127), *Salmonella* Bareilly (2/127), *Salmonella* Give (2/127), *Salmonella* Indiana (2/127), *Salmonella* Lagos (1/127), *Salmonella* Montevideo (1/127), *Salmonella* Newport (1/127), and *Salmonella* Regent (1/127). However, 24 isolates could not be identified.

Antimicrobial susceptibility testing

Antimicrobial resistance of the isolates is summarized in Table 1 and 2. All the 127 isolated *Salmonella* strains were tested against 18 antimicrobials (Table 1). The maximum percentage of resistance was observed against penicillin (78.7%), followed by tetracycline (68.5%) and kanamycin (65.4%). None of the antimicrobials were effective against every *Salmonella* isolate. Of the 127 isolates, 117 (92.1%) were resistant to ≥3 antimicrobials (Table 3), and 2 (n=1, *Salmonella* Hadar; n=1, *Salmonella* spp.) to all 18 antimicrobials.

DISCUSSION

The "One Health" concept acknowledges that many

Table 1. Antimicrobial resistances of 127 *Salmonella* strains

Antimicrobials	Susceptible (%)	Intermediate (%)	Resistant (%)
Amoxicillin/ clavulanic acid	56.7	8.7	34.6
Ampicillin	44.9	7.9	47.2
Apramycin	34.6	23.6	41.8
Cephalexin	70.9	3.2	25.9
Ceftiofur	49.6	3.2	47.2
Ciprofloxacin	66.1	7.9	26.0
Doxycycline	33.9	18.9	47.2
Enrofloxacin	67.7	5.5	26.8
Florfenicol	48.8	5.5	45.7
Flumequine	31.5	7.9	60.6
Gentamicin	48.0	11.8	40.2
Kanamycin	11.8	22.8	65.4
Neomycin	40.9	15.8	43.3
Oxytetracycline	49.6	3.9	46.5
Penicillin	11.8	9.5	78.7
Spectinomycin	65.4	3.9	30.7
Sulfamethoxazole/ trimethoprim	36.2	6.3	57.5
Tetracycline	14.2	17.3	68.5

Table 2. *Salmonella* serovars resistant to the tested antimicrobials

Antimicrobials	*Salmonella* spp.	*Salmonella* Typhimurium	*Salmonella* Albany	*Salmonella* Hadar	*Salmonella* Enteritidis	*Salmonella* Muenster	*Salmonella* Agona	*Salmonella* London	*Salmonella* Bareilly	*Salmonella* Give	*Salmonella* Indiana	*Salmonella* Lagos	*Salmonella* Montevideo	*Salmonella* Newport	*Salmonella* Regent
Amoxicillin/ clavulanic acid	29.2% (7/24)*	26.9% (7/26)	40.9% (9/22)	30.0% (6/20)	73.3% (11/15)	0.0% (0/4)	0.0% (0/3)	33.3% (1/3)	50.0% (1/2)	0.0% (0/2)	0.0% (0/2)	0.0% (0/1)	100% (1/1)	100% (1/1)	0.0% (0/1)
Ampicillin	37.5% (9/24)	46.2% (12/26)	45.5% (10/22)	45.0% (9/20)	80.0% (12/15)	0.0% (0/4)	33.3% (1/3)	33.3% (1/3)	100% (2/2)	50.0% (1/2)	0.0% (0/2)	0.0% (0/1)	100% (1/1)	100% (1/1)	100% (1/1)
Apramycin	29.2% (7/24)	38.5% (10/26)	63.6% (14/22)	50.0% (10/20)	33.3% (5/15)	50.0% (2/4)	0.0% (0/0)	66.7% (2/3)	0.0% (0/2)	50.0% (1/2)	0.0% (0/2)	0.0% (0/1)	100% (1/1)	100% (1/1)	0.0% (0/1)
Cephalexin	33.3% (8/24)	23.1% (6/26)	22.7% (5/22)	15.0% (3/20)	40.0% (6/15)	25.0% (1/4)	0.0% (0/0)	66.7% (2/3)	50.0% (1/2)	0.0% (0/2)	0.0% (0/2)	0.0% (0/1)	100% (1/1)	0.0% (0/1)	0.0% (0/1)
Ceftiofur	50.0% (12/24)	46.2% (12/26)	40.9% (9/22)	50.0% (10/20)	80.0% (12/15)	0.0% (0/0)	0.0% (0/0)	66.7% (2/3)	0.0% (0/2)	50.0% (1/2)	50.0% (1/2)	0.0% (0/1)	0.0% (0/1)	100% (1/1)	0.0% (0/1)
Ciprofloxacin	29.2% (7/24)	23.1% (6/26)	22.7% (5/22)	25.0% (5/20)	46.7% (7/15)	0.0% (0/0)	0.0% (0/0)	66.7% (2/3)	0.0% (0/2)	0.0% (0/2)	0.0% (0/2)	0.0% (0/1)	0.0% (0/1)	100% (1/1)	0.0% (0/1)
Doxycycline	37.5% (9/24)	46.2% (12/26)	59.1% (13/22)	25.0% (5/20)	73.3% (11/15)	25.0% (1/4)	66.7% (2/3)	33.3% (1/3)	50.0% (1/2)	100% (2/2)	0.0% (0/2)	0.0% (0/1)	100% (1/1)	100% (1/1)	100% (1/1)
Enrofloxacin	25.0% (6/24)	34.6% (9/26)	18.2% (4/22)	35.0% (7/20)	40.0% (6/15)	25.0% (1/4)	0.0% (0/0)	0.0% (0/0)	0.0% (0/0)	50.0% (1/2)	0.0% (0/2)	0.0% (0/1)	0.0% (0/1)	0.0% (0/1)	0.0% (0/1)
Florfenicol	75.0% (18/24)	30.8% (8/26)	50.0% (11/22)	40.0% (8/20)	46.7% (7/15)	0.0% (0/0)	0.0% (0/0)	33.3% (1/3)	50.0% (1/2)	50.0% (1/2)	50.0% (1/2)	0.0% (0/1)	0.0% (0/1)	100% (1/1)	100% (1/1)
Flumequine	54.2% (13/24)	50.0% (13/26)	81.8% (18/22)	65.0% (13/20)	66.7% (10/15)	25.0% (1/4)	66.7% (2/3)	66.7% (2/3)	50.0% (1/2)	50.0% (1/2)	100% (2/2)	0.0% (0/1)	0.0% (0/1)	0.0% (0/1)	100% (1/1)
Gentamicin	50.0% (12/24)	30.8% (8/26)	40.9% (9/22)	30.0% (6/20)	73.3% (11/15)	25.0% (1/4)	0.0% (0/0)	66.7% (2/3)	50.0% (1/2)	0.0% (0/2)	50.0% (1/2)	0.0% (0/1)	0.0% (0/1)	0.0% (0/1)	0.0% (0/1)
Kanamycin	54.2% (13/24)	61.5% (16/26)	72.7% (16/22)	80.0% (16/20)	73.3% (11/15)	50.0% (2/4)	33.3% (1/3)	100% (3/3)	50.0% (1/2)	100% (2/2)	0.0% (0/2)	0.0% (0/1)	100% (1/1)	0.0% (0/1)	100% (1/1)
Neomycin	50.0% (12/24)	34.6% (9/26)	68.2% (15/22)	40.0% (8/20)	40.0% (6/15)	25.0% (1/4)	0.0% (0/0)	33.3% (1/3)	100% (2/2)	0.0% (0/2)	0.0% (0/2)	0.0% (0/1)	100% (1/1)	0.0% (0/1)	0.0% (0/1)
Oxytetracycline	50.0% (12/24)	30.8% (8/26)	59.1% (13/22)	50.0% (10/20)	73.3% (11/15)	0.0% (0/0)	66.7% (2/3)	0.0% (0/0)	50.0% (1/2)	50.0% (1/2)	0.0% (0/2)	0.0% (0/1)	0.0% (0/1)	100% (1/1)	0.0% (0/1)
Penicillin	87.5% (21/24)	65.4% (17/26)	100% (22/22)	75.0% (15/20)	80.0% (12/15)	50.0% (2/4)	66.7% (2/3)	66.7% (2/3)	100% (2/2)	50.0% (1/2)	50.0% (1/2)	0.0% (0/1)	100% (1/1)	100% (1/1)	100% (1/1)
Spectinomycin	29.2% (7/24)	30.8% (8/26)	36.4% (8/22)	30.0% (6/20)	40.0% (6/15)	25.0% (1/4)	0.0% (0/0)	33.3% (1/3)	0.0% (0/2)	0.0% (0/2)	0.0% (0/2)	0.0% (0/1)	100% (1/1)	0.0% (0/1)	100% (1/1)
Sulfamethoxazole/ trimethoprim	66.7% (16/24)	46.2% (12/26)	81.8% (18/22)	40.0% (8/20)	66.7% (10/15)	25.0% (1/4)	33.3% (1/3)	33.3% (1/3)	100% (2/2)	100% (2/2)	50.0% (1/2)	0.0% (0/1)	0.0% (0/1)	0.0% (0/1)	100% (1/1)
Tetracycline	66.7% (16/24)	65.4% (17/26)	72.7% (16/22)	65.0% (13/20)	73.3% (11/15)	50.0% (2/4)	66.7% (2/3)	66.7% (2/3)	100% (2/2)	100% (2/2)	50.0% (1/2)	100% (1/1)	100% (1/1)	100% (1/1)	0.0% (0/1)

*Number of isolates resistant to each antimicrobial.

https://doi.org/10.7853/kjvs.2023.46.3.211

Table 3. Antimicrobial resistance in *Salmonella* isolates

Number of antimicrobials	Number of isolates showing antimicrobial resistance (%)
0	2 (1.6)
1	4 (3.1)
2	4 (3.1)
3	6 (4.7)
4	11 (8.7)
5	7 (5.5)
6	11 (8.7)
7	6 (4.7)
8	9 (7.1)
9	10 (7.9)
10	14 (11.0)
11	11 (8.7)
12	17 (13.4)
13	6 (4.7)
14	5 (3.9)
15	1 (0.8)
16	1 (0.8)
17	0 (0)
18	2 (1.6)

health issues and disease outbreaks are caused by interactions between humans, animals, and the environment (WHO, 2017). Apart from companion animals, farm animals that are sources of meat and eggs can influence human health (Stevens et al, 2009; WHO, 2017). In South Korea, duck production increased significantly from 30 million in 2006 to 67 million in 2018. The issue of antimicrobial resistance in *Salmonella* spp. in duck farms has also been raised from the "One Health" perspective (Cho et al, 2011; Cha et al, 2013; Kim et al, 2021; Oh et al, 2023). Hence, the Korean Animal and Plant Quarantine Agency started monitoring antimicrobial resistance in ducks from 2018. Based on the observable trend, we investigated the prevalence of *Salmonella* spp. and antimicrobial resistances in duck farms of Jeollanam-do Province, South Korea.

The prevalence (45.41%) of *Salmonella* spp. in duck farms of this province was lower than that (65.2%) observed in a previous study in South Korea (Cha et al, 2013), wherein nationwide inspections were conducted. The difference in results may be attributed to the variation in geographical scope of the two studies. Furthermore, another recent study showed high prevalence (59.3%) of *Salmonella* spp. in chick farms in South Korea (Im et al, 2015). These results suggest that poultry products are one of the potential sources of *Salmonella* transmission in South Korea, thus emphasizing the need for developing biosecurity measures against *Salmonella* spp. transmission in poultry farms.

The prevalence of *Salmonella* spp. in breeding duck farms (48%) was similar to that in broiler duck farms (45.0%). This might have occurred because adult ducks may serve as carriers of the disease, and vertical transmission could be attributed to similar positivity ratios (Knap et al, 2011). On the contrary, the prevalence of *Salmonella* spp. in the samples collected from the breeding duck farms (5.2%) was different from that obtained from broiler duck farms (13.6%). The difference in prevalence of *Salmonella* spp. in the samples may be attributed to the sampling methods used in breeding and broiler duck farms. In broiler duck farms, samples were collected from ducks suspected of being diseased, while in breeding duck farms, samples were randomly collected. This is because the mortality rate is higher in younger ducks, making it easier to identify the occurrence of diseases (Flament et al, 2012). However, adult ducks often become asymptomatic carriers, excreting the bacteria in their feces without showing any clinical signs of the disease (Flament et al, 2012). These factors may explain the difference in prevalence of *Salmonella* spp. in the samples.

We found that *Salmonella* Typhimurium, *Salmonella* Albany, *Salmonella* Hadar, and *Salmonella* Enteritidis were predominant serovars in duck farms in Jeollanam-do Province, which conforms to the results of previous studies in South Korea (Im et al, 2015; Kim et al, 2016; Kim et al, 2021). *Salmonella* Typhimurium and *Salmonella* Enteritidis are the most frequently reported serovars related to foodborne salmonellosis in humans (Adzitey et al, 2012; Tariq et al, 2022). Moreover, owing to their capacity to invade, replicate, and survive within human host cells, almost all *Salmonella* strains are pathogenic and can cause enteric fever, gastroenteritis, bacteremia, and potentially life-threatening illness (Eng et al, 2015). The emergence of antimicrobial resistance in *Salmonella* strains is a significant global health concern (Chiu et al, 2002; Eng et al, 2015). Patients infected with antimicrobial-resistant zoonotic pathogens may experience adverse clinical outcomes, such as death or treatment failure, as well as negative economic consequences, including increased costs of care and prolonged hospital stays due to delayed treatment and failed antimicrobial treatment (Yoon et al, 2017). The primary contributing factor to the emergence of antimicrobial-resistant pathogens, such as *Salmonella* spp., is the widespread use of antimicrobials in animal feed to enhance the growth of food animals, as well as their application in veterinary medicine for the treatment of bacterial infections in these animals (Eng et al, 2015). Therefore, careful monitoring of the emergence of antimicrobial-resistant strains in food animals, with particular emphasis on understanding the prevalence of antimicrobial resistance in zoonotic pathogens, is necessary for public health.

The *Salmonella* isolates identified in our study showed high resistance to penicillin (78.7%), tetracycline (68.5%), and kanamycin (65.4%), suggesting that these antimicrobials are commonly used in this region. The presence of penicillin-resistant bacteria in poultry, poultry environment, and retail meat products is well established (Singh et al, 2013; Thung et al, 2016). However, according to recent studies in South Korea, *Salmonella* spp. isolated in duck farms showed relatively low resistance in tetracycline (15.7~38.1%) and kanamycin (0~3.1%) (Kim et al, 2016; Kim et al, 2021). These results indicate changes in resistance patterns and/or significant differences in the use of antimicrobials, which implies that various emerging antimicrobial-resistant *Salmonella* strains that potentially infect humans may threaten public health in South Korea due to altered antimicrobial resistance.

In this study, 117 of 127 isolates were resistant to ≥3 antimicrobials, and 68% of the isolates were resistant to 5~18 antimicrobials, which is higher than that observed in previous studies conducted in South Korea (1.2~27%), Belgium (31%), Malaysia (21%), and China (20%) (Adzitey et al, 2012; Flament et al, 2012; Cha et al, 2013; Kim et al, 2016; Pan et al, 2010). Additionally, *Salmonella* spp. resistant to 18 antimicrobials in duck farms of South Korea were first detected in this study. These results indicate that the excessive use of antimicrobials in duck farms has increased the number of MDR *Salmonella* strains and rates of antimicrobial resistances. The high levels of resistance and existence of MDR *Salmonella* isolates, as revealed in this study, indicate the potential emergence of public health concerns.

In conclusion, this study demonstrates the prevalence and antimicrobial resistance of *Salmonella* spp. in duck farms of Jeollanam-do Province, South Korea. We found that *Salmonella* spp. commonly occur in duck farms, and their prevalence is not significantly dependent on whether the ducks are breeders or broilers. The highest resistance was observed in response to penicillin, followed by tetracycline and kanamycin. We believe our study provides useful information regarding the establishment of guidelines for antimicrobial agent usage in the duck production industry. Furthermore, the emergence of MDR *Salmonella* stains in duck farms suggest that antimicrobial must be used carefully to prevent public health issues.

ACKNOWLEDGEMENTS

This work was supported by Korean Institute of Planning and Evaluation for Technology in Food, Agriculture and Forestry (IPET) through the Animal Disease Management Technology Development Program, funded by the Ministry of Agriculture, Food and Rural Affairs (MAFRA) (322002021HD020).

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

https://doi.org/10.7853/kjvs.2023.46.3.211

ORCID

Sin-Wook Park, https://orcid.org/0000-0002-0158-463X
Keon Kim, https://orcid.org/0000-0002-8759-7764
Chang-Yun Je, https://orcid.org/0009-0001-2166-1217
Chang-Hyeon Choi, https://orcid.org/0009-0003-9529-1313
Sang-Gyue Choi, https://orcid.org/0009-0006-9387-9334
Jong-Soo Lim, https://orcid.org/0009-0001-7479-7249
Ok-Mi Jeong, https://orcid.org/0000-0003-2159-2693
Guk-Hyun Suh, https://orcid.org/0000-0003-0910-3340
Chang-Min Lee, https://orcid.org/0000-0002-7867-1053

REFERENCES

Adzitey F, Rusul G, Huda N. 2012. Prevalence and antibiotic resistance of Salmonella serovars in ducks, duck rearing and processing environments in Penang, Malaysia. Food Res Int 45: 947-952.

Cha SY, Kang M, Yoon RH, Park CK, Moon OK, Jang HK. 2013. Prevalence and antimicrobial susceptibility of Salmonella isolates in Pekin ducks from South Korea. Comp Immunol Microbiol Infect Dis 36: 473-479.

Chiu CH, Wu TL, Su LH, Chu C, Chia JH, Kuo AJ, Chien MS, Lin TY. 2002. The emergence in Taiwan of fluoroquinolone resistance in Salmonella enterica serotype Choleraesuis. N Engl J Med 346: 413-419.

Cho JK, Kang MS, Kim KS. 2011. Serotypes, antimicrobial resistance of Salmonella spp. and plasmid profiles, phage types, PFGE of S. Enteritidis and S. Typhimurium isolated from ducks in Daegu-Gyeongbuk Province. Korean J Vet Serv 34: 217-226.

Eng SK, Pusparajah P, Ab Mutalib NS, Ser HL, Chan KG, Lee LH. 2015. Salmonella: a review on pathogenesis, epidemiology and antibiotic resistance. Front Life Sci 8: 284-293.

Flament A, Soubbotina A, Mainil J, Marlier D. 2012. Prevalence of Salmonella serotypes in male mule ducks in Belgium. Vet Rec 170: 311-311.

Gast RK, Guraya R, Jones DR, Anderson KE. 2014. Contamination of eggs by Salmonella Enteritidis in experimentally infected laying hens housed in conventional or enriched cages. Poult Sci 93: 728-733.

Gong J, Xu M, Zhu C, Miao J, Liu X, Xu B, Zhang J, Yu Y, Jia X. 2013. Antimicrobial resistance, presence of integrons and biofilm formation of Salmonella pullorum isolates from Eastern China (1962~2010). Avian Pathol 42: 290-294.

Henry RR. 2000. Salmonella infection in ducks. Salmonella in Domestic Animals 157-169.

Im MC, Jeong SJ, Kwon YK, Jeong OM, Kang MS, Lee YJ. 2015. Prevalence and characteristics of Salmonella spp. isolated from commercial layer farms in Korea. Poult Sci 94: 1691-1698.

Jibril AH, Okeke IN, Dalsgaard A, Kudirkiene E, Akinlabi OC, Bello MB, Olsen JE. 2020. Prevalence and risk factors of Salmonella in commercial poultry farms in Nigeria. PLoS One 15: e0238190.

Jorgensen JH, Hindler JF, Reller LB, Weinstein MP. 2007. New consensus guidelines from the Clinical and Laboratory Standards Institute for antimicrobial susceptibility testing of infrequently isolated or fastidious bacteria. Clin Infect Dis 44: 280-286.

Kim H, Lee J, Jang Y, Chang B, Kim A, Choe N. 2016. Prevalence and antimicrobial resistance of Salmonella spp. and Escherichia coli isolated from ducks in Korea. Korean J Vet Res 56: 91-95.

Kim TS, Kim GS, Son JS, Mo IP, Jang H. 2021. Prevalence, biosecurity factor, and antimicrobial susceptibility analysis of Salmonella species isolated from commercial duck farms in Korea. Poult Sci 100: 100893.

Knap I, Kehlet A, Bennedsen M, Mathis G, Hofacre C, Lumpkins B, Jensen M, Raun M, Lay A. 2011. Bacillus subtilis (DSM17299) significantly reduces Salmonella in broilers. Poult Sci 90: 1690-1694.

Kuang X, Hao H, Dai M, Wang Y, Ahmad I, Liu Z, Zonghui Y. 2015. Serotypes and antimicrobial susceptibility of Salmonella spp. isolated from farm animals in China. Front Microbio 6: 602.

Lai J, Wu C, Wu C, Qi J, Wang Y, Wang H, Liu Y, Shen J. 2014. Serotype distribution and antibiotic resistance of Salmonella in food-producing animals in Shandong Province of China, 2009 and 2012. Int J Food Microbiol 180: 30-38.

Lu Y, Wu CM, Wu GJ, Zhao HY, He T, Cao XY, Dai L, Xia LN, Qin SS, Shen JZ. 2011. Prevalence of antimicrobial resistance among Salmonella isolates from chicken in China. Foodborne Pathog Dis 8: 45-53.

McEwen SA. 2012. Human health importance of use of antimicrobials in animals and its selection of antimicrobial resistance. Antimicrobial Resistance in the Environment. Canada: Wiley-Blackwell: 391-423.

Mondal T, Khan M, Alam M, Purakayastha M, Das M, Siddique M. 2008. Isolation, identification and characterization of Salmonella from duck. Bangladesh J Vet Med 6: 7-12.

Oh H, Yoon Y, Yoon JW, Oh SW, Lee S, Lee H. 2023. Salmonella risk assessment in poultry meat from farm to consumer in Korea. Foods 12: 649.

Pan Z, Geng S, Zhou Y, Liu Z, Fang Q, Liu B, Jiao X. 2010. Prevalence and antimicrobial resistance of Salmonella sp. isolated from domestic animals in Eastern China. J Anim Vet Adv 9: 2290-2294.

Singh R, Yadav A, Tripathi V, Singh R. 2013. Antimicrobial resistance profile of Salmonella present in poultry and poultry environment in North India. Food Control 33: 545-548.

Stevens MP, Humphrey TJ, Maskell DJ. 2009. Molecular insights into farm animal and zoonotic Salmonella infections. Philos Trans R Soc B: Biol Sci 364: 2709-2723.

Tariq S, Samad A, Hamza M, Ahmer A, Muazzam A, Ahmad S, Amhabj AMA. 2022. Salmonella in poultry; an overview. Int J Multidiscip Sci Art 1: 80-84.

Thung T, Mahyudin NA, Basri DF, Radzi CWM, Nakaguchi Y, Nishibuchi M, Radu S. 2016. Prevalence and antibiotic resistance of Salmonella Enteritidis and Salmonella Typhimurium in raw chicken meat at retail markets in Malaysia. Poult Sci 95: 1888-1893.

WHO. 2017. One health. World Health Organization 736. https://www.otago.ac.nz/wellington/otago635537.

Yoon KB, Song BJ, Shin MY, Lim HC, Yoon YH, Jeon DY, Ha H, Yang SI, Kim JB. 2017. Antibiotic resistance patterns and serotypes of Salmonella spp. isolated at Jeollanam-do in Korea. Osong Public Health Res Perspect 8: 211.

https://doi.org/10.7853/kjvs.2023.46.3.211