

ANTIMICROBIAL RESISTANCE OF *YERSINIA ENTEROCOLITICA* IN DIFFERENT FOODS. A REVIEW

MILAD TAVASSOLI¹, ASMA AFSHARI¹, DOINA DRĂGĂNESCU², ANDREEA LETIȚIA ARSENE^{3*}, TATYANA I. BURYKINA⁴, RAMIN REZAEI⁵

¹Department of Nutrition, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

²Department of Pharmaceutical Physics and Informatics, Faculty of Pharmacy, "Carol Davila" University of Medicine and Pharmacy, 6 Traian Vuia Street, 020956, Bucharest, Romania

³Department of General and Pharmaceutical Microbiology, Faculty of Pharmacy, "Carol Davila" University of Medicine and Pharmacy, 6 Traian Vuia Street, 020956, Bucharest, Romania

⁴Department of Analytical and Forensic Medical Toxicology, Sechenov University, 2-4 Bolshaya Pirogovskaya Street, 119991 Moscow, Russia

⁵Clinical Research Unit, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

*corresponding author: andreeanitulescu@hotmail.com

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Abstract

Emergence of multidrug-resistant pathogens has become an important issue in the treatment of infectious diseases and poisonings. Unfortunately, the irrational use of antibiotics has rendered some pathogens resistant towards anti-microbial agents. Today, infections caused by antibiotic-resistant strains are difficult to treat. *Yersinia* is a bacterium that causes many diseases in humans. Since pigs are the main source of this bacterium, extensive research has been done on pork products compared to other foods, though the presence of *Yersinia* in other foods have also been reported. For the treatment of acute gastroenteritis, as one of the most common symptoms of bacterial infections, several antibiotics are prescribed. Three species of *Yersinia* from the *Enterobacteriaceae* family, are human pathogens and *Y. enterocolitica* is known as the most prevalent one. This review discusses the antimicrobial resistance pattern of *Y. enterocolitica* in different foods, based on the reports published from 1977 to 2018.

Rezumat

Apariția agenților patogeni rezistenți la mai multe medicamente a devenit o problemă importantă în tratamentul bolilor infecțioase și intoxicațiilor. Din păcate, utilizarea irațională a antibioticelor a făcut ca anumiți agenți patogeni să fie rezistenți la substanțele antimicrobiene. Astăzi, infecțiile cauzate de tulpini rezistente la antibiotice sunt dificil de tratat. *Yersinia* este o bacterie care provoacă multe boli la om. Deoarece porcii sunt principala sursă a acestei bacterii, s-au făcut cercetări ample cu privire la produsele din carne de porc, în comparație cu alte alimente, deși prezența *Yersinia* în alte alimente a fost de asemenea raportată. Pentru tratamentul gastroenteritelor acute, ca unul dintre cele mai frecvente simptome ale infecțiilor bacteriene, sunt prescrise mai multe antibiotice. Trei specii de *Yersinia* din familia *Enterobacteriaceae* sunt agenți patogeni umani și *Y. enterocolitica* este cunoscută ca cea mai răspândită. Acest review analizează modelul de rezistență antimicrobiană la *Y. enterocolitica* în diferite alimente, pe baza rapoartelor publicate între anii 1977 și 2018.

Keywords: Antimicrobial resistance, *Yersinia enterocolitica*, foods, microbial resistance, *Enterobacteriaceae*

Introduction

Contamination with *Yersinia enterocolitica* can cause a variety of diseases, but mainly affects the digestive system. *Y. enterocolitica* causes pseudoappendicitis leading to unnecessary surgeries. Thus, monitoring microbial contamination along with proper administration of anti-microbial agents for treatment of infectious diseases, is of crucial importance [1]. *Yersinia* bacteria are non-spore forming, Gram-negative, rod-shaped or coccoid cells (0.5 - 0.8 μm wide and 1 - 3 μm long) which exert bacterial motion (except for *Yersinia pestis*) at 22 - 30°C but not at 37°C. Their motility is due to the existence of the peritrichous flagella. *Yersinia* can be cultured in

non-selective and certain selective media in aerobic and anaerobic environments, at temperatures ranging from 0 to 45°C with the best growth observed at 25 - 28°C [2]. It has been reported that the use of anti-microbial agents in animal agriculture has remarkably enhanced the prevalence of zoonotic pathogens [3]. An increasing trend is observed in antimicrobial-resistance prevalence among *Y. enterocolitica* strains [4, 5] *Y. enterocolitica* as a main foodborne enteropathogen, causes different clinical presentations ranging from mild gastroenteritis to serious complications such as conjunctivitis and lymphadenitis [6]. Epidemiological studies have emphasized on the importance of detection of virulence genes in parallel with evaluation of antibiotic resistance. The genes

that are mainly responsible for the virulence of *Y. enterocolitica* isolates are *ail*, *inv* and *ist*. Also, pYV which is a 70 kb plasmid, may carry virulence factors [7]. Compared to other *Yersinia* species, *Y. enterocolitica* more frequently causes disease in humans and animals. *Y. enterocolitica* species are categorized into six biotypes from which 1B, 2, 3, 4 and 5 are disease-causing biotypes in humans and animals, while biotype 1A species are primarily not pathogenic [8]. Since *Y. enterocolitica* can easily grow in foods stored at room and cold temperatures, it can survive longer in rancid foods due to availability of increased levels of nutrients. Indeed, yersinosis is currently the third and largest food-borne zoonotic infection across Europe, as 8000 cases of yersinosis have been reported so far [9]. Nowadays, high levels of antimicrobial chemicals are used for the treatment of infected animals, prevention in case of disease outbreaks and enhancement of animals' growth and food consumption. Globally, it is accepted that increased resistance towards antibiotics correlates well with inappropriate administration of these agents to animals (for production or veterinary care) and humans [10]. The consequence is the transmission of antibiotic-resistant strains to foods and subsequently to humans [11]. It is assumed that, by 2050, approximately 10 million deaths may annually occur due to antimicrobial resistance, with an overall economic burden of \$100 trillion [12]. Following exposure of animals' pathogens to antibiotics, they may become resistant towards these agents and transmitted to humans while carrying resistance genes. This transfer from one species to another may take place through food, direct contact when resources (e.g. water) are mutually used [12]. Although yersinosis is seldom treated with anti-microbials, immunodeficient individuals need medication. Since *Y. enterocolitica* produces β -lactamase, it exerts resistance towards β -lactam antibiotics (e.g. ampicillin, carbenicillin, penicillin and first-generation cephalosporins) [13, 14]. Moreover, *Y. enterocolitica* has an internal resistance towards antibiotics such as ampicillin, ticarcillin, amoxicillin/ clavulanic acid, cefazolin and cephalothin [8]. The resistance of *Y. enterocolitica* towards antibiotics is at least in part, induced by β -lactamases-encoding genes, *blaA* and *blaB*. There is an alarming growing prevalence of *Y. enterocolitica* strains that show resistance towards antibiotics, including the multidrug-resistant *Y. enterocolitica* strains [15]. Nevertheless, fluoroquinolones and third-

generation cephalosporins, are considered the most effective choices for treatment of enterocolitis in immunodeficient hosts and in patients with septicaemia or invasive infections, where the mortality rate may reach 50% [4].

The aim of this literature review was to evaluate the antimicrobial susceptibility of *Y. enterocolitica* isolated from different foods and investigate the pattern of *Y. enterocolitica* resistance towards various antibiotics based on the reports published between 1977 and 2018.

Methods

Search strategy

Scientific databases including ScienceDirect, Scopus, PubMed, SID and Google Scholar were searched for studies published between 1 January 1977 and 28 February 2018. In this literature search, we used the following combination of keywords: ("Antibiotic" or "Antibiogram") and ("*Yersinia*" or "*Yersinia enterocolitica*") and "Food" in the "title" and "abstract" of the articles. Duplicate publications, irrelevant topics and book chapters were excluded and were not further evaluated.

Results and discussion

Antimicrobial resistance of *Y. enterocolitica* in pigs

A total 22 of articles, evaluating *Y. enterocolitica* antibiotic resistance in pigs as the main source of *Yersinia*, were found (Table I). According to these studies, *Y. enterocolitica* isolated from pigs has the highest level of sensitivity towards cefotaxime, ciprofloxacin, chloramphenicol, streptomycin, sulphonamide, tetracycline, gentamicin, trimethoprim and trimethoprim-sulfamethoxazole, while exhibited the highest levels of resistance towards ampicillin, ticarcillin, clindamycin and amoxicillin [16-21]. Variable antimicrobial susceptibility for *Y. enterocolitica* was reported towards nalidixic acid [16, 19, 21-23]. Noteworthy, pigs play an important role in *Y. enterocolitica* epidemiology and these asymptomatic carriers are considered the source of human enteropathogenic *Y. enterocolitica*, particularly bioserotype 4/O:3 [5, 24-26]. In a research conducted by Novoslavskij *et al*, all tested *Y. enterocolitica* 4/O:3 strains exhibited resistance to ampicillin and erythromycin and susceptibility to ciprofloxacin. Among the studied strains, 5% were resistant to tetracycline and streptomycin [5].

Table I

Resistance toward antimicrobials among different strains of <i>Y. enterocolitica</i> in pork and pigs					
Strains	Antibiotic to which the strains were resistant	Antibiotic to which the strains were sensitive	Place	Year	Ref.
All*	amoxicillin, ampicillin, neomycin, streptomycin, imipenem, sulfamethoxazole, vancomycin, nitroimidazole, nalidixic acid, florfenicol and tiamulin	ciprofloxacin, kanamycin, gentamicin, rifampicin, tetracycline and chloramphenicol	Brazil	2018	[48]
3 variant/O: 3	nalidixic acid, ampicillin, ticarcillin, tetracycline, clindamycin and amoxicillin	-	Malaysia	2017	[16]
1B/O: 8	clindamycin	-			
1A/O: 5	ampicillin ticarcillin, amoxicillin and clindamycin	-			
All*	nalidixic acid, clindamycin, ampicillin, ticarcillin, tetracycline and amoxicillin	-			
All*	ampicillin (100%), sulphonamides (98.2%) and streptomycin (78.2%)	amoxicillin-clavulanic acid, gentamicin, ceftazidime, ertapenem and meropenem, 94.5% to cefotaxime, 89.1% to kanamycin and 78.2% to tetracycline	Northern Italy	2016	[17]
4/O: 3	cephalothin and ampicillin	-	Italy	2013	[18]
2/O: 9	cephalothin and ampicillin	-			
All*	cephalothin (92%), ampicillin (89%) and amoxicillin/clavulanic acid (8%)	ciprofloxacin, ceftazidime, cefotaxime, chloramphenicol, enrofloxacin, gentamicin, kanamycin and neomycin			
All*	amoxicillin-clavulanic acid, ampicillin and erythromycin	cefotaxime, ciprofloxacin, chloramphenicol, nalidixic acid, streptomycin, sulphonamide, tetracycline, trimethoprim and trimethoprim-sulfamethoxazole	Italy	2010	[19]
4/O:3	ampicillin, cephalothin, erythromycin, streptomycin, sulfamethoxazole, and tetracycline	amoxicillin-clavulanic acid, aztreonam, cefotaxime, ceftriaxone, chloramphenicol, ciprofloxacin, nalidixic acid, trimethoprim and trimethoprim-sulfamethoxazole	Latvia	2010	[23]
All*	ampicillin and sulfamethoxazole	ciprofloxacin, nalidixic acid, gentamicin, ceftiofur, tetracycline, kanamycin, cefotaxime and chloramphenicol	Germany	2010	[22]
All*	-	amoxicillin/clavulanic acid, ampicillin, ceftriaxone, cefuroxime, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, neomycin, polymyxin, streptomycin, tetracycline, trimethoprim, trimethoprim/sulfamethoxazole, and sulphonamide	Switzerland	2007	[20]
O:3	tetracycline, gentamicin, kanamycin, sulphonamides, nalidixic acid, trimethoprim, and streptomycin	-	Austria	2004	[21]
4/O:3	ampicillin and erythromycin	ciprofloxacin	Lithuania**	2012	[5]

*All: All strains of *Yersinia enterocolitica*, ** Study of pigs and humans

Antimicrobial resistance of *Y. enterocolitica* found in meats

Meat and meat products as the main sources of food-borne infectious diseases are crucial parts of the chain from food-producing animals to humans [21]. For growth enhancement as well as prevention and

treatment of infections, antimicrobial agents have been efficaciously administered to poultry. But, the afore mentioned application has led to increased bacterial resistance to many antibiotics [27, 28]. *Y. enterocolitica* isolated from meat and meat products [11] showed the highest resistance to clindamycin,

cephalothin, ampicillin, trimethoprim, amoxicillin, ciprofloxacin, streptomycin and tetracycline while exhibited sensitivity to tobramycin, imipenem, gentamicin, chloramphenicol, cefotaxime, sulphonamide and sulfamethoxazole.[19, 21] *Y. enterocolitica* has shown different reactions towards some antibiotics

that are further discussed in the conclusion section [27-29]. Some reports from Brazil, Northern Italy, Latvia and Australia, showed resistance of *Y. enterocolitica* isolated from pigs to streptomycin, but susceptibility was shown in reports from Italy and Switzerland.

Table II

Antimicrobial resistance pattern among *Y. enterocolitica* strains isolated from meats

Strains	Antibiotic to which the strains were resistant	Antibiotic to which the strains were sensitive	Place	Year	Ref.
All*	clindamycin	tobramycin and imipenem	Turkey	2015	[29]
All*	cephalothin, ampicillin, trimethoprim, amoxicillin, ciprofloxacin, nalidixic acid, streptomycin, tetracycline	gentamicin and chloramphenicol	Iran	2013	[59]
All*	amoxicillin-clavulanic acid	cefotaxime, ciprofloxacin, chloramphenicol, nalidixic acid, streptomycin, sulphonamide, tetracycline, trimethoprim, and trimethoprim-sulfamethoxazole.	Italy	2010	[19]
All*	cephalothin (98%) and ampicillin (52%)	ciprofloxacin (95%)	Iran	2009	[11]
All*	tetracycline, gentamicin, kanamycin, sulphonamides, nalidixic acid, trimethoprim, chloramphenicol and streptomycin	-	Austria	2004	[21]

*All: All strains of *Yersinia enterocolitica*

Milk and dairy products are mainly contaminated with non-pathogenic isolates of *Y. enterocolitica*. Interestingly, contamination of such products with pathogenic strains is mostly linked with outbreaks of yersiniosis [30]. Several dairy products, including raw and pasteurized milk, ice cream, cheese and cream were found to be contaminated with *Y. enterocolitica* and *Y. enterocolitica*-like organisms [31]. The most frequently found species in dairy products were *Y. enterocolitica* biotype 1A, *Yersinia intermedia* and *Yersinia frederiksenii* [32, 33].

However, since pathogenic form of *Y. enterocolitica* can grow at refrigeration temperatures (0 - 4°C), the presence of this form of *Y. enterocolitica* in milk is highly possible, which renders it a matter of health concern for dairy producers [31]. *Y. enterocolitica* isolated from milk and dairy products had the highest resistance to tetracycline, cephalothin, ampicillin, streptomycin, amoxicillin, nalidixic acid and clindamycin, but were sensitive to chloramphenicol and ciprofloxacin [29, 34].

Table III

Antimicrobial resistance pattern among *Y. enterocolitica* strains in dairy products

Strains	Antibiotic to which the strains were resistant	Antibiotic to which the strains were sensitive	Place	Year	Ref.
All*	amoxicillin, ceftiofur, cephalexin and amoxicillin - clavulanic acid	tetracycline, ticarcillin, ciprofloxacin, nalidixic acid, ceftriaxone, trimethoprim and sulfamethoxazole	Italy	2018	[49]
All*	tetracycline (48.3%), followed by ciprofloxacin and cephalothin (each 17.2%), ampicillin (13.8%), streptomycin (6.9%), and amoxicillin and nalidixic acid (each 3.4%).	gentamicin and chloramphenicol	Iran	2015	[34]
All*	clindamycin	tobramycin and imipenem	Turkey	2015	[29]

*All: All strains of *Yersinia enterocolitica*

Antimicrobial resistance of Y. enterocolitica detected in fruits and vegetables

Fruits, vegetables and their products are regarded as potential carriers of *Y. enterocolitica* [35]. Although, *Y. enterocolitica* might be potentially transmitted via consumption of fruits and vegetables [36], few studies have evaluated the existence of pathogenic and non-pathogenic *Y. enterocolitica* and other *Yersinia* spp. in fruits, vegetables and related products.

Furthermore, the growing trend of antibiotic resistance necessitates investigation of resistance to antimicrobials among bacteria detected in food products [6]. Studies in fruits and vegetables showed that *Y. enterocolitica* isolated from these products had the highest resistance to ampicillin, erythromycin, amoxicillin/clavulanic acid, streptomycin, cephalothin and carbenicillin but were susceptible to ciprofloxacin, gentamicin, enrofloxacin, cefotaxime, imipenem,

meropenem, tobramycin, colistin, trimethoprim, chloramphenicol and kanamycin [6, 36].
sulfamethoxazole, nalidixic acid, tetracycline,

Table IV

Antimicrobial resistance pattern among *Y. enterocolitica* strains isolated from fruits and vegetables

Strains	Antibiotic to which the strains were resistant	Antibiotic to which the strains were sensitive	Place	Year	Ref.
All*	ampicillin (100%), followed by erythromycin (98.1%), amoxicillin/clavulanic acid (77.4%) and streptomycin (39.6%)	ciprofloxacin, gentamicin, enrofloxacin, cefotaxime, imipenem, meropenem, tobramycin, colistin, trimethoprim and trimethoprim-sulfamethoxazole	European Union	2017	[6]
All*	ampicillin, cephalothin, carbenicillin	nalidixic acid, streptomycin, tetracycline, tobramycin, chloramphenicol, kanamycin, gentamicin, trimethoprim and ciprofloxacin	Korea	2004	[36]

*All: All strains of *Yersinia enterocolitica*

Antimicrobial resistance of Y. enterocolitica detected in frozen foods

Without causing evident decomposition in frozen food products, *Y. enterocolitica* can stay alive at low temperatures [15]. In this regard, Ye *et al* showed that all strains isolated from frozen products were sensitive to ticarcillin but they were resistant to two

or more antibiotics, and 48.6% of the strains were resistant to four to nine antibiotics. Resistance rates of 98.6, 95.7, 74.3, 28.6, 18.6 and 12.9%, were observed for ampicillin, cephalothin, trimethoprim/sulfamethoxazole, amoxicillin/clavulanic acid, nalidixic acid and chloramphenicol, respectively [15].

Table V

Antimicrobial resistance pattern among *Y. enterocolitica* strains isolated from frozen foods

Strains	Antibiotic to which the strains were resistant	Antibiotic to which the strains were sensitive	Place	Year	Ref.
All*	ampicillin, cephalothin, trimethoprim-sulfamethoxazole, amoxicillin/clavulanic acid, nalidixic acid and chloramphenicol	ticarcillin	China	2015	[15]

*All: All strains of *Yersinia enterocolitica*

Antimicrobial resistance Y. enterocolitica found in retail seafood

In a study that evaluated resistance pattern in sea-food-borne *Y. enterocolitica* strains, all isolates were sensitive to cefotaxime, cefuroxime, chloramphenicol,

ciprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, tetracycline and trimethoprim. However, these isolates were resistant towards cephalothin (83.3% of isolates), amoxicillin (83.3%), and ampicillin (50.0%) [37].

Table VI

Antimicrobial resistance pattern among *Y. enterocolitica* strains isolated from retail seafood

Strains	Antibiotic to which the strains were resistant	Antibiotic to which the strains were sensitive	Place	Year	Ref.
All*	cephalothin, amoxicillin, ampicillin	cefotaxime, cefuroxime, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, tetracycline, and trimethoprim	Germany	2018	[37]

*All: All strains of *Yersinia enterocolitica*

Antimicrobial resistance of Yersinia enterocolitica strains obtained from foods and humans

A small number of 57 O serogroups are regarded as humans and animals pathogens. Globally, strains that belong to serogroups O:3 (biogroup 4), O:5,27 (biogroups 2 and 3), O:8 (biogroup 1B) and O:9 (biogroup 2), are the ones that are most commonly isolated from human samples [4, 38]. Nevertheless, in Europe, *Y. enterocolitica* serogroups O:3 and O:9

are of crucial importance while in the United States, serogroup O:8 has raised concerns [4]. In a study, Lucero-Estrada C *et al* found all the *Y. enterocolitica* strains isolated susceptible to amikacin, aztreonam, cefuroxime, ciprofloxacin, chloramphenicol, colistin, fosfomycin, furazolidone, gentamicin, kanamycin, nalidixic acid, neomycin, tetracycline and trimethoprim-sulfamethoxazole, but resistant to ampicillin, cephalothin, erythromycin and rifampicin [39].

Table VII

Antimicrobial resistance pattern among *Yersinia enterocolitica* strains isolated from foods and humans

Strains	Antibiotic to which the strains were resistant	Antibiotic to which the strains were sensitive	Place	Year	Ref.
Food samples	2,3,1A	amikacin, aztreonam, cefuroxime, ciprofloxacin, chloramphenicol, colistin, fosfomycin, furazolidone, gentamicin, kanamycin, nalidixic acid, neomycin, tetracycline and trimethoprim-sulfamethoxazole	Argentina	2015	[39]
Clinical samples	3,1A				

Different food-borne serotypes of *Y. enterocolitica* show various responses to antibiotics; for instance in Malaysia, 1B/O:8 strain was resistant to only one antibiotic (i.e. clindamycin) but O: 3 and 1A/O:5 serotypes were resistant to clindamycin, nalidixic acid, ampicillin, ticarcillin, tetracycline and amoxicillin-clavulanic acid [16]. These finding should be considered when choosing treatments strategies against different strains of *Y. enterocolitica*. Several studies showed that *Y. enterocolitica* was resistant to clindamycin [15, 40-45]. In some studies, the greatest resistance rate was seen against ampicillin and amoxicillin [10, 46-49]. Resistance to ampicillin was observed in all of the reviewed studies including with the reports from Switzerland, Germany and the United Kingdom [20, 22, 50]. In contrast, in samples collected from the USA in 2006 and Prince Edward Island in 1995, only 87 and 77% of *Y. enterocolitica* isolates were resistant to ampicillin, respectively [51-53]. High resistance rate of *Y. enterocolitica* towards ampicillin and cephalothin has been widely reported by different studies [15, 54-56]. Sensitivity of *Y. enterocolitica* to amoxicillin varied among different studies as it showed sensitivity in northern Italy, Switzerland, southern Germany and the United States [46, 57, 58] while exhibited resistance in studies conducted in Brazil [48], Germany [59], China [15], Italy [19], Iran and Malaysia [16, 34, 37].

In studies conducted in the United States, Switzerland and Germany, sensitivity to ciprofloxacin, gentamicin, enrofloxacin, cefotaxime, imipenem, meropenem, tobramycin, colistin, trimethoprim and trimethoprim/sulfamethoxazole, were more commonly observed compared to other antibiotics [46, 57, 58, 60]. *Y. enterocolitica* showed susceptibility to some aminoglycoside antibiotics (including amikacin, neomycin, kanamycin and gentamicin), as well as colistin and cefuroxime [20, 39, 56, 61, 62].

Y. enterocolitica was found to be resistant to macrolide antibiotics such as erythromycin [5, 6, 19, 23, 39]. Additionally, the highest rate of resistance was reported for sulphonamides in the United States and Germany [60, 63]. Also, *Y. enterocolitica* was more sensitive to sulfamethoxazole in samples collected from the European Union (EU) member states, but a report from Germany detected resistance to sulfamethoxazole in three (2%) 4/O:3 strains as also reported by a Chinese study. These data showed variability among results obtained by studies done in the EU countries [6, 15, 19, 20, 60]. Some studies found resistance to streptomycin in most of the strains, as shown by the studies performed in the EU, Iran, Latvia [6, 17, 21, 23, 34]; however, there are reports from Germany, Iran, Italy, Switzerland and Korea that showed sensitivity of *Y. enterocolitica* towards streptomycin. These studies showed that resistance pattern towards streptomycin

has changed over the years in the EU and Asia [19, 20, 36, 37, 59].

Although since 1994, administration of chloramphenicol to food-producing animals has been prohibited in the EU, a report from Austria and another report from a non-EU country (i.e. China) showed that up to 60% of *Y. enterocolitica* strains were resistant to chloramphenicol [10, 15, 21, 53]. Conversely, studies done in Brazil, Switzerland, Germany, Argentina, Iran, Korea and Italy reported sensitivity to chloramphenicol [19-21, 34, 36, 37, 39, 48, 59, 64].

For tetracycline, resistance was reported from Malaysia, Iran and Austria [16, 21, 59], but sensitivity was found in studies done in Brazil, Argentina, Germany, Korea, Switzerland, Italy and north Italy [17, 19, 20, 36, 37, 39, 48].

In reports from the EU countries, Korea and Iran, *Y. enterocolitica* was mostly sensitive to trimethoprim-sulfamethoxazole [6, 11, 20, 36, 49, 55, 56, 65] while resistance was reported by studies done in Ireland and Germany [55, 65].

Resistance towards ticarcillin was investigated by a few studies; reports from China and Italy found *Y. enterocolitica* susceptible to ticarcillin while resistance was showed by a report from Malaysia [15, 16, 49]. Most studies found *Y. enterocolitica* sensitive towards ciprofloxacin [5, 6, 11, 19, 20, 22, 23, 37, 39, 48, 49, 56, 62]; but, an Iranian report published in 2009, showed that *Y. enterocolitica* was sensitive to ciprofloxacin, while it was found resistant in studies performed during 2013 and 2014, indicating the possibility of changes in resistance pattern of *Y. enterocolitica* to ciprofloxacin in Iran [11, 34, 59].

Concerning nalidixic acid, studies done in Brazil, Malaysia, Australia, China and Iran, found *Y. enterocolitica* resistant, while it was reported to be sensitive by research in Germany, Korea, Argentina, Latvia and Italy [15, 16, 19, 21-23, 34, 36, 37, 39, 48, 49].

The anti-microbial resistance/sensitivity pattern of *Y. enterocolitica* was studied in different types of foods. All *Y. enterocolitica* isolated from different foods were resistant to three antibiotics namely, ampicillin, amoxicillin and cephalothin. *Y. enterocolitica* isolated from fruits and vegetables [15, 36], dairy [49, 59] products and retail seafood [37] were sensitive to nalidixic acid; however, strains isolated from frozen food and meat products were resistant. *Y. enterocolitica* isolated from dairy products and frozen food were sensitive to ticarcillin [15, 16, 49]. *Y. enterocolitica* isolated from different foods showed different reactions to streptomycin as those isolated from meat products in Iran and Australia, were resistant to streptomycin, while a study done in Italy showed sensitivity towards streptomycin [19, 21, 59]. In dairy products, fruits and vegetables collected from the EU countries, *Y. enterocolitica* was resistant to streptomycin, but sensitive in fruits

and vegetables samples collected from Korea and retail sea food samples in Germany [6, 34, 36, 37]. In terms of resistance towards sulfamethoxazole, *Y. enterocolitica* isolated from dairy products, meat and fruits and vegetables showed susceptibility [6, 19, 49]. Different reactions were observed following treatment of *Y. enterocolitica* isolated from different food, with tetracycline; *Y. enterocolitica* isolated from dairy products [17, 19, 20], fruits and vegetables [22, 36, 37] and retail sea food were sensitive [39, 48, 49], while those isolated from dairy products in Iran were resistant [34].

With regard to resistance/sensitivity towards trimethoprim, *Y. enterocolitica* isolated from was meat products in Iran were susceptible but those isolated from frozen foods in China were resistant [15, 59].

Conclusions

The anti-microbial resistance pattern of *Y. enterocolitica* to different antibiotics were almost similar in most of the reviewed studies but antibiotics such as sulphonamides, chloramphenicol, tetracycline, trimethoprim-sulfamethoxazole, ciprofloxacin and nalidixic acid had inconsistent results. Studies showed that different strains of *Y. enterocolitica* have different reactions to the above-noted antibiotics in different geographical regions. Therefore, it could be suggested that geographical region and type of food consumed, should be considered for choosing appropriate strategies for treatment of the *Y. enterocolitica* infections.

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