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Antibiotic Resistance Patterns and Serotypes of *Salmonella* spp. Isolated at Jeollanam-do in Korea

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Objectives: Few long-term studies have been conducted on the serotype and antibiotic resistance patterns of *Salmonella* speices (spp.) The aim of this study was to determine the serotypes and antibiotic resistance patterns of *Salmonella* spp. isolated at Jeollanam-do in Korea from 2004 to 2014.
Methods: A total of 276 *Salmonella* samples were evaluated. Serotyping was carried out according to the Kauffmann–White scheme. Antibiotic susceptibility was determined using the Vitek II system with an AST-N169 card.
Results: A total of 22 different serotypes were identified, and the major serotypes were *Salmonella* Enteritidis (116 strains, 42.0%) and *Salmonella* Typhimurium (60 strains, 21.7%). The highest resistance was observed in response to nalidixic acid (43.4%), followed by ampicillin (40.5%) and tetracycline (31.6%). Resistance to nalidixic acid was detected in 81.0% of *S.* Enteritidis. Multidrug resistance was detected in 43.3% of *Salmonella* spp. *S.* Enteritidis and *S.* Typhimurium presented the highest resistance (98.3%) and multidrug resistance rate (73.3%), respectively. The most highly observed antibiotic resistance pattern among *Salmonella* spp. in this study was ampicillin-chloramphenicol (14 strains, 5.7%),
Conclusion: Overall, *S.* Enteritidis and *S.* Typhimurium showed higher antibiotic resistance than the other *Salmonella* serotypes tested in this study. Our study will provide useful information for investigating the sources of *Salmonella* infections, as well as selecting effective antibiotics for treatment.

Key Words: *Salmonella* spp., antibiotic susceptibility, serotype

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INTRODUCTION

Salmonella is a notorious pathogen that causes gastroenteritis in humans, and 94 million cases of salmonellosis are globally reported every year [1]. *Salmonella* infection is mainly caused by foods such as meat, eggs, fish, and shellfish, and the symptoms include nausea, vomiting, abdominal pain, diarrhea, and fever [2,3]. *Salmonella* infection is one of the most common diseases in developed countries, and *Salmonella* speices (spp.) are frequently isolated from diarrhea patients in Korea [4]. In the United States, about 26% of all foodborne infections are estimated to be due to *Salmonella* spp., and the socioeconomic cost reached over one billion US dollar in 1987 [3,5,6]. In Korea, the medical expenses and productivity loss associated with salmonellosis were estimated to cost approximately 5.9 billion Korean won in 1996 [2]. Approximately 2,500 different serotypes of *Salmonella* spp. have been reported [7]. Serotypes serve as epidemiologi-

cal markers, and specific *Salmonella* spp. serotypes are associated with human disease [8]. In Korea, *Salmonella* Typhi, which is related to human infection, was frequently detected in the early 1990s [9], and *Salmonella* Enteritidis and *Salmonella* Typhimurium, which are also related to human infection, are observed frequently [10–12]. Kim et al. [13] reported that *S.* Enteritidis and *S.* Typhimurium were major serotypes among *Salmonella* spp. isolated from Gwangju in Korea during 2000–2009.

Antibiotics, which are metabolites produced by microorganisms, inhibit the growth of other pathogenic microorganisms at low concentrations. Since the first use of penicillin in 1940, more than 5,000 antibiotics have been developed, with a variety in current use [14,15]. Antibiotics play a decisive role in treatment by killing the causative organisms of infectious diseases, reducing the socioeconomic loss caused by infectious diseases [16]. However, antibiotic-resistant microorganisms are increasing due to indiscreet use of antibiotics [3]. Based on global surveillance results, the World Health Organization [17] reported that the antibiotic resistance of *Salmonella* spp. has increased in past years. Kim et al. [13] reported that the patterns of bacterial antibiotic resistance are constantly changing, and the emergence of multidrug-resistant *Salmonella* threatens public health worldwide [18].

Thus, determination of the serotypes and changing antibiotic resistance patterns of *Salmonella* spp. is needed to investigate infection sources and select effective antibiotics. The Korea Centers for Disease Control and Prevention (KCDC) summarized and published the nationwide incidence of salmonellosis as a part of a national monitoring program for acute diarrheal disease. Short-term studies have published the serotypes and antibiotic resistance patterns of *Salmonella* spp. associated with gastroenteritis in humans [3,7,11,19]. However, long-term studies are lacking. Thus, the aim of this study was to determine the serotypes and antibiotic resistance patterns of *Salmonella* spp. isolated at Jeollanam-do in Korea from 2004 to 2014.

MATERIALS AND METHODS

1. Bacterial strains

A total of 276 stocked *Salmonella* spp. were evaluated in this study. These strains were isolated from national surveillance "laboratory surveillance for diarrheal disease" at Jeollanam-do and were commissioned by a public health center at Jeollanam-do in Korea from 2004 to 2014. All strains were stored at –70°C in Tryptone soy broth (Oxoid, Basingstoke, UK) containing 0.6% yeast extract (Oxoid) with 20% glycerol (Difco, Detroit, MI, USA). All strains were inoculated into 5 mL of Selenite broth (Oxoid) for reactivation, followed by incubation at 37°C for 18 hours. The enrichment cultures were streaked onto Brilliance *Salmonella* agar (BSA; Oxoid) and then incubated at 37°C for 18 hours. Presumptive colonies exhibiting a purple color during culture on BSA were selected for biochemical testing. One colony from each BSA was identified to reconfirm *Salmonella* spp. strains using the Vitek II system with a GNI card (bioMerieux Inc., Marcy l'Etoile, France) and then sub-cultured on Tryptone soy agar (TSA; Oxoid) for serotyping and antibiotic susceptibility testing.

2. Serotyping

Serotyping of *Salmonella* spp. strains was carried out according to the Kauffmann–White scheme [20]. Somatic (O) antigens of each *Salmonella* spp. strain were determined using the slide agglutination method, with polyvalent and monovalent O antigens provided from the KCDC. Further serotyping was performed with flagella (H) antisera (Difco) using the tube agglutination method. The O and H antigen agglutination results for each *Salmonella* spp. were combined, and specific serotypes were determined according to the Antigenic Formulae of the *Salmonella* serovars [21].

3. Antimicrobial susceptibility

Antibiotic susceptibilities of the isolated and collected *Salmonella* spp. strains were determined using the Vitek II system with an AST-N169 card (bioMerieux Inc.) according to the manufacturer's instructions. All strains, sub-cultured onto TSA plates at 37°C overnight, were suspended in saline solution and then adjusted to a McFarland standard of 0.6 with a Vitek II DensiCHEK instrument (bioMerieux Inc.). Each adjusted bacterial solution (145 μL) was injected into 3 mL of saline solution, mixed well, and used for antibiotic susceptibility testing. Antibiotic susceptibilities of the *Salmonella* spp. strains were interpreted according to the standards [22] issued by the Clinical and Laboratory Standards Institute (CLSI). The following antibiotics were tested: ampicillin, amoxicillin/clavulanic acid, ampicillin/sulbactam, cefalothin, cefazolin, cefotetan, cefoxitin, cefotaxime, ceftriaxone, imipenem, amikacin, gentamycin, nalidixic acid, ciprofloxacin, tetracycline, chloramphenicol, and trimethoprim/sulfamethoxazole.

RESULTS

1. Serotypes of *Salmonella* strains

As shown in Table 1, a total of 22 different serotypes were divided among 276 *Salmonella* spp. tested in this study. Somatic (O) antigen groups observed were D (53.5%), B (31.2%), C (12.4%),

Table 1. Serotypes of *Salmonella* spp. isolated at Jeollanam-do in Korea from 2004 to 2014

Serotype	No. of strains (%)	Somatic antigen group
Salmonella Enteritidis	116 (42.0)	D
Salmonella Typhimurium	60 (21.7)	B
Salmonella I 4,[5],12:i:-	25 (9.1)	B
Salmonella Typhi	24 (8.7)	D
Salmonella Thompson	22 (8.0)	C
Salmonella Hillingdon	6 (2.2)	D
Salmonella Rissen	3 (1.1)	C
Salmonella Paratyphi A	2 (0.7)	A
Salmonella Stanley	2 (0.7)	B
Salmonella Braenderup	2 (0.7)	C
Salmonella Infantis	2 (0.7)	C
Salmonella Ohio	2 (0.7)	C
Salmonella Schwarzengrund	1 (0.4)	B
Salmonella Fyris	1 (0.4)	B
Salmonella Schleisshem	1 (0.4)	B
Salmonella Budapest	1 (0.4)	B
Salmonella Concord	1 (0.4)	C
Salmonella Potsdam	1 (0.4)	C
Salmonella Virchow	1 (0.4)	C
Salmonella Emek	1 (0.4)	C
Salmonella Kotu	1 (0.4)	D
Salmonella Welterveden	1 (0.4)	E
Total	276	

Table 2. Antibiotic resistance of *Salmonella* spp. isolated at Jeollanam-do in Korea from 2004 to 2014

Class of antibiotics	Antimicrobials	No. of resistance strains (%) (n = 247)[a]
Penicillins	AM	100 (40.5)
	AMC	12 (4.9)
β-Lactam combination	SAM	34 (13.8)
Cephalosporins	CF	28 (11.3)
	CZ	25 (10.1)
	CTT	1 (0.4)
	FOX	22 (8.9)
	CTX	10 (4.0)
	CRO	10 (4.0)
Carbapenems	IPM	0 (0)
Phenicols	C	49 (19.8)
Aminoglycosides	AN	0 (0)
	GM	19 (7.7)
Quinolones	NA	107 (43.3)
	CIP	0 (0)
Tetracyclines	TE	78 (31.6)
Sulfonamides	SXT	20 (8.1)

AM, ampicillin; AMC, amoxicillin/clavulanic acid; SAM, ampicillin/sulbactam; CF, cefalothin; CZ, cefazolin; CTT, cefotetan; FOX, cefoxitin; CTX, cefotaxime; CRO, ceftriaxone; IPM, imipenem; C, chloramphenicol; AN, amikacin; GM, gentamycin; NA, nalidixic acid; CIP, ciprofloxacin; TE, tetracycline; SXT, trimethoprim/sulfamethoxazole.
[a]*S.* Enteritidis, *S.* Typhimurium, *S.* I 4,[5],12:i:-, *S.* Typhi, *S.* Thompson were analyzed in this study.

A (0.7%), and E (0.4%). The major serotype was *S.* Enteritidis (116 strains, 42.0%), followed by *S.* Typhimurium (60 strains, 21.7%), *S.* I 4,[5],12:i:- (25 strains, 9.1%), *S.* Typhi (24 strains, 8.7%), and *S.* Thompson (22 strains, 8.0%), accounting for 89.5% of *Salmonella* spp. The 17 other serotypes had a low detection rate (10.5% combined).

2. Antibiotic resistance of *Salmonella* strains

Antibiotic resistance patterns of *Salmonella* spp. strains isolated from Jeollanam-do in Korea during 2004–2014 are shown in Table 2. The antibiotic resistance test was performed on five major serotypes: *S.* Enteritidis, *S.* Typhimurium, *S.* I 4,[5],12:i:-, *S.* Typhi, and *S.* Thompson. The highest resistance was observed in response to nalidixic acid (43.4%), followed by ampicillin (40.5%), tetracycline (31.6%), chloramphenicol (19.8%), cefalothin (11.3%), cefazolin (10.1%), cefoxitin (8.9%), and trimethoprim/sulfamethoxazole (8.1%). Lower resistance was observed in response to amoxicillin/clavulanic acid (4.9%), cefotaxime (4.0%), and ceftriaxone (4.0%). All strains in this study were susceptible to imipenem and amikacin. As shown in Table 3, the resistance rate of each antibiotic differed among *Salmonella* serotypes. Overall, *S.* Enteritidis and *S.* Typhimurium showed higher antibiotic resistance than the other tested serotypes. The resistance rates for ampicillin were 70.0, 40.5, and 36.0% in *S.* Typhimurium, *S.* Enteritidis, and *S.* I 4,[5],12:i:-, respectively. Nalidixic acid showed a resistance rate of 81.0% in *S.* Enteritidis. The highest resistance observed was to trimethoprim/sulfamethoxazole, in *S.* Typhimurium (85.0%).

3. Multidrug resistance of *Salmonella* serotypes

The multidrug resistance of *Salmonella* serotypes isolated at Jeollanam-do from 2004 to 2014 is presented in Table 4. Of the 247 *Salmonella* samples, 51 (20.6%) were susceptible to all of the antibiotics tested in this study. The highest antibiotic susceptibil-

Table 3. Antibiotic resistance of *Salmonella* spp. serotypes isolated at Jeollanam-do in Korea from 2004 to 2014

Class of antibiotics	Antimicrobials	No. of resistance strains (%)				
		S. Enteritidis (n = 116)	*S.* Typhimurium (n = 60)	*S.* I 4,[5],12:i:- (n = 25)	*S.* Typhi (n = 24)	*S.* Thompson (n = 22)
Penicillins	AM	47 (40.5)	42 (70)	9 (36.0)	0 (0)	2 (9.1)
	AMC	1 (0.9)	11 (18.3)	0 (0)	0 (0)	0 (0)
β-Lactam combination	SAM	11 (9.5)	22 (36.7)	1 (4.0)	0 (0)	0 (0)
Cephalosporins	CF	11 (9.5)	12 (20)	1 (4.0)	3 (12.5)	1 (4.5)
	CZ	12 (10.3)	12 (20)	0 (0)	0 (0)	1 (4.5)
	CTT	1 (0.9)	0 (0)	0 (0)	0 (0)	0 (0)
	FOX	8 (6.9)	11 (18.3)	0 (0)	3 (12.5)	0 (0)
	CTX	10 (8.6)	0 (0)	0 (0)	0 (0)	0 (0)
	CRO	10 (8.6)	0 (0)	0 (0)	0 (0)	0 (0)
Carbapenems	IPM	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Phenicols	C	34 (29.3)	12 (20)	0 (0)	3 (12.5)	0 (0)
Aminoglycosides	AN	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	GM	8 (6.9)	11 (18.3)	0 (0)	0 (0)	0 (0)
Quinolones	NA	94 (81.0)	9 (15.0)	0 (0)	3 (12.5)	1 (4.5)
	CIP	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tetracyclines	TE	8 (6.9)	51 (85.0)	19 (76.0)	0 (0)	0 (0)
Sulfonamides	SXT	1 (0.9)	17 (28.3)	1 (4.0)	0 (0)	1 (4.5)

AM, ampicillin; AMC, amoxicillin/clavulanic acid; SAM, ampicillin/sulbactam; CF, cefalothin; CZ, cefazolin; CTT, cefotetan; FOX, cefoxitin; CTX, cefotaxime; CRO, ceftriaxone; IPM, imipenem; C, chloramphenicol; AN, amikacin; GM, gentamycin; NA, nalidixic acid; CIP, ciprofloxacin; TE, tetracycline; SXT, trimethoprim/sulfamethoxazole.

Table 4. Multidrug resistance of *Salmonella* serotypes isolated at Jeollanam-do in Korea from 2004 to 2014

No. of resistance antibiotics	Total (n = 247)	No. of resistance strains (%)				
		S. Enteritidis (n = 116)	*S.* Typhimurium (n = 60)	*S.* I 4,[5],12:i:- (n = 25)	*S.* Typhi (n = 24)	*S.* Thompson (n = 22)
0	51 (20.6)	2 (1.7)	5 (8.3)	6 (24.0)	18 (75.0)	20 (90.9)
1	89 (36.0)	65 (56.0)	11 (18.3)	10 (40)	3 (12.5)	0 (0)
2	30 (12.1)	20 (17.2)	3 (5.0)	6 (24.0)	0 (0)	1 (4.5)
3	27 (10.9)	10 (8.6)	11 (18.3)	3 (12.0)	3 (12.5)	0 (0)
4	23 (9.3)	7 (6.0)	15 (25.0)	0 (0)	0 (0)	1 (4.5)
5	4 (1.6)	1 (0.9)	3 (5.0)	0 (0)	0 (0)	0 (0)
6	1 (0.4)	0 (0)	1 (1.7)	0 (0)	0 (0)	0 (0)
7	14 (5.7)	4 (3.4)	10 (16.7)	0 (0)	0 (0)	0 (0)
8	5 (2.0)	5 (4.5)	0 (0)	0 (0)	0 (0)	0 (0)
9	2 (0.8)	1 (0.9)	1 (1.7)	0 (0)	0 (0)	0 (0)
11	1 (0.4)	1 (0.9)	0 (0)	0 (0)	0 (0)	0 (0)

ity was observed in *S.* Thompson (20 strains, 90.9%), followed by *S.* Typhi (18 strains, 75.0%), *S.* I 4,[5],12:i:- (six strains, 24.0%), *S.* Typhimurium (five strains, 8.3%), and *S.* Enteritidis (two strains, 1.7%). Resistance to one antibiotic was observed in 89 (36.0%) samples, while multidrug resistance, defined as resistance to two or more antibiotics, was detected in 107 (43.3%) *Salmonella* samples. Multidrug resistance was observed most frequently in *S.* Typhimurium (44 strains, 73.3%), followed by *S.* Enteritidis (49 strains, 42.2%), *S.* I 4,[5],12:i:- (nine strains, 36.0%), *S.* Typhi (three strains, 12.5%), and *S.* Thompson (two strains, 9.0%). *S.* Enteritidis and *S.* Typhimurium presented the highest resistance (98.3%) and multidrug resistance rates (73.3%), respectively. Tables 5–9 present the antibiotic resistance patterns of the *Salmonella* serotypes. The most highly observed antibiotic resistance patterns among *Salmonella* spp. in this study were against ampicillin-chloramphenicol (14 strains, 5.7%), ampicillin-tetracycline-trimethoprim/sulfamethoxazole (11 strains, 4.5%), and ampicillin-amoxicillin/clavulanic acid-ampicillin/sulbactam-cefalothin-cefazolin-cefoxitin-tetracycline (10 strains, 4.0%). The most frequent antibiotic resistance patterns of *Salmonella* serotypes were ampicillin-chloramphenicol (14 strains, 12.1%) in *S.* Enteritidis, ampicillin-tetracycline-trimethoprim/sulfamethoxazole (10 strains, 16.7%) in *S.* Typhimurium, ampicillin-tetracycline (six strains, 24.0%) in *S.* I 4,[5],12:i:-, cefalothin-cefoxitin-chloramphenicol (three strains, 12.5%) in *S.* Typhi, and ampicillin-cefalothin-cefazolin-nalidixic acid (one strain, 4.5%) in *S.* Thompson.

DISCUSSION

Serotyping can provide useful epidemiological information on salmonellosis [23]. *S.* Enteritidis and *S.* Typhimurium were major serotypes among *Salmonella* spp. tested in this study, consistent with previous domestic [3,11–13] and overseas studies [7,24]. *S.* Typhi was also frequently detected, which is highly abundant in South and East Asia but rarely detected in North America and Europe [25], and causes typhoid fever, one of the most notable infectious diseases in Korea. *S.* Typhi was highly recovered before 1973, but its detection rate has decreased due to improved sanitation conditions in Korea [9]. The 8.7% detection rate of *S.* Typhi observed in our study is similar to a previous result reporting that *S.* Typhi constituted 7.9% of *Salmonella* isolates in Korea during 2004–2005 [11], but higher than its 1.5% detection rate in

Table 5. Antibiotic resistance patterns of *Salmonella* Enteritidis isolated at Jeollanam-do in Korea from 2004 to 2014

No. of antibiotics	Patterns	Antimicrobials	No. of strains (%) (n = 116)
1	A	AM	5 (4.3)
	B	NA	60 (51.7)
2	F	AM-C	14 (12.1)
	G	FOX-NA	5 (4.3)
	H	NA-C	1 (0.9)
3	J	AM-NA-C	8 (6.9)
	K	AM-SAM-C	1 (0.9)
	Q	FOX-NA-C	1 (0.9)
4	S	AM-CF-NA-C	1 (0.9)
	X	AM-SAM-NA-C	6 (5.2)
5	AD	AM-SAM-FOX-NA-C	1 (0.9)
7	AH	AM-CF-CZ-CTX-CRO-GM-NA	3 (2.6)
	AI	AM-CF-CZ-CTX-CRO-GM-NA	1 (0.9)
8	AJ	AM-CF-CZ-CTX-CRO-GM-NA-TE	4 (3.4)
	AK	AM-SAM-CF-CZ-CTX-CRO-NA-TE	1 (0.9)
9	AM	AM-SAM-CF-CZ-CTX-CRO-GM-NA-TE	1 (0.9)
11	AN	AM-AMC-SAM-CF-CZ-CTT-FOX-NA-TE-C-SXT	1 (0.9)
Total			114 (98.3)

AM, ampicillin; NA, nalidixic acid; C, chloramphenicol; FOX, cefoxitin; SAM, ampicillin/sulbactam; CF, cefalothin; CZ, cefazolin; CTX, cefotaxime; CRO, ceftriaxone; GM, gentamycin; TE, tetracycline; AMC, amoxicillin/clavulanic acid; SXT, trimethoprim/sulfamethoxazole.

Table 6. Antibiotic resistance patterns of *Salmonella* Typhimurium isolated at Jeollanam-do in Korea from 2004 to 2014

No. of antibiotics	Patterns	Antimicrobials	No. of strains (%) (n = 60)
1	B	NA	2 (3.3)
	C	TE	9 (15.0)
2	D	AM-TE	2 (3.3)
	I	NA-TE	1 (1.7)
3	N	AM-TE-SXT	10 (16.7)
	O	AM-CZ-TE	1 (1.7)
4	T	AM-CF-TE-SXT	1 (1.7)
	U	AM-GM-NA-C	1 (1.7)
	V	AM-GM-TE-C	3 (5.0)
	W	AM-SAM-GM-TE	4 (6.7)
	Y	AM-SAM-TE-C	2 (3.3)
	Z	AM-SAM-TE-SXT	2 (3.3)
	AA	GM-NA-TE-SXT	1 (1.7)
	AB	AM-TE-C-SXT	1 (1.7)
5	AC	AM-GM-NA-C-SXT	1 (1.7)
	AE	AM-SAM-NA-TE-C	2 (3.3)
6	AF	AM-SAM-GM-TE-C-SXT	1 (1.7)
7	AG	AM-AMC-SAM-CF-CZ-FOX-TE	10 (16.7)
9	AL	AM-AMC-SAM-CF-CZ-FOX-NA-TE-C	1 (1.7)
Total			55 (91.7)

NA, nalidixic acid; TE, tetracycline; AM, ampicillin; SXT, trimethoprim/sulfamethoxazole; CZ, cefazolin; CF, cefalothin; GM, gentamycin; C, chloramphenicol; SAM, ampicillin/sulbactam; AMC, amoxicillin/clavulanic acid; FOX, cefoxitin.

Table 7. Antibiotic resistance patterns of *Salmonella* I 4,[5],12:i:- isolated at Jeollanam-do in Korea from 2004 to 2014

No. of antibiotics	Patterns	Antimicrobials	No. of strains (%) (n = 25)
1	C	TE	10 (40.0)
2	D	AM-TE	6 (24.0)
3	L	AM-SAM-TE	1 (4.0)
	M	AM-CF-TE	1 (4.0)
	N	AM-TE-SXT	1 (4.0)
Total			19 (76.0)

TE, tetracycline; AM, ampicillin; SAM, ampicillin/sulbactam; CF, cefalothin; SXT, trimethoprim/sulfamethoxazole.

Table 8. Antibiotic resistance patterns of *Salmonella* Typhi isolated at Jeollanam-do in Korea from 2004 to 2014

No. of antibiotics	Patterns	Antimicrobials	No. of strains (%) (n = 24)
1	B	NA	3 (12.5)
3	P	CF-FOX-C	3 (12.5)
Total			6 (25.0)

NA, nalidixic acid; CF, cefalothin; FOX, cefoxitin; C, chloramphenicol.

the Gwangju area during 2000–2009 [13]. *S.* Typhi was the fourth most prevalent serotype in this study, suggesting that continuous investigation of serotyping is important. *S.* I 4,[5],12:i:- was first reported in Spain in 2009 [26] and is an unexpressed mutant of phase 2 *S.* Typhimurium [3,26,27]. The detection rate of *S.* I 4,[5],12:i:-, which causes diseases in humans and animals, has recently increased in Korea [28].

Resistance rates to nalidixic acid, ampicillin, tetracycline, and chloramphenicol in *Salmonella* spp. in this study were similar to previous results; indicating that resistance to these antibiotics is common in *Salmonella* spp. [23,29]. These antibiotics are frequently used to treat salmonellosis [30]. *Salmonella* spp. tested in this study showed higher resistance rates to antibiotics such as ampicillin/sulbactam, cefalothin, cefazolin, and nalidixic acid

Table 9. Antibiotic resistance patterns of Salmonella Thompson isolated at Jeollanam-do in Korea from 2004 to 2014

No. of antibiotics	Patterns	Antimicrobials	No. of strains (%) (n = 22)
2	E	AM-SXT	1 (4.5)
4	R	AM-CF-CZ-NA	1 (4.5)
Total			2 (9.0)

AM, ampicillin; SXT, trimethoprim/sulfamethoxazole; CF, cefalothin; CZ, cefazolin; NA, nalidixic acid.

compared to the resistance rates of *Salmonella* spp. isolated from the Gwangju area during 2000–2009 [13]. Our results show higher resistances to cephalosporin group antibiotics compared to previous results suggesting that most *Salmonella* spp. are merely sensitive to cephalosporins [3,13,31]. Antibiotic resistance profiles were different among *Salmonella* serotypes. *S.* Enteritidis and *S.* Typhimurium are two of the most frequently isolated foodborne pathogens [32], and both had higher antibiotic resistance rates compared with other *Salmonella* serotypes tested in this study. These results are consistent with worldwide studies [3,33,34]. In *S.* Enteritidis, resistance rates for ampicillin (40.5%), chloramphenicol (29.3%), and nalidixic acid (81.0%) were similar to the KCDC national survey results in 2009 [4] but higher than previous results [3] presenting resistance rates of 13.5, 7.7, and 5.4% for ampicillin, chloramphenicol, and nalidixic acid, respectively. Furthermore, similar resistance to these antibiotics has been reported in *Salmonella* spp. isolated in Brazil [23] and Turkey [34]. *S.* Typhimurium presented the highest rate of resistance to tetracycline (85.0%) among the antibiotics tested in this study, consistent with *S.* Typhimurium isolated in Seoul from 1999 to 2002 [35]. The KCDC [4] reported in 2009 that *S.* Typhimurium was highly resistant to tetracycline (60.4%). This is concerning, as tetracycline, a useful antibiotic agent against a wide range of bacteria, is frequently used to treat salmonellosis [36].

Salmonella spp. tested in this study presented a lower multidrug resistance rate (43.3%) compared with samples (52.6%) from the Gwangju area from 2000–2009 [13]. Of the *S.* Typhimurium samples, 44 out of 60 (73.3%) displayed multidrug resistance, consistent with the 70.5% multidrug resistance observed for *S.* Typhimurium in the Gwangju study [13]. The multidrug resistance of *S.* Typhimurium phage type DT104 causes global health problems [37]. Multidrug resistant *Salmonella* spp. threatens public health worldwide [18], and the antibiotic resistance pattern of *Salmonella* spp. can be altered [38]. The most highly observed antibiotic resistance pattern among *Salmonella* spp. in this study was ampicillin-chloramphenicol. Ampicillin and chloramphenicol are used to treat bacterial diseases such as meningitis, salmonellosis, and endocarditis, and combined chloramphenicol and ampicillin treatment is a useful therapy for salmonellosis [29,30]. Thus, it is not surprising that the ampicillin-chloramphenicol resistance pattern is the most highly observed. This highlights the important of preventing the overuse of antibiotics to reduce the multidrug resistance of *Salmonella* spp.

In conclusion, this study found that *S.* Enteritidis and *S.* Typhimurium were major serotypes in *Salmonella* spp., and the highest resistance was observed in response to nalidixic acid, followed by ampicillin and tetracycline. Our study will provide useful information for investigating the source and selecting effective antibiotics for *Salmonella* infection.

CONFLICTS OF INTEREST

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

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