Occurrence and Antimicrobial Susceptibility Profile of *Salmonella* spp. in Raw and Ready-To-Eat Foods and *Campylobacter* spp. in Retail Raw Chicken Meat in Transylvania, Romania

Emil Tırziu, Gabriel Bârbălan, Adriana Morar, Viorel Herman, Romeo T. Cristina, and Kálmán Imre

Abstract

The survey was undertaken to investigate the presence and antimicrobial susceptibility profile of *Salmonella* spp. in raw and ready-to-eat (RTE) foods, and *Campylobacter* spp. in the retail raw chicken meat collected in two counties of Transylvania, Romania. A total of 13.1% (51/388) of the examined food samples were found to be *Salmonella* positive, with a distribution of 14.7% (48/326) in the raw food (i.e., pork, chicken carcass, and shell egg) and 4.8% (3/62) in the RTE samples (i.e., sausages, but not ham and salami), respectively. These differences were statistically significant (*p* = 0.034). The isolates were serotyped as *Salmonella* *Infantis* (*n* = 19), *Salmonella Typhimurium* (*n* = 11), *Salmonella Rissen* (*n* = 8), *Salmonella Derby* (*n* = 3), *Salmonella Enteritidis* (*n* = 3), *Salmonella Bredeney* (*n* = 2), *Salmonella Brandenburg* (*n* = 1), *Salmonella Gloucester* (*n* = 1), *Salmonella Goldcoast* (*n* = 1), *Salmonella Kottbus* (*n* = 1), and *Salmonella Ruzizi* (*n* = 1). *Campylobacter* strains were present in 29.4% (10/34) of the investigated chicken samples, and the identified species were *Campylobacter coli* (70%) and *C. jejuni* (30%).

From the 14 tested antimicrobials, the *Salmonella* isolates were resistant against azithromycin (88.2%), tetracycline (54.9%), sulfamethoxazole (54.9%), ciprofloxacin (45.1%), nalidixic acid (43.1%), ampicillin (35.3%), chloramphenicol (33.3%), tigecycline (25.5%), cefotaxime (13.7%), colistin (13.7%), trimethoprim (7.8%), and gentamicin (2%), resulting in the expression of 21 multidrug-resistant (MDR) profiles. Of 10 *Campylobacter* isolates, 80% were resistant to ciprofloxacin and nalidixic acid, 40% to tetracycline, and 10% to streptomycin and erythromycin, respectively. Our findings indicate that Romanian isolates of *Salmonella* spp. and *Campylobacter* spp., contaminating animal-origin foods, can exhibit MDR patterns, representing a public health risk.

Keywords: *Salmonella*, *Campylobacter*, food, antimicrobial resistance, Romania

Introduction

*Salmonella* spp. and *Campylobacter* spp. are recognized as two of the most important foodborne pathogens that can cause severe infections in humans and economic losses worldwide. Their presence is monitored in different steps of the food chain, and especially in finished raw and ready-to-eat (RTE) products, as a safety criterion for the consumer, representing a very important tool for implementing efficient food safety systems (Antunes *et al.*, 2016; Khan *et al.*, 2018).

In recent years, the large-scale overuse of common antimicrobials in human and veterinary medicine with different purposes (e.g., therapeutics, prophylactics, and growth promoters) have accelerated the emergence and spread of antibiotic-resistant foodborne bacteria. Nowadays, the antimicrobial resistance (AMR) phenomenon is considered one of the most worrisome public health concerns, with negative impact on the effectiveness of public health interventions (Zhang *et al.*, 2018; European Food Safety Authority, 2019).

The European Union (EU) member states make great efforts to establish harmonized interinstitutional strategies under a One Health approach to combat AMR. The collection of comparable, up-to-date, and reliable data is a prerequisite for the implementation of effective risk management measures by Departments of 1Animal Production and Veterinary Public Health, 2Infectious Diseases and Preventive Medicine, and 3Pharmacology and Pharmacy, Faculty of Veterinary Medicine, Banát’s University of Agricultural Sciences and Veterinary Medicine “King Michael I of Romania”, Timişoara, Romania.

© Emil Tırziu *et al.*, 2020; Published by Mary Ann Liebert, Inc. This Open Access article is distributed under the terms of the Creative Commons 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.

479
assessors. In this regard, baseline information about the occurrence of AMR zoonotic bacteria from the human–animal–food interface in Europe is published yearly by the European Food Safety Authority (EFSA) and European Center for Disease Prevention and Control, within a summary report (European Food Safety Authority, 2019), with the contribution of each member state. In the most recent EFSA report, data provided by Romania revealed a total of 1154 (with 5.9 notification rates per 100,000 populations) human confirmed cases of salmonellosis and campylobacteriosis, respectively.

Data provided by Romania regarding the overall AMR profile of food origin pathogens refers especially to strains isolated from raw pork, beef, and poultry meat, without offering any supplementary information about their origin, according to the types of finished products, and in association with detailed antibiotic susceptibility profile data of the implicated species and/or serotypes. In addition, in the context of the importance of the global fight against AMR, the number of scientific reports on Salmonella and Campylobacter in our country are quite limited (Mihaiu et al., 2014; Dan et al., 2015; Morar et al., 2015; Tîrziu et al., 2015), and additional studies are still required.

This study aimed to provide data on the occurrence and antimicrobial susceptibility profile of two major foodborne pathogens (Salmonella spp., Campylobacter spp.) in different food products, from two Transylvanian counties of Romania.

Materials and Methods

The study was undertaken between 2016 and 2018 in two counties of the historical Transylvania region, located in central Romania. A total of 292 raw food samples of pork (n = 146), chicken carcasses (n = 98), and shell eggs (n = 48; deriving from whole chicken eggs) provided from private production units were screened for the presence of Salmonella spp. within the self-control process of each batch, in conformity with Regulation (EC) 1441/2007 (EC 1441/2007). Similarly, 62 RTE products, including sausages (n = 37), ham (n = 9), and salami (n = 16), and fresh chicken meat samples (n = 34), randomly collected from retail markets by veterinary inspectors within the official organized controls, were analyzed, to detect Salmonella spp. In addition, the retail chicken samples were monitored for the presence of Campylobacter spp.

In nine sampling days of the first month of each trimester of the calendar year, a total of 17 randomly selected different retail markets of surveyed area were visited. On the sampling day of each of these from two to four food matrices providing from different batches was sampled. The samples were collected using sterile gloves in sterile bags and labeled. On the same day, the specimens were transported in an isothermal box to the Food Microbiology Laboratory of the Sanitary Veterinary Directorate of each county.

Salmonella spp. and Campylobacter spp. isolates were detected using the national standardized methods SR EN ISO 6579/2003 AC/2006 (Romanian Standards Association, 2003) and SR EN ISO 10272/2006 (Romanian Standards Association, 2006), respectively. In brief, for the isolation of Salmonella spp. from the 25 g pre-enriched food matrix, the xylose lysine deoxycholate (Biokar Diagnostics) and Ramsbach (Biokar Diagnostics) mediums were used and the inoculated plates were incubated afterward at 37°C for 24 h. The isolation of Campylobacter spp. from the enriched samples was carried out on Columbia agar supplemented with sheep blood (Oxoid) at 42°C for 48 h under microaerobic conditions. For each positive sample, a single randomly selected bacterial strain was submitted to the Institute for Hygiene and Public Health (București, Romania) for antimicrobial susceptibility testing and serotyping in case of Salmonella isolates. Serotyping was carried out in accordance with the Kaufmann–White scheme by microtiter slide agglutination using polyvalent O- and H-antisera (Difco; BD, Detroit, MI).

Antimicrobial susceptibility testing was performed using the Sensititre® microtiter system (Trek Diagnostic Systems, Inc., Cleveland, OH), in accordance with the manufacturer’s instructions, and following the International Organization for Standardization for Standardization [ISO 20776-1:2007 (ISO, 2007)] guideline. For Salmonella the EUVSEC (Trek Diagnostics Systems, Inc.) plate was used and the quality control used the Escherichia coli ATCC 25922 strain. In case of Campylobacter the EUCAMP2 (Trek Diagnostics Systems, Inc.) plate, together with C. jejuni 33560, as a quality control strain, was used. For both pathogens, the resistance breakpoints were established according to the Clinical and Laboratory Standards Institute (CLSI, 2018, M100-28) and the European Committee on Antimicrobial Susceptibility Testing (EUCAST, 2017) (for colistin and tigecycline only) guidelines. The isolates were categorized as resistant, intermediate, or susceptible. In this survey, only absolutely but not intermediate resistant strains were considered as resistant isolates.

The tested 14 antibiotics for Salmonella strains were provided from 12 classes. The antimicrobial substances and their concentrations included in the panel were as follows: β-lactams—ampicillin (AMP; 1–64 μg/mL), aminoglycosides—gentamicin (GEN; 0.5–32 μg/mL), carbapenem—meropenem (MEM; 0.03–16 μg/mL), cephalosporins—cefotaxime (CTX; 0.25–4 μg/mL), ceftazidime (CAF; 0.5–8 μg/mL), fluoroquinolones—ciprofloxacin (CIP; 0.015–8 μg/mL), glycylcycline—tigecycline (TGC; 0.25–8 μg/mL), polymyxins—colistin (CST; 1–16 μg/mL), macrolide—azithromycin (AZM; 2–64 μg/mL), nitrobenzenes—chloramphenicol (CHL; 8–128 μg/mL), sulfonamides—sulfamethoxazole (SMX; 8–1024 μg/mL), trimethoprim (TMP; 0.25–32 μg/mL), quinolones—nalidixic acid (NAL; 4–128 μg/mL), and tetracyclines—tetracycline (TET; 2–64 μg/mL).

In case of Campylobacter spp. the selected drugs belonged to five classes and included the following: fluoroquinolones—CIP (0.12–16 μg/mL); macrolide—erythromycin (ERY; 1–128 μg/mL); GEN (0.12–16 μg/mL); quinolones—NAL (1–64 μg/mL); aminoglycosides—streptomycin (STR 0.25–16 μg/mL), and tetracyclines—TET (0.5–64 μg/mL). The isolates were considered multidrug-resistant (MDR) if they exhibited nonsusceptibility to at least one antimicrobial in three or more antimicrobial classes (Magiorakos et al., 2012).

The statistical analysis of the frequency of isolation of pathogens in relation to their sample origin was performed with the Pearson’s chi-square (χ²) test (Microsoft Excel 2007, Redmond, WA), and a value of p ≤ 0.05 was considered significant.

Results

Altogether, 13.1% (51/388) of the examined food samples were found to be Salmonella positive. The overall prevalence
of Salmonella spp. in raw food samples was 14.7% (48/326), and its frequency of isolation according to the tested products was 22.6% (33/146) in pork, 9.1% (12/132) in chicken (9.2%—9/98 of carcasses and 11.8%—4/34 fresh retail meat), and 6.3% (3/48) in shell egg samples. For RTE products, 4.8% (3/62) were contaminated with Salmonella spp., and all isolates were recovered from sausages (8.1%; 3/37). No bacteria were isolated in ham and salami samples. It was found that 29.4% (10/34) of the raw retail chicken samples were contaminated with Campylobacter spp. strains. Statistical analysis showed that the percentage of Salmonella spp. isolates in raw food samples was significantly higher \((p=0.034)\) than that observed in RTE foods. In addition, a significantly higher Salmonella spp. detection rate was recorded in pork compared with chicken meat \((p=0.002)\).

A total of 11 Salmonella serotypes were recorded. Their distribution according to the tested food samples is presented in Table 1. In pork, Salmonella Typhimurium \((n=9\) isolates) was the dominant serotype, followed by Salmonella Rissen \((n=8)\), Salmonella Infantis \((n=6)\), Salmonella Bredeney \((n=2)\), Salmonella Derby \((n=2)\), Salmonella Brandenburg \((n=1)\), Salmonella Enteritidis \((n=1)\), Salmonella Gloucester \((n=1)\), Salmonella Goldcoast \((n=1)\), Salmonella Kottbus \((n=1)\), and Salmonella Ruzzi \((n=1)\). Of note, all strains isolated from chicken meat were Salmonella Infantis. In shell eggs, Salmonella Enteritidis \((n=2)\) and Salmonella Infantis \((n=1)\) were identified, whereas the sausages were found to be contaminated with Salmonella Typhimurium \((n=2)\) and Salmonella Derby \((n=1)\). The identified Campylobacter species in the raw chicken meat were Campylobacter coli \((7/10)\) and C. jejuni \((3/10)\).

The exhibited antimicrobial susceptibility profile of all isolates according to their sample origin is given in Table 1. Of the Salmonella strains, 92.2% \((47/51)\) showed resistance to one or more (pork origin Salmonella strains to 1–8 agents; chicken—to 3–8 agents; shell eggs—to 2 and 7 agents; sausage—to 5 and 8 agents, respectively) of the tested 14 antimicrobials, resulting in the expression of a total of 25 resistance profiles. Resistance to AZM \((88.2\%)\) was the most common, followed by that to TET \((54.9\%)\), SMX \((54.9\%)\), CIP \((45.1\%)\), NAL \((43.1\%)\), AMP \((35.3\%)\), CLH \((33.3\%)\), TGC \((25.5\%)\), CTX \((13.7\%)\), CST \((13.7\%)\), TMP \((7.8\%)\), and GEN \((2\%)\). None of the isolates were resistant to MEM and C AF. Regarding the most commonly three encountered serotypes, all the Salmonella Infantis \((n=19)\) and the majority \((63.6\%, 7/11)\) of Salmonella Typhimurium isolates showed MDR, whereas among S. Rissen only three \((37.5\%, 3/8)\) strains exhibited MDR profile. The other eight less frequently occurring serotypes exhibited a highly variable \((1–8 agents)\) resistance pattern.

Antimicrobial susceptibility tests of the Campylobacter isolates revealed that all C. jejuni strains were MDR to a single triple combination, whereas from the C. coli strains only one \((14.3\%, 1/7)\) was MDR \((\text{Table 1})\).

**Discussion**

This survey generated preliminary results on the distribution of Salmonella spp. in raw and RTE foods, and Campylobacter spp. in the retail chicken meat collected in two counties of Transylvania, the central historical region of Romania. Our study revealed that Salmonella was identified in 22.6%, 9.1%, and 6.3% of the pork, chicken, and shell egg samples, respectively, with an overall prevalence of 14.7% among all screened raw food samples. These results highlight that the investigated animal-derived foods may constitute a potential public health risk. The occurrence of Salmonella spp. in fresh raw meat has been previously confirmed in several studies conducted worldwide \([\text{reviewed by Baer et al. (2013)}\) and Antunes et al. (2016)]. Of them, investigations with similar designs to our study highlighted different contamination levels in the Czech Republic \((2.7\%\) in pork and 13.6\% in chicken (Mysková and Karpišková, 2017)), Germany \((0.4\%\) in pork and 17.0\% in chicken (Schwaiger et al., 2012)), or the Republic of China \((7.1\%\) in pork and 22.5\% in chicken (Ren et al., 2017); 63.6\% in chicken and 73.1\% in pork (Zhang et al., 2018)). In Romania, previously published research data showed a variable Salmonella detection rate for raw chicken \([13.2\%\) (Țirziu et al., 2015); 22.8\% (Mihaiu et al., 2014); 4.2\% (Dan et al., 2014)] and pork \([19.7\%\) (Morar et al., 2015); 23.1\% (Mihaiu et al., 2014)] samples.

The recorded significantly higher \((p=0.002)\) Salmonella contamination level registered in pork, compared with chicken in this study is in contrast with the results published by several authors (Schwaiger et al., 2012; Ren et al., 2017; Mysková and Karpišková, 2017), but caution should be taken in comparing these results because differences in study design \((\text{e.g., sample size, sampling methodology and season, and period}, detection methods, or different processing technologies of the raw material may be considered sources of variation of the recorded Salmonella prevalence. The isolation of Salmonella from shell eggs \((6.3\%)\) is a common finding, which has been previously pointed out by many authors \([\text{reviewed by Galis et al., 2013}]\), and serves as a risk factor for cross-contamination of other foods, especially during their household preparation by the consumers.

Of the RTE-examined products, only sausages \((8.1\%)\) were found to be Salmonella positive. Nonetheless, in the most recent EU summary report, no Salmonella data were reported from Romania at the retail level from RTE foods \([\text{European Food Safety Authority, 2018}]\). To the authors’ knowledge, this is the first published report on the occurrence of this pathogen in RTE foods in Romania. Similar to our findings, the presence of Salmonella has been confirmed in sausages in France producing foodborne infections nationwide \([\text{Bone et al., 2010}]\). Applied heat treatments, smoking procedures, and the presence of ingredients in RTE products can support the significantly lower \((p=0.034)\) Salmonella detection rate in these foods compared with raw foods. Nevertheless, the findings highlight a possible undercooking, contamination from raw materials, or food handlers of RTE products \([\text{Baer et al., 2013}]\).

The recorded dominance of Salmonella Typhimurium \([\text{reported as the most frequently isolated serotype from humans in Romania (European Food Safety Authority, 2019)}]\) and Salmonella Rissen in pork and Salmonella Enteritidis in shell eggs, and presence of Salmonella Infantis exclusively in chicken meat is in agreement with the current knowledge \([\text{Baer et al., 2013}; Galiş et al., 2013; Antunes et al., 2016; Zhang et al., 2018}]\), according to which all these serotypes are typical of the tested products. Other rare serotypes, such as Salmonella Gloucester, Salmonella Goldcoast, and Salmonella Kottbus were recorded for the first time in Romania, emphasizing the spreading of sporadic serovars in our country.
| Salmonella serotypes and Campylobacter spp. and their origin (no. of isolates) | n (% of resistant strains to) | AZM | AMP | CHL | CTX | CIP | CST | ERY | GEN | NAL | SMX | STR | TET |TMP | TGC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Raw pork** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Salmonella* Typhimurium (9) | 7 (77.8) | 5 (55.6) | 2 (22.2) | — | 1 (11.1) | 1 (11.1) | — | — | — | 4 (44.4) | — | 4 (44.4) | — | — |
| *Salmonella* Rissen (8) | 7 (87.5) | 2 (25) | 4 (50) | — | 3 (37.5) | — | — | — | 2 (25) | — | 2 (25) | — | — |
| *Salmonella* Infantis (6) | 5 (83.3) | 2 (33.3) | 3 (50) | — | 6 (100) | — | — | — | 5 (83.3) | 5 (83.3) | — | 5 (83.3) | 1 (16.6) | 2 (33.3) |
| *Salmonella* Bredeney (2) | 2 (100) | — | — | — | 2 (100) | — | 1 (50) | — | — | — | — | — | — | — |
| *Salmonella* Derby (2) | 1 (50) | 1 (50) | 1 (50) | — | 1 (50) |  | — | — | 1 (50) | 1 (50) | — | 1 (50) | 1 (50) | — |
| *Salmonella* Brandenburg (1) | 1 (100) | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Salmonella* Enteritidis (1) | 1 (100) | 1 (100) | — | — | 1 (100) | — | — | — | — | — | — | — | — | — |
| *Salmonella* Gloucester (1) | 1 (100) | 1 (100) | — | — | — | — | — | 1 (100) | — | 1 (100) | — | — | — | — |
| *Salmonella* Goldcoast (1) | 1 (100) | — | — | 1 (100) | — | 1 (100) | — | — | — | 1 (100) | 1 (100) | — | 1 (100) | — |
| *Salmonella* Kottbus (1) | 1 (100) | 1 (100) | — | — | — | — | — | — | — | — | — | — | — | — |
| *Salmonella* Ruzizi (1) | 1 (100) | — | — | — | — | — | — | — | — | — | — | — | — | — |
| **Raw chicken** | 11 (91.7) | 2 (16.7) | 5 (41.7) | 5 (41.6) | 11 (91.7) | 12 (100) | 10 (83.3) | 11 (91.7) | 7 (58.3) |  |  |  |  |  |  |
| *Salmonella* Infantis (12) | 11 (91.7) | 2 (16.7) | 5 (41.7) | 5 (41.6) | 11 (91.7) | 12 (100) | 10 (83.3) | 11 (91.7) | 7 (58.3) |  |  |  |  |  |  |
| **Eggshell** | 2 (100) | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *Salmonella* Enteritidis (2) | 1 (100) | 1 (100) | — | — | 1 (100) | — | — | — | 1 (100) | 1 (100) | — | 1 (100) | — | — |
| **Sausage** | 2 (100) | 1 (50) | — | 1 (50) | 1 (50) | — | — | — | 1 (50) | 2 (100) | — | 2 (100) | 1 (50) | 2 (100) |
| *Salmonella* Typhimurium (2) | 1 (100) | 1 (100) | 1 (100) | 1 (100) | — | — | — | — | 1 (100) | — | 1 (100) | — | — | — |
| **Raw chicken** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Campylobacter coli* (7) | — | — | — | — | 5 (71.4) | 1 (14.3) | — | — | 5 (71.4) | 1 (14.3) | 1 (14.3) | — | — | — |
| *C. jejuni* (3) | — | — | — | 3 (100) | — | 3 (100) | — | 3 (100) | — | — | — | — | — | — | — |

*Only seven antibiotics were tested.*

—, no resistance was recorded; AZM, azithromycin; AMP, ampicillin; CHL, chloramphenicol; CTX, cefotaxime; CIP, ciprofloxacin; CST, colistin; ERY, erythromycin; GEN, gentamicin; NAL, nalidixic acid; SMX, sulfamethoxazole; STR, streptomycin; TET, tetracycline; TMP, trimethoprim; TGC, tigecycline.
In our study, of the 51 tested Salmonella strains, 92.2% were resistant to at least one antibiotic. Moreover, 68.6% (35/51) exhibited multidrug resistance. Only four pork origin strains were susceptible to all tested drugs (Table 1). No notable associations were recorded between the expressions of the antibiotic resistance patterns of the tested Salmonella strains and their isolation source. High resistance levels were recorded to AZM (88.2%), TET (54.9%), SMX (54.9%), CIP (45.1), and NAL (43.1%). These resistance rates (except AZM, for which this is the first published evaluation report in Romania) are consistent with previous reports for both chicken (Tirziu et al., 2015) and pork (Mihaiu et al., 2014) origin Salmonella strains, and reflect their overusage in veterinary medicine.

Similar to our results, increasing AMR trends were published for TET in China [87.5% (Ren et al., 2017); 75.3% (Zhang et al., 2018)], Thailand [73.3% (Sinwat et al., 2015)], North Vietnam [58.5% (Thai et al., 2012)] and the Czech Republic [100% (Myšková and Karpišková, 2017)]; for SMX in Thailand (Sinwat et al., 2015) and Latvia (Terentjeva et al., 2017); for CIP in Latvia [24.0% (Terentjeva et al., 2017)]; and for NAL in North Vietnam [28.8% (Thai et al., 2012)]. Even if the recorded resistance level to another seven antibiotics, including AMP (35.3%), CHL (33.3%), TGC (25.5%), CTX (13.7%), CST (13.7%), TMP (7.8%), and GEN (2%) were moderate or low, the obtained results underscored a wide and worrying resistance spectrum of the Salmonella strains. This aspect together with the occurrence of the MDR strains (n = 35) in different combination forms (n = 21) highlight an urgent need for the implementation of efficient antimicrobial stewardship programs in animal husbandry. On the contrary, the lack of AMR toward MEM and CAF can constitute a promising tool for clinicians in the management of human salmonella infections.

The detection rate of Campylobacter spp. in the raw chicken meat in this study was found to be 29.4%, which is <37.4%, the overall frequency of isolation from broiler meat reported by 18 EU member states (European Food Safety Authority, 2018). Compared with several other countries, our prevalence was lower than that reported in India [38.6% (Khan et al., 2018)], Iran [63% (Taremi et al., 2006)], or Republic of Korea [68.3% (Han et al., 2007)], but higher than that obtained in a previous survey in Romania [15.3% (Dan et al., 2015)]. These findings together with the exclusive detection of the two major human pathogens (C. jejuni and C. coli) in this survey highlight that raw chicken meat can greatly contribute to the human campylobacteriosis cases, the most commonly reported foodborne infections in the EU since 2005.

Among the six tested antimicrobials, a high degree of resistance to CIP (80%), NAL (80%), and TET (40%) were found. Only one strain (10%) was resistant to STR and ERY, and all strains were susceptible to GEN. These resistance levels are higher than those that had been previously recorded for chicken origin Campylobacter strains in Romania [31.8% for TET, 9.1% for CIP and NAL, 0% for STR (Dan et al., 2015)]. Different resistance levels were reported for these drugs in other studies conducted in several countries, such as Northern India [59.4%—TET, 6.9%—CIP and NAL—(Khan et al., 2018)], Republic of Korea [99.1—TET, 92.2—CIP and NAL (Han et al., 2007)], or Iran [45.8%—TET, 69.4%—CIP and 75%—NAL (Taremi et al., 2006)]. No data are available on the AMR profile of human origin Campylobacter isolates in the most recent EU summary report (European Food Safety Authority, 2019). The occurrence of MDR strains, as in the case of Salmonella isolates, could reflect the urgent adaptation and strengthening of guidelines for the prudent use of antimicrobials during poultry production.

Conclusions

The results of this study showed that the investigated animal-derived foods from Transylvania region, Romania, can harbor MDR Salmonella and Campylobacter strains, constituting a potential public health risk. Likewise, the findings could reflect an urgent need for the implementation of efficient antimicrobial stewardship programs in animal husbandry, and indirectly can constitute a promising tool for clinicians in the understanding of the complex puzzle of AMR phenomenon of the foodborne pathogens in our country.

Disclosure statement

No competing financial interests exist.

Funding Information

The research was funded by the POSCCE Project SMIS No. 2669 titled “Dezvoltarea infrastructurii de cercetare, educație și servicii în domeniul medicinii veterinare și tehnologiilor innovative pentru RO 05”.

References

Antunes P, Mourão J, Campos J, Peixe L. Salmonellosis: The role of poultry meat. Clin Microbiol Infect 2016;22:110–121. Baer AA, Miller MJ, Dilger AC. Pathogens of interest to the pork industry: A review of research on interventions to assure food safety. Compr Rev Food Sci Food Saf 2013;12:183–217. Bone A, Noel H, Le Hello S, Pihier N, Danan C, Raguenaud ME, Salah S, Bellali H, Vaillant V, Weill FX, Jourdan-da Silva N. Nationwide outbreak of Salmonella enterica serotype 4,12:i:- infections in France, linked to dried pork sausage, March–May 2010. Eurosurveillance 2010;15:19592. Clinical and Laboratory Standard Institute (CLSI). Performance Standards for Antimicrobial Susceptibility Testing. 28th ed. CLSI document M100-S28. Wayne, PA: CLSI, 2018. Commission Regulation (EC) No. 1441/2007 of 5 December 2007 amending Regulation (EC) No. 2073/2005 on microbiological criteria for foodstuffs. Off J Eur Union L 338/1. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R1441&from=GA, accessed July 15, 2019. Dan SD, Tabaran A, Mihaiu L, Mihaiu M. Antibiotic susceptibility and prevalence of foodborne pathogens in poultry meat in Romania. J Infect Dev Ctries 2015;9:35–41. EUCAST. European Committee on Antimicrobial Susceptibility Testing (EUCAST) Breakpoint Tables for Interpretation of MICs and Zone Diameters, Version 7.1. 2017. Available at: http://euCAST.org/fileadmin/src/media/PDFs/EUCAST_files/Breakpoint_tables/v_7.1_Breakpoint_Tables.pdf, accessed July 8, 2019. European Food Safety Authority. Scientific report of EFSA and ECDC. The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2017. EFSA J 2018;16:5500.
European Food Safety Authority. Scientific report of EFSA and ECDC. The European Union summary report on antimicrobial resistance in zoonotic and indicator bacteria from humans, animals and food, 2017. EFSA J 2019;17:5598.

Gališ AM, Marcq C, Marlier D, Portetelle D, Van I, Beckers Y, Théwis A. Control of Salmonella contamination of shell eggs—preharvest and postharvest methods: A review. Compr Rev Food Sci Food Saf 2013;12:155–182.

Han K, Jang SS, Choo E, Heu S, Ryu S. Prevalence, genetic diversity, and antibiotic resistance patterns of Campylobacter jejuni from retail raw chickens in Korea. Int J Food Microbiol 2007;114:50–59.

International Organization for Standardization. ISO 20776-1:2007. Clinical Laboratory Testing and In Vitro Diagnostic Test Systems-Susceptibility Testing of Infectious Agents and Evaluation of Performance of Antimicrobial Susceptibility Test Devices-Part 1: Reference Method for Testing the In Vitro Activity of Antimicrobial Agents Against Rapidly Growing Aerobic Bacteria Involved in Infectious Diseases. Geneva, Switzerland: International Organization for Standardization, 2007.

Khan JA, Rathore RS, Abulreesh HH, Qais FA, Ahmad I. Prevalence and antibiotic resistance profile of Campylobacter jejuni isolated from poultry meat and related samples at retail shops in Northern India. Foodborne Pathog Dis 2018;15:218–225.

Magiorakos AP, Srinivasan A, Carey RB, Carmeli Y, Falagas ME, Giske CG, Harbarth S, Hindler JF, Kahlmeter G, Olsson-Liljequist B, Paterson DL, Rice LB, Stelling J, Struelens MJ, Vatopoulos A, Weber JT, Monnet DL. Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: An international expert proposal for interim standard definitions for acquired resistance. Clin Microbiol Infect 2012;18:268–281.

Mihaiu L, Lapusan A, Tanasuica R, Sobolu R, Mihaiu O, Mihaiu M. First study of Salmonella in meat in Romania. J Infect Dev Ctries 2014;15:50–58.

Morar A, Sala C, Imre K. Occurrence and antibiotic susceptibility of Salmonella isolates recovered from the pig slaughter process in Romania. J Infect Dev Ctries 2015;9:99–104.

Myšková P, Karpišková P. Prevalence and characteristics of Salmonella in retail poultry and pork meat in the Czech Republic in 2013–2014. Czech J Food Sci 2017;35:106–112.

Ren D, Chen P, Wang Y, Wang J, Liu H, Liu H. Phenotypes and antimicrobial resistance genes in Salmonella isolated from retail chicken and pork in Changchun, China. J Food Saf 2017;37:e12314.

Romanian Standards Association. SR EN ISO 6579/2003, SR EN ISO 6579 AC/2009. Microbiology of Food and Feeding Stuffs. Horizontal Method for the Detection of Salmonella spp. Bucharest, Romania: Romanian Standard Association, 2003.

Romanian Standards Association. SR EN ISO 10272/2006. Microbiology of Food and Feeding Stuffs. Horizontal Method for the Identification and Isolation of Campylobacter spp. 2006.

Schwaiger K, Huther S, Hörlzel C, Kümpf P, Bauer J. Prevalence of antibiotic-resistant enterobacteriaceae isolated from chicken and pork meat purchased at the slaughterhouse and at retail in Bavaria, Germany. Int J Food Microbiol 2012;154:206–211.

Sinwat N, Angkittitrakul S, Chuanchuen R. Characterization of antimicrobial resistance in Salmonella enterica isolated from pork, chicken meat, and humans in Northeastern Thailand. Foodborne Pathog Dis 2015;12:759–765.

Taremi M, Soltan Dallal MM, Gachkar L, Moez-Ardalan S, Zolfagharian K, Zali MR. Prevalence and antimicrobial resistance of Campylobacter isolated from retail raw chicken and beef meat, Tehran, Iran. Int J Food Microbiol 2006;108:401–403.

Terentjeva M, Avsejenko J, Streikiša M, Utināne A, Kovajenko K, Bērziņš A. Prevalence and antimicrobial resistance of Salmonella in meat and meat products in Latvia. Ann Agric Environ Med 2017;24:317–321.

Thai TH, Hirai T, Lan NT, Yamaguchi R. Antibiotic resistance profiles of Salmonella serovars isolated from retail pork and chicken meat in North Vietnam. Int J Food Microbiol 2012;156:147–151.

Tîrziu E, Lazar R, Sala C, Nichita I, Morar A, Seres M, Imre K. Salmonella in raw chicken meat from the Romanian seaside: Frequency of isolation and antibiotic resistance. J Food Prot 2015;78:1003–1006.

Zhang L, Fu Y, Xiong Z, Ma Y, Wei Y, Qu X, Zhang H, Zhang J, Liao M. Highly prevalent multidrug-resistant Salmonella from chicken and pork meat at retail markets in Guangdong, China. Front Microbiol 2018;9:2104.

Address correspondence to:
Kálmán Imre, PhD
Department of Animal Production and Veterinary Public Health
Faculty of Veterinary Medicine
Banat’s University of Agricultural Sciences and Veterinary Medicine “King Michael I of Romania”
Calea Aradului No. 119
Timișoara 300645
Romania

E-mail: kalman_imre27@yahoo.com