UK Health Security Agency

Literature review: a review of AMR in *Listeria monocytogenes* and other *Listeria* spp. in the food chain

Five-year review, 2020 to 2024

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Summary

Listeria monocytogenes is associated with a high case fatality rate and antimicrobial drugs are important in treatment of invasive infections. In addition, it is unclear what the pattern of drug resistance is in *Listeria* and whether there is any evidence that this is increasing. As listeriosis is caused by ingestion of food, a literature review focusing on the prevalence of antimicrobial resistance (AMR) of *Listeria* spp. isolated from food and animal sources was performed. Publications between January 2020 and December 2024 were included with the terms 'Listeria' 'antimicrobial resistance' and 'food' used in the initial search. After excluding reviews and papers focussing on resistance to sanitisers including quaternary ammonium compounds (QAC), 80 publications were included; the food items described were sorted into broad food categories for analysis.

All 6 World Health Organization (WHO) regions were represented, although there were no publications from the UK identified. All the major food categories were represented, according to ISO 16140-1:2016. Various AMR methods were used and the number of samples tested to isolate *Listeria* differed greatly from 19 to 44,141 (median 300 samples). The 4 antimicrobial classes reviewed were not all tested consistently in the data-set of publications. In the penicillin and trimethoprim/sulfamethoxazole (SXT) classes, there was no resistance seen until 2013 but with no clear pattern of gradual increase between 2013 and 2024. The aminoglycoside and carbapenem classes did see a gradual increase of resistance but in general, most studies reported lower than 50% of isolates resistant. Resistance rates generally decreased from primary production or raw categories to ready-to-eat (RTE) and ready-to-heat categories. Differences were also seen between broad food categories; for example, for meat, resistance was higher at primary production stage than in raw meat and ready-to-cook products.

Variable AMR rates in *Listeria* spp. were seen geographically from lowest rates in the Western Pacific and Europe, to the highest resistance in south-east Asia and Eastern Mediterranean. These differences may be explained by different food types studied and methods used, but it may also reflect the different regulation and use of antimicrobials in both clinical and agricultural settings in different parts of the world. Although Europe indicated lower levels than most other regions, 9 countries showed medium to high resistance in β-lactams and are also seeing multi-drug resistant *L. monocytogenes* isolates.

In conclusion, AMR rates in *Listeria* isolated from the food chain are variable, and comparisons have been challenging due to the different sizes of studies, AMR testing methods and types of antimicrobials studied. However, most authors have recommended more surveillance of AMR in *Listeria* in the food chain.

Background

According to UK Health Security Agency (UKHSA) data, there were approximately 160 reported cases of listeriosis in England and Wales each year between 2015 and 2024. Although this is a relatively small number of cases annually, listeriosis is an important public health concern due to the severity of infection and high case fatality rate. Infections with *Listeria monocytogenes* can most commonly manifest as bacteraemia, sepsis, meningitis, encephalitis, brain abscess, endocarditis, and gastroenteritis. Treatment for these is by antimicrobial therapy. Ampicillin (a penicillin) is the preferred drug for initial treatment for systemic (non-gastroenteric) manifestations. Gastroenteritis alone is usually self-limiting. Patients with febrile gastroenteritis who are immunocompromised, of older age (that is, 60 years or older), or pregnant require treatment with amoxicillin or trimethoprim /sulfamethoxazole (SXT; a combination of a diaminopyrimidine and a sulfonamide). Consideration of combination therapy with gentamicin (an aminoglycoside) is indicated in bacteraemia and severe infections.

In patients with a penicillin allergy or intolerance, SXT is effective. Meropenem (a carbapenem) may also be used, but it is associated with higher treatment failure and mortality rate. SXT should be avoided during the first trimester of pregnancy due to its effect on folic acid metabolism. The British Infection Association recommends intravenous ampicillin or amoxicillin as first line therapy for confirmed meningitis (1).

Due to the reliance on antimicrobial use in treating clinical *L. monocytogenes* infections, antimicrobial resistance (AMR) in *L. monocytogenes* has become of interest. *L. monocytogenes* strains are intrinsically resistant to cefotaxime, cefepime, fosfomycin, oxacillin, and lincosamides (2) but are susceptible to a wide range of antibiotics which have bactericidal effects against Gram positive bacteria. However, due to adaptive mechanisms, including the exchange of antimicrobial resistance determinants with other bacterial species through horizontal gene transfer, biofilm-forming ability, and efflux pumps, *L. monocytogenes* strains can acquire resistance to the antimicrobials used, resulting in their ineffectiveness.

This review will focus on identifying any recent increase of resistance to the more therapeutically significant antimicrobial groups: penicillins, aminoglycosides, carbapenems and SXT. Studies reviewed and summarised include both food and animal isolates from several countries.

Method

To initially gather relevant publications, PubMed was used. The terms ‘Listeria’ ‘antimicrobial resistance’ and ‘food’ were entered, with a time period between January 2013 and December 2024, spanning 11 years.

PubMed retrieved 170 relevant publications from 2013 to 2024. For this report, a subset of these were taken, published between January 2020 and December 2024; however, the dates of isolation, where known, ranged from 1998 to 2023. Review papers were omitted to eliminate duplication of analyses. Papers describing resistance to QAC/sanitiser and samples from only humans were also omitted from this review.

A number of caveats were identified that could restrict interpretation of this review:

1. The majority of these were small scale studies from one country and looking at one type of food commodity or processing plant.
2. Various methods to test antibiotic sensitivities were used and a range of antimicrobials were investigated, which made different studies difficult to compare.
3. For the penicillin class, ampicillin, amoxicillin and penicillin were tested in different studies: where more than one class of antibiotic were tested in an individual study, the highest resistance observed was used for analysis.
4. Similarly, detection of AMR genes was not performed in all the papers reviewed, and where AMR genes were investigated, different studies used either PCR detection or whole genome sequencing to provide this information.

When extracting the food items from the literature, these were sorted into the respective broad food categories (as per BS EN ISO 16140-2:2016, Annexe A; see Figure 3 below) to form larger groups and allow more meaningful analyses.

Results and discussion

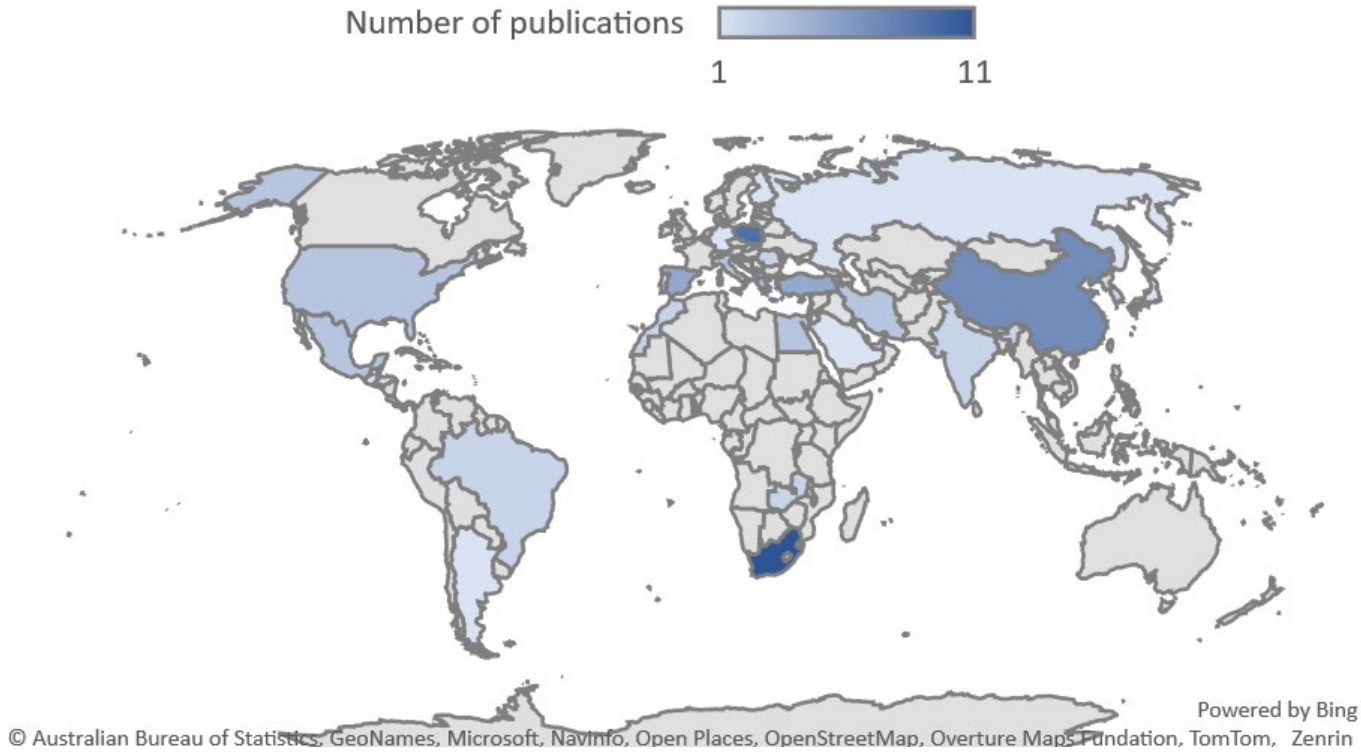
Of 170 publications retrieved, 80 were identified as particularly relevant and are summarised in Table 1. A third of the 80 publications were published in 2024 (n=27), and most of the sampling for these ended after 2020.

Table 1. Number of relevant publications extracted from literature search, by publication date and year sampling ended

Pub date	Year sampling ended												Total
	2009	2013	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	
2020	1	2	0	2	1	2	0	1	0	0	0	0	**9**
2021	0	0	1	1	1	1	3	4	0	0	0	0	**11**
2022	0	0	0	0	0	0	6	5	5	1	0	0	**17**
2023	0	0	0	0	0	1	5	3	3	1	3	0	**16**
2024	0	1	0	0	1	1	0	2	6	8	6	2	**27**
Total	**1**	**3**	**1**	**3**	**3**	**5**	**14**	**15**	**14**	**10**	**9**	**2**	**80**

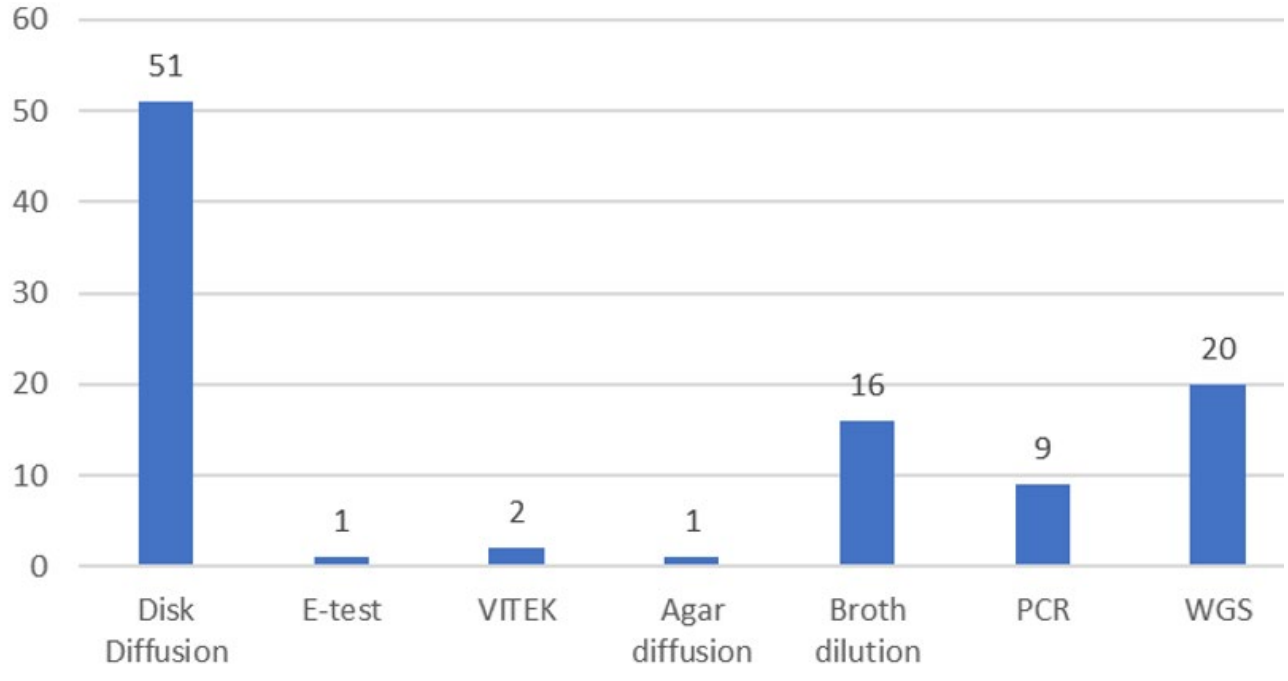
Geographically, studies have been published from all 6 WHO regions: Africa (n=13), Americas (8), East Mediterranean (10), Europe (34), South-East Asia (2), Western Pacific (10) and 2 papers used global data.

Figure 1. Geographical distribution of publications 2020 to 2024



A variety of AMR methods were used (see Figure 2), where 20 publications used 2 different methods (a phenotypic and genotypic method).

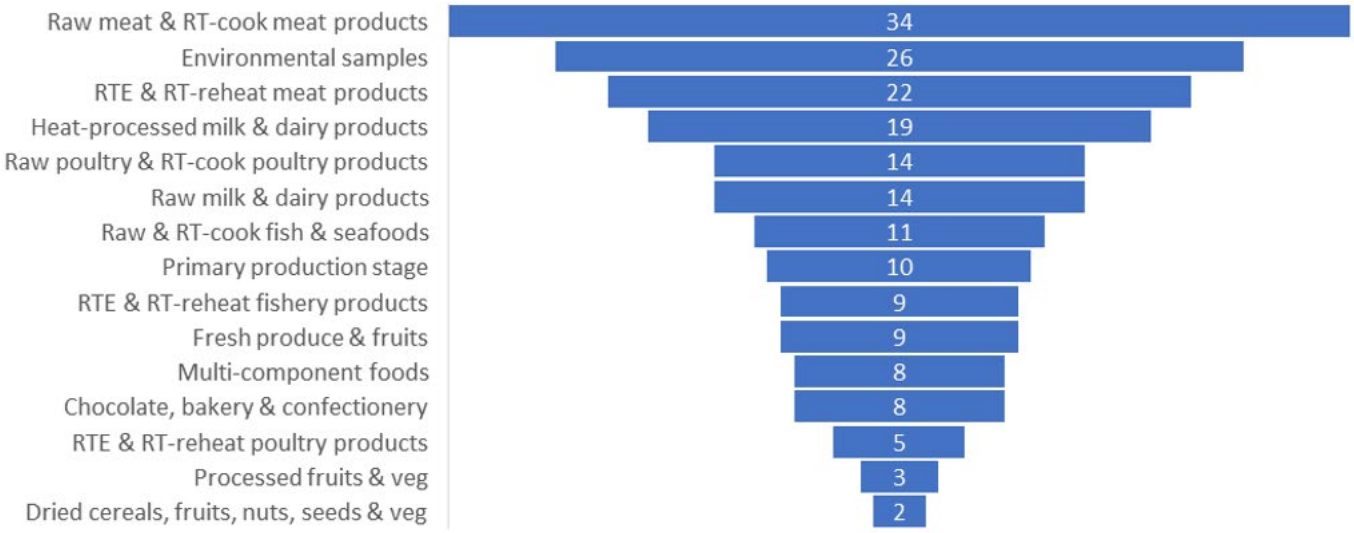
Figure 2. AMR methods used



The majority of papers (78.8%, 63 out of 80) focused on sampling food items and/or from the environment (for example, processing environment, abattoir setting). A further 7 papers included samples from humans, 6 from animals and 4 papers describing sampling from food, humans and animals. Samples were taken from 15 of the 18 food categories, as described in ISO 16140-2 (Figure 3 - 'infant formula and infant cereal', 'eggs and egg products' and 'pet food and animal feed' not represented), where 32 papers focused on only one food category. Figure 3 illustrates the number of food categories covered by the publications; however, they are not mutually exclusive.

The number of samples investigated vary from publication to publication, as did the *Listeria* isolation rate and the subsequent antimicrobial resistance proportions. There were 24 out of 80 publications that did not report the number of samples tested, with the remaining publications testing from 19 to 44,141 samples (median 300 samples). Seventy-six out of 80 publications isolated *L. monocytogenes* with the remaining 4 publications isolating other *Listeria* spp. but were included in the analysis due to relevant antimicrobial resistance data.

Figure 3. Matrix type



Abbreviations

RTE = ready to eat; RT = ready to…

Four antimicrobial classes were analysed: penicillin data was reported by 69 of the 80 papers, aminoglycosides (62), carbapenems (55) and SXT (60).

When plotting the penicillin resistance (including penicillin (PEN), ampicillin (AMP) and amoxicillin (AMX) data) against year the last sample was taken (or where no sample dates are known, the year that the study was published), there is no resistance seen until 2013 (Figure 4). However, this may be an artefact of using the publication year for analysis when the sampling period was unknown, therefore creating bias of most data points being created after 2019. Penicillin resistance levels varied between studies, ranging from 0% in 2012 to levels between 0 and 100% from 2013 onwards and this is also similar to SXT levels (Figure 5), with no clear pattern of gradual increase.

Figure 4. PEN/AMP/AMX resistance (%) distribution 2008 to 2024

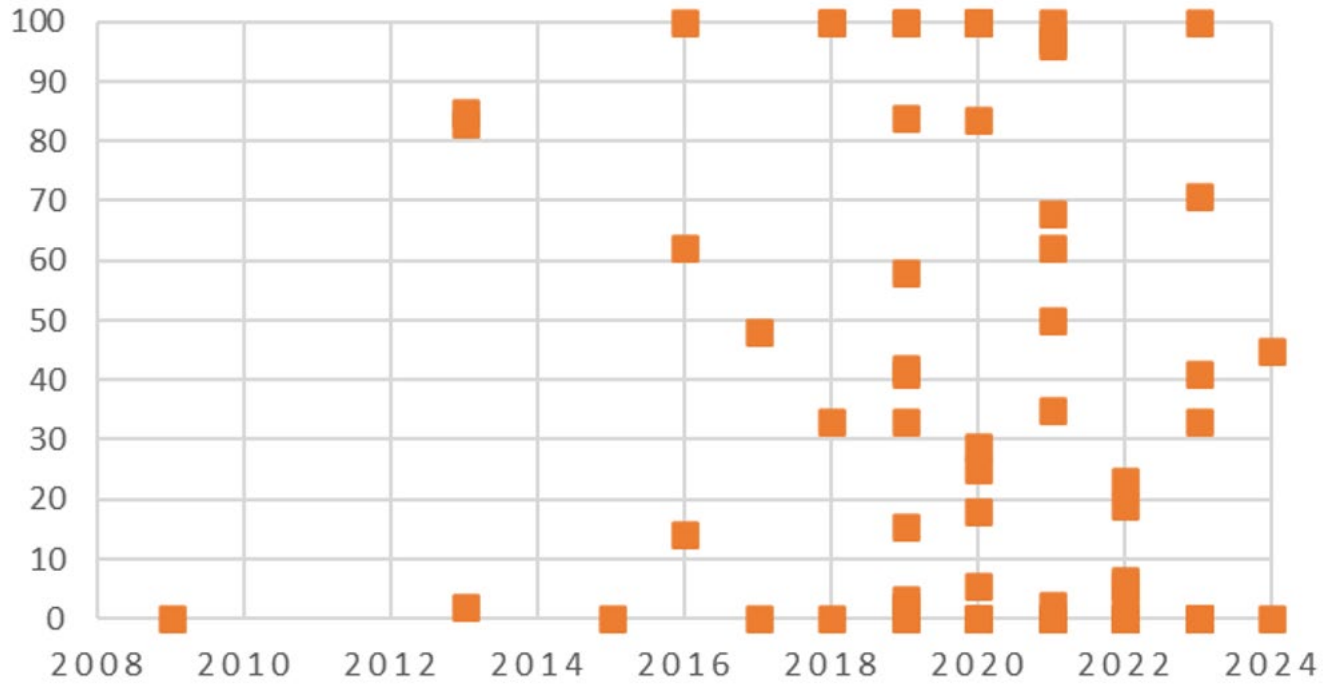
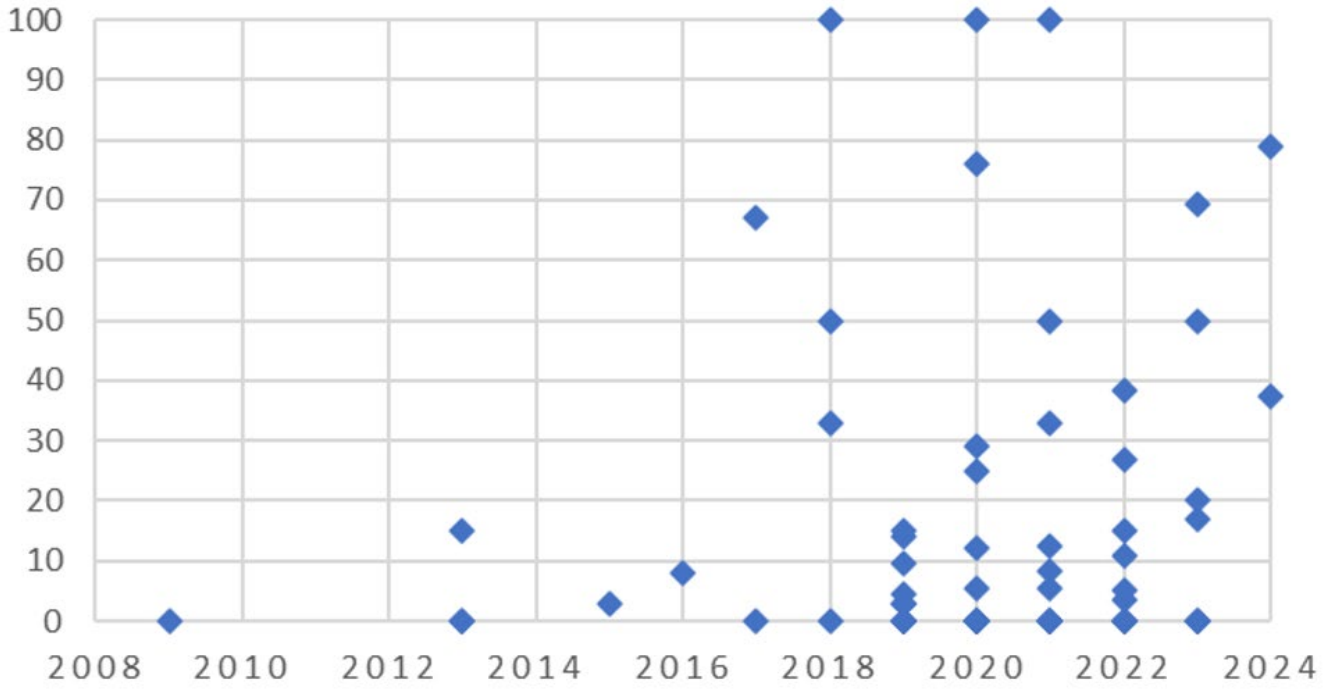


Figure 5. SXT resistance (%) distribution 2008 to 2024



The aminoglycoside (gentamicin, GEN, Figure 6) and carbapenem (meropenem, MER or imipenem, IMI, Figure 7) data did show a more gradual temporal increase, where most studies are lower than 50%, with only 3 outlying studies at over 90%. A study from Iran (3) focused on sampling fresh chicken and beef meat from retail in one city but revealed all 45 isolates were SXT, tetracycline, PEN and GEN resistant from 90 samples. Badawy and colleagues (4) reported over 91% resistance for SXT, GEN, PEN and IMI from 3 dairy suppliers in Egypt in *L.*

monocytogenes isolates, and whilst *L. monocytogenes* was not isolated from a similar study in Turkey (5), all 4 *Listeria* spp isolates were GEN and rifampicin resistant. The 3 studies highlighted that a comprehensive microbial assessment, continuous monitoring and strict hygiene measures is recommended to better assess and control the prevalence and antibiotic resistance of *Listeria*.

Figure 6. GEN resistance (%) distribution 2008 to 2024

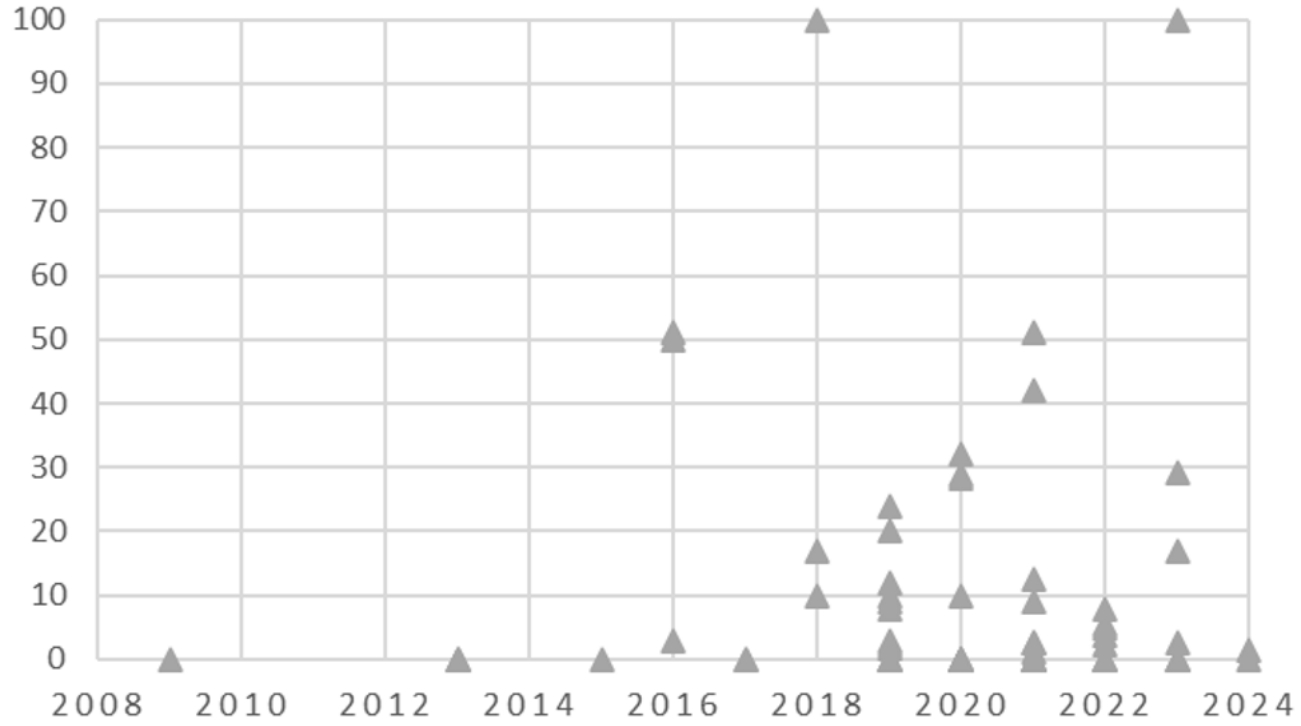
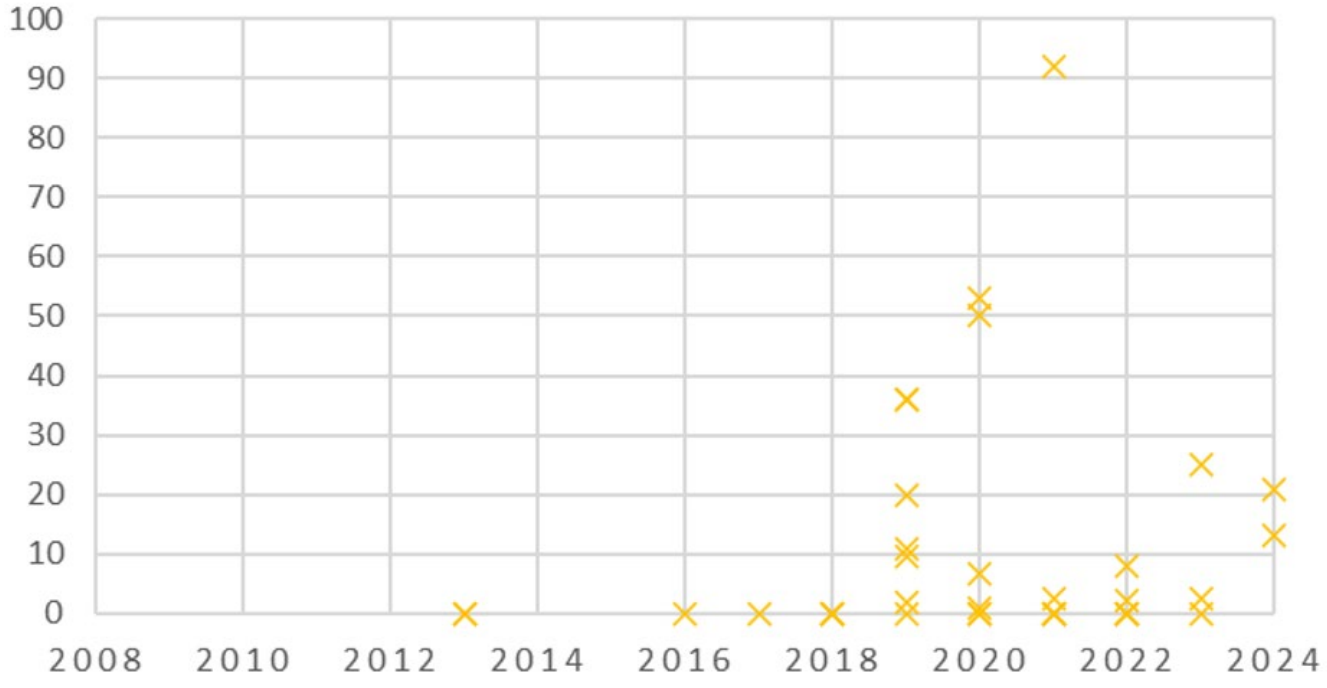


Figure 7. MER/IMI resistance (%) distribution 2008 to 2024

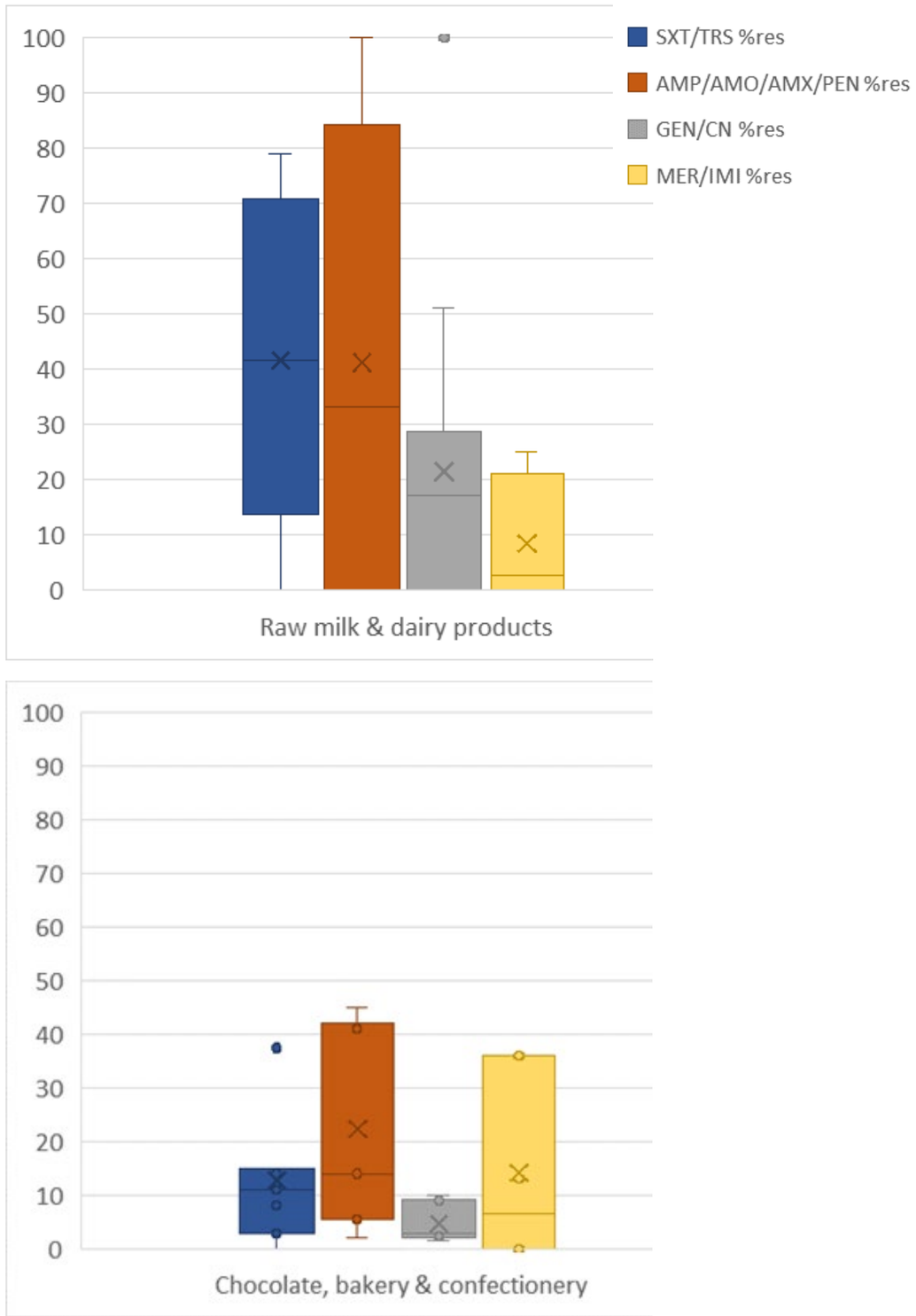


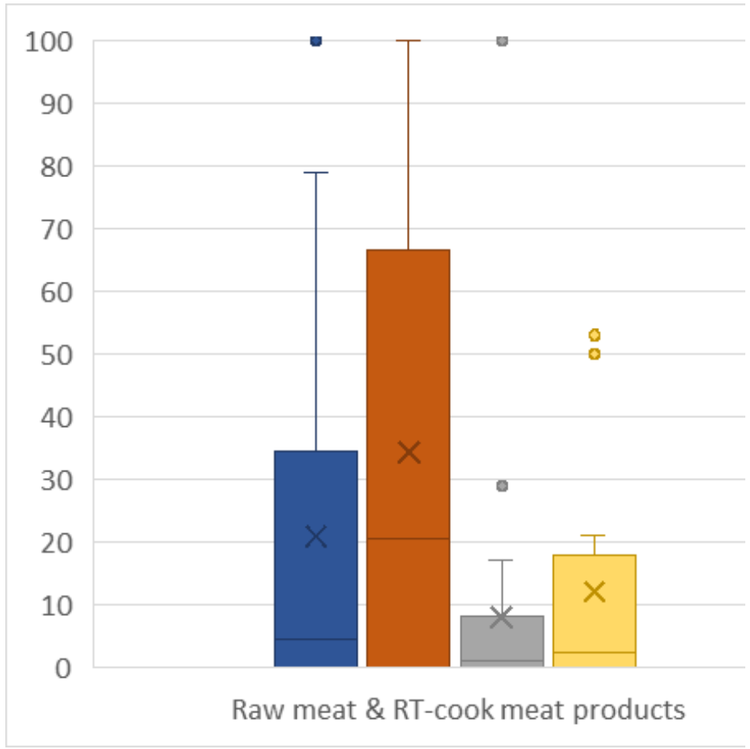
Comparison of resistance for different sample matrices

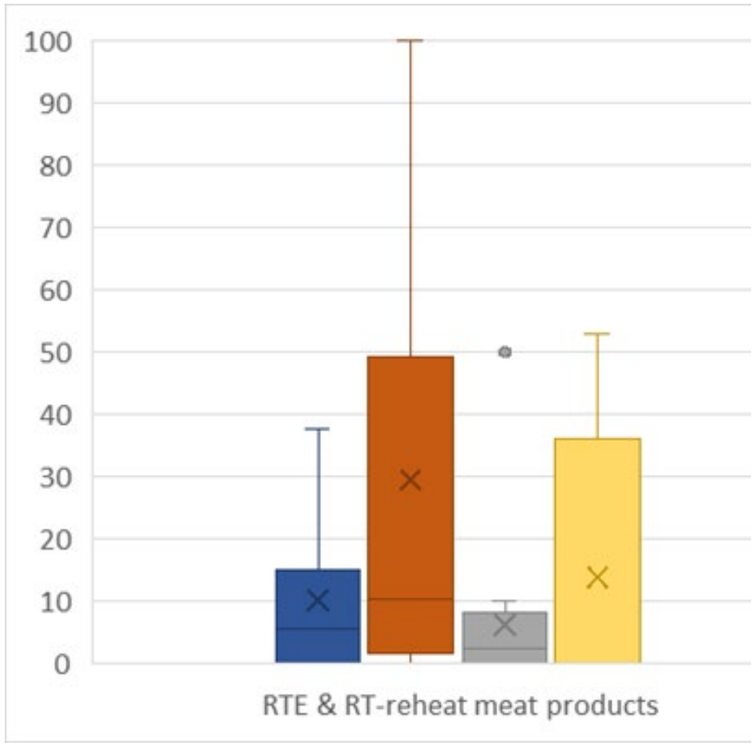
A graph was not produced for the food category ‘dried cereals, fruits, nuts, seeds and veg’ as only one publication reported no positive phenotypic results for this food category (43). Similarly, ‘processed fruits and veg’ did not have enough data points to produce a box and whisker chart.

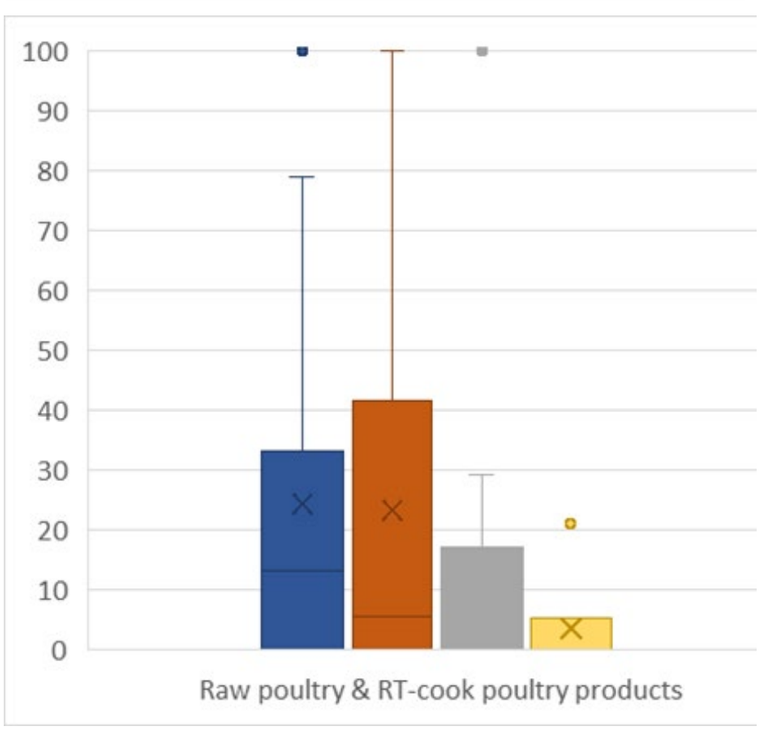
Analysing the antimicrobial classes against the different matrix types did show varied AMR rates, visualised as a box and whisker chart, where the ‘x’ is the mean value of resistance (%), the solid box contains the 1st to the 3rd quartile of data points, and the whiskers denote the minimum and maximum % values (Figure 8). One caveat in this analysis is that most papers did not break down the resistance data into individual matrix types, therefore the same resistant value may have been plotted for multiple matrix types from one paper’s findings.

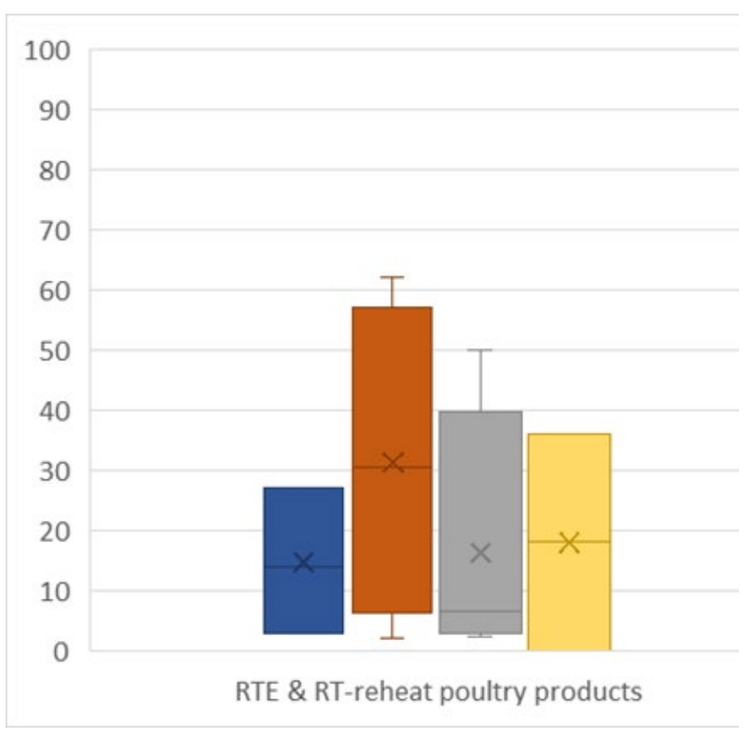
Figure 8. Average resistance rates (%) of 4 antimicrobial classes, per matrix type

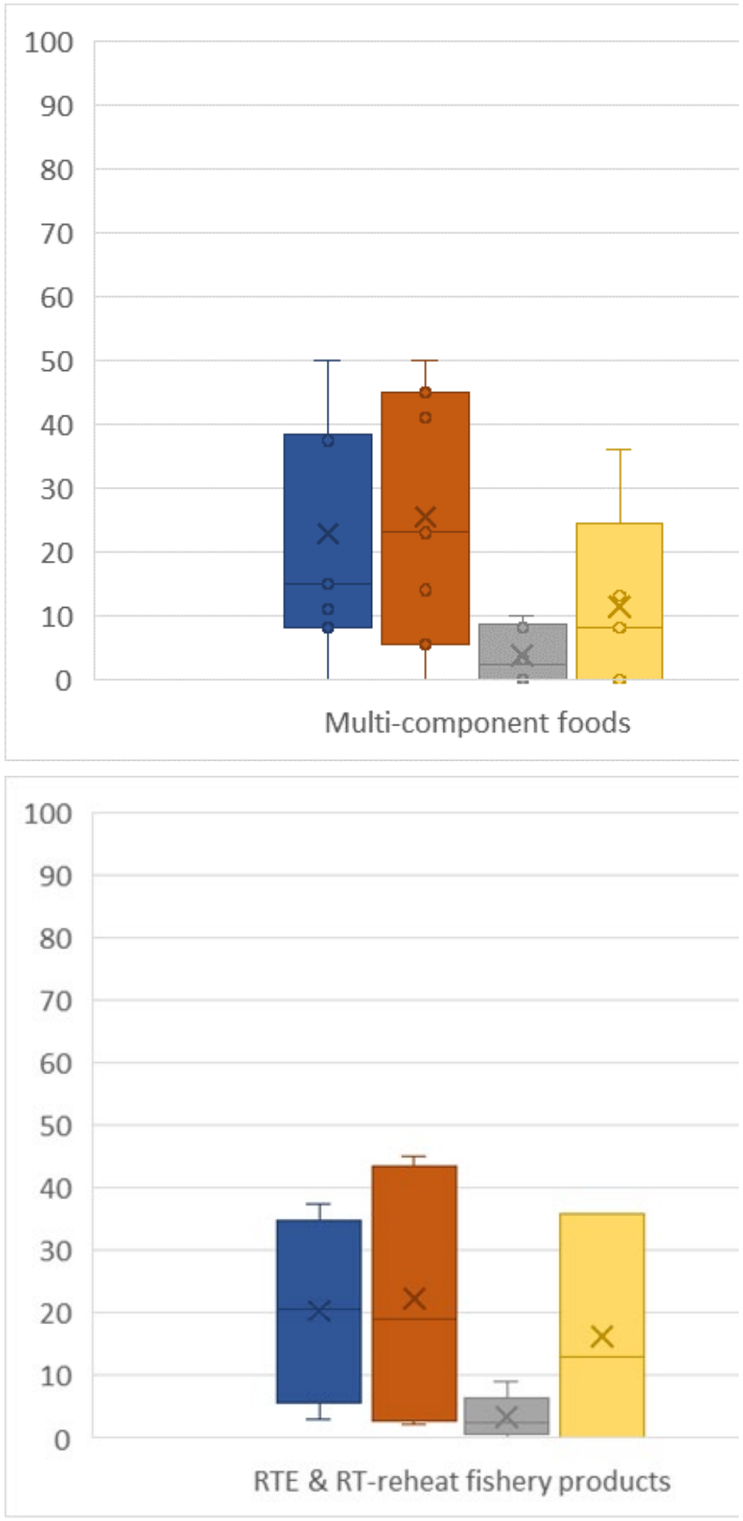


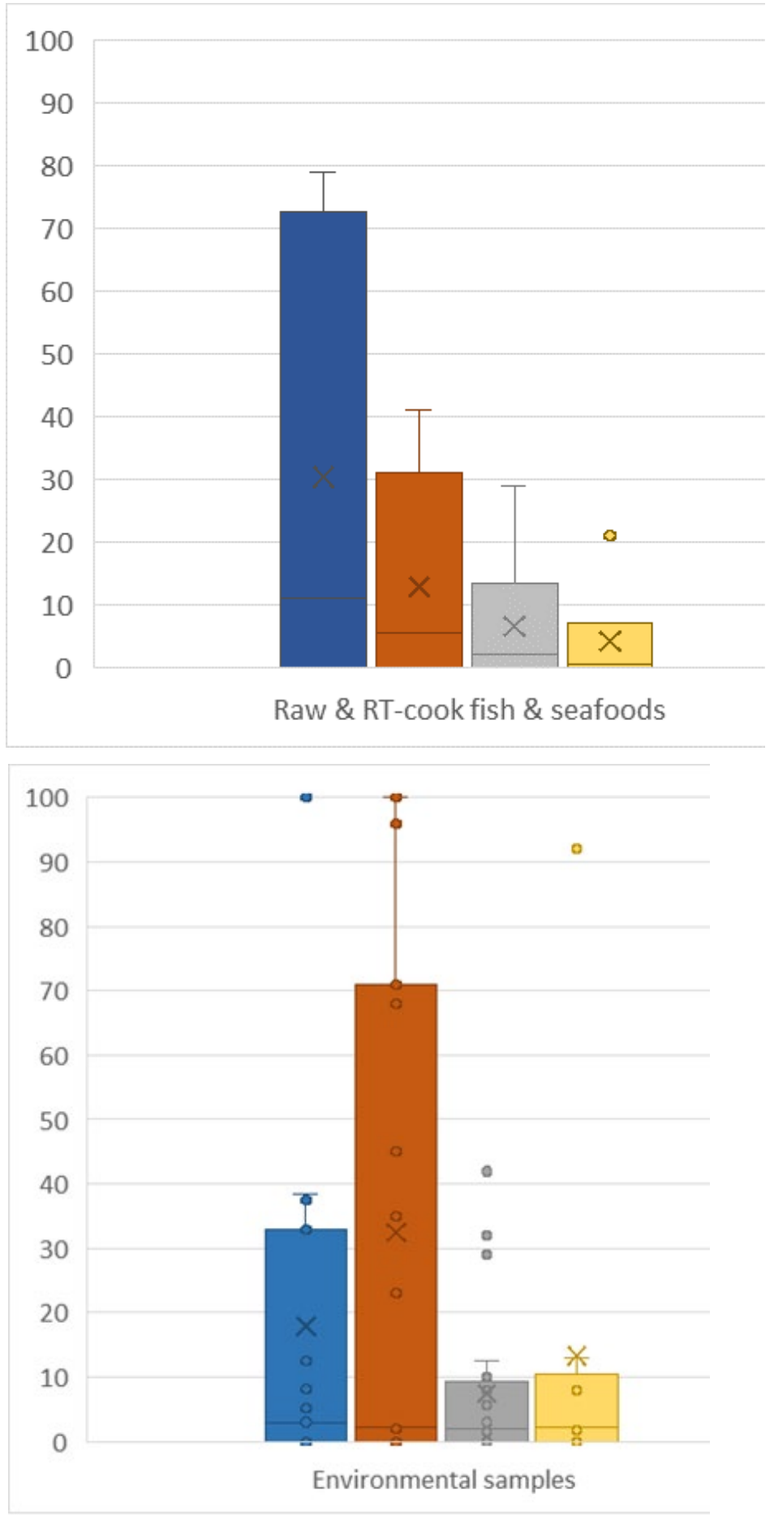

100
90
80
70
60
50
40
30
20
10
0
Raw meat & RT-cook meat products

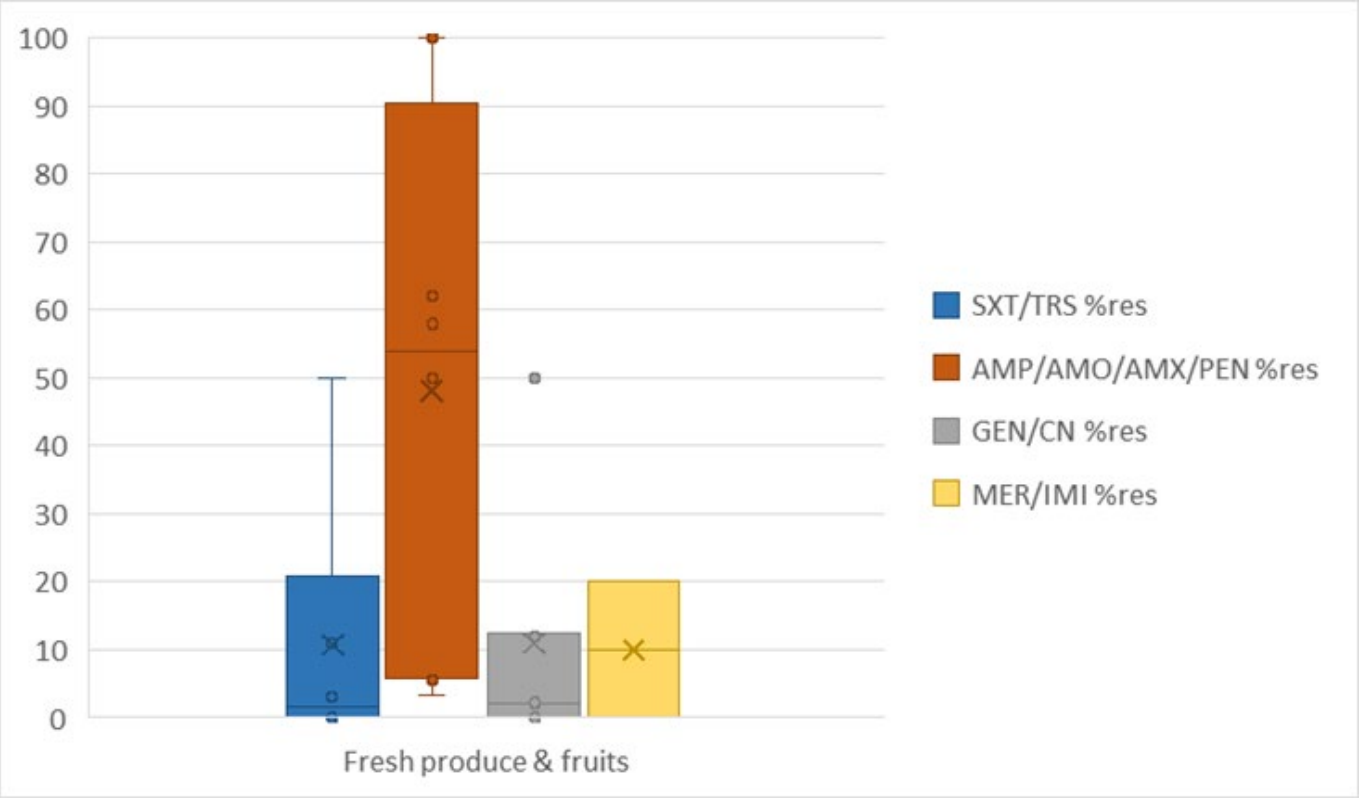

100
90
80
70
60
50
40
30
20
10
0
RTE & RT-reheat meat products


100
90
80
70
60
50
40
30
20
10
0
Raw poultry & RT-cook poultry products


100
90
80
70
60
50
40
30
20
10
0
RTE & RT-reheat poultry products


100
90
80
70
60
50
40
30
20
10
0
Multi-component foods
RTE & RT-reheat fishery products


100
90
80
70
60
50
40
30
20
10
0
Raw & RT-cook fish & seafoods
Environmental samples



In general, when looking at the matrix types in a 'farm to fork' perspective (primary production stage to processed foods; for example, multi-component foods or chocolate, bakery and confectionary), AMR rates decrease, which is a similar pattern to isolation rates of *Listeria* (6). Overall, the highest 75%-quartile resistance was seen from the penicillin-class antibiotics for all the matrices, except for the raw and ready-to-cook fish and seafood, where SXT was around 72% compared to PEN at approximately 30%. Focusing on primary production stage (10 publications), despite carbapenem resistance being seemingly high, only 4 publications tested for carbapenems, and 2 of these reported 0% resistance, one publication 11% (7) and the fourth was 92% (4).

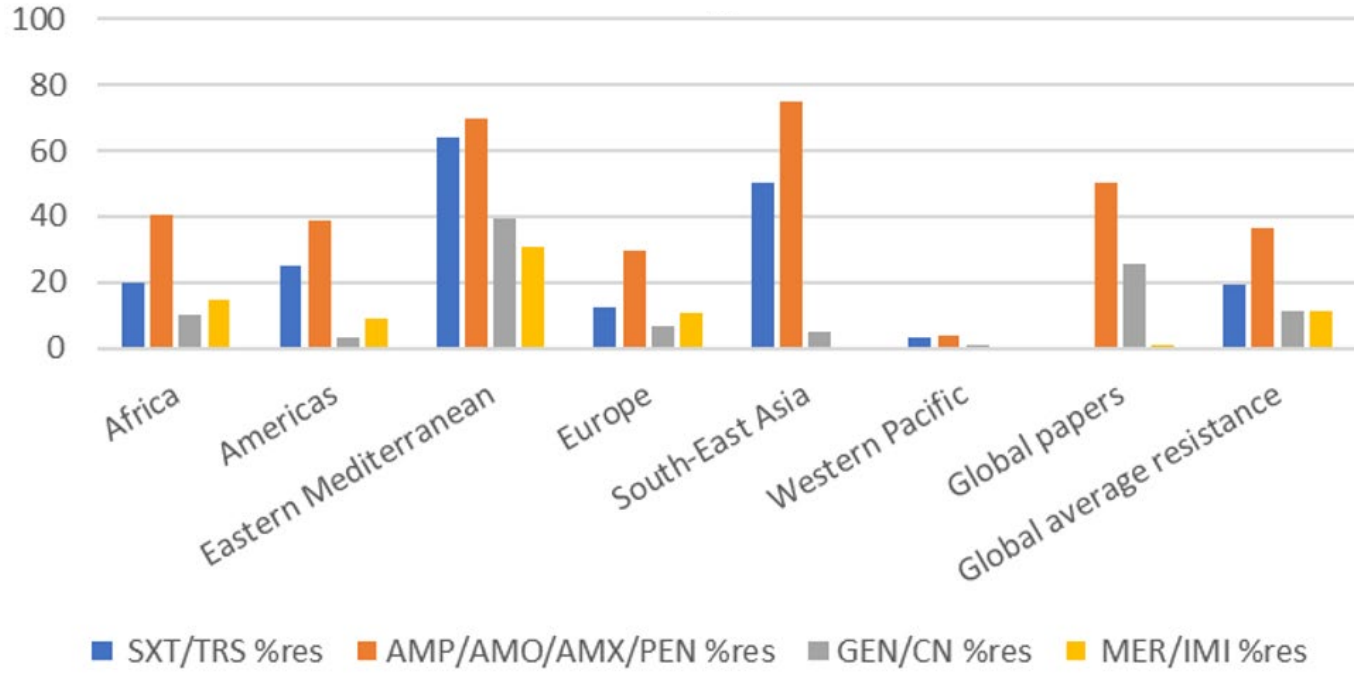
Carbapenemase resistance revealed an interesting increase from the 'raw and RT-cook' types to the 'RTE and RT-reheat' types of milk, meat, poultry and fish, with the greatest difference in the two poultry products (5% in raw poultry products compared to 37% in RTE poultry). However, this is based on 6 medium-sized studies where raw chicken was sampled and only 2 large-scale studies where RTE chicken was stated, which may be skewing the data.

Geographical distribution of AMR

When comparing the WHO regions, there were variable resistance rates for the 4 antimicrobial classes (Figure 9). The highest average resistance for penicillin was observed in the south-east Asia region, which is due to studies from India, and the Eastern Mediterranean (high resistance from Iran and Morocco). Sulfonamide resistance was also the highest from these 2 regions, with highest resistance reported from Iran and Egypt. The Eastern Mediterranean region was also highest for aminoglycoside and carbapenem resistance.

The lowest average resistance rates were seen in Western Pacific (China, Japan and South Korea) and Europe (Italy, Poland and Spain). A study of *Listeria* isolates from chicken meat in Japan compared resistance rates in 2012 and 2017 (8). Although the *Listeria* contamination rate of chicken meat reduced between 2012 and 2017, the rates of antimicrobial resistance increased, with multidrug resistance rising from 47% of isolates in 2012 to 83% in 2017. In addition, a study from Italy found that food, human and environmental isolates showed an increased frequency of oxacillin resistance (22% in 1998 to 2006 to 28% in 2007 to 2009), and intermediate sensitivity to clindamycin (from 26% to 35%, respectively) and ciprofloxacin (from 21% to 34%, respectively, $p<0.05$) (9). However, these 2 studies still revealed low or no resistance to antibiotics used to treat human listeriosis, and the rising resistance was associated with less clinically significant antimicrobials.

Figure 9. Average antimicrobial resistance (%) in WHO regions



Whilst some of the differences observed may be explained by variations in methodology or food types, the high rates of resistance to clinically important antimicrobials are a significant concern, particularly in relation to foods that are imported to the UK and may reflect less strict regulation of antimicrobial use, either clinically and/or in agriculture in these countries.

The 34 studies from the European region indicated lower levels of resistance found in food to the main antibiotics of clinical significance for *Listeria* infections. However, whilst resistance to β-lactams ranged from 0 to 3.3% in 15 publications from Greece, Italy, Poland, Portugal, Spain, and Turkey, the same 6 countries in other publications, plus Germany, Romania and Serbia reported levels between 14 and 100%. Reported ranges from the European region for sulphonamides, aminoglycosides and carbapenems were 0 to 69.2%, 0 to 100% and 0 to 53%, respectively. Focusing on papers reporting high resistance, a study in Romania reported 17 of 221 (7.7%) of food samples positive for *L. monocytogenes*, and all the isolates showed some

multi-drug resistance (resistance to at least one antimicrobial in 3 or more classes) and were isolated from raw and ready-to-eat meat and dairy products, which the authors highlighted as a public health and medical concern, especially for vulnerable populations (10). Likewise, Rippa and colleagues (11) studied 269 *L. monocytogenes* isolates from a wide variety of foods in Italy and 235 (87.4%) were multi-drug resistant, where only one isolate was fully sensitive. Although both of these studies showed high resistance to β-lactams, they also showed very low or no resistance to gentamicin, which is also used for the treatment for human listeriosis. A study from Portugal (12), revealed a low *L. monocytogenes* detection rate (13 of 227 samples yielding 6%) over 12 years from food products or food-processing environments. However, resistance was seen to β-lactams (23%), sulphonamides (38.4%), aminoglycosides (8%) and carbapenems (8%) in these 13 isolates, as well as all exhibiting a high biofilm-forming capacity which highlights the potential for persistence in the food-processing environment to subsequently cause contamination and public health incidents.

There were no UK publications from within the stated timeframe that reported antimicrobial analyses on samples from the food chain for *L. monocytogenes*. However, there was one UK publication outside of this scope that described isolates from human cases and, whilst focus was on determining mortality risk factors, antimicrobial sensitivity testing performed on 63 case isolates revealed no resistant strains (13). In addition, a UK study tested 307 samples of raw, fresh salmon fillets collected in 2024 and *L. monocytogenes* was detected in 5 samples (1.6%) (14). Including a further 15 *L. monocytogenes* strains from a previous raw salmon examination between 2015 and 2024, the 20 isolates revealed no acquired antimicrobial resistance.

Conclusion

Overall, rates of resistance amongst *Listeria* isolates from the food chain are varied, with highest resistance seen in β-lactams, and studies from the Eastern Mediterranean and South-East Asia regions. However, there is considerable variation between different studies and countries, which are likely to be affected by variations in methodology as well as genuine differences in resistance rates. Where studies have seen high resistance to antibiotics recognised by WHO as clinically important (15) (for example, erythromycin, ciprofloxacin), several studies have highlighted the importance of more surveillance of *Listeria* in the food chain and recommended monitoring antimicrobial resistance.

As there were no UK publications reviewed within the timeframe of this review, there is an opportunity to focus on AMR testing (or detection of AMR determinants by WGS) in *L. monocytogenes* strains in the UK. This information gap may warrant further investigation due to the apparent increase in resistance over time in other global regions.

Annexe: summary of 80 relevant publications included in this review

Year of study	Country	Sampling source	Isolation rate (%)	Phenotypic antibiotic resistance (%)	AMR genes present (%)	Other comments	Reference
1998 to 2009	Italy	Food, environment, human	274 Lm	Ampicillin (0%) Penicillin (0%) Gentamicin (0%) SXT (0%)	NT	Increase in clindamycin and ciprofloxacin resistance in 2007 to 2009 compared to 1998 to 2006	(9)
2000 to 2018	China	raw meat, raw poultry, RTE and aquatic products	322 Lm	NT	Six intrinsic genes found and 4 acquired. aacA4 (**aminoglycoside**) in 10 isolates, tetS in 1 isolate, tetM in 13, dfrG (**trimethoprim**) in 1	Monitoring aacA4 gene in Lm isolates is important for listeriosis treatment	(16)
2000 to 2020	Poland	Bivalves	30 isolates	SXT (0%) No testing for carbapenems, AMP and GEN	WGS: Most had genetic resistance to aminoglycosides, fluoroquinolones, lincosamides, macrolides, peptides and sulfonamides 3 out of 30 had aacA4 (aminogly) 4 out of 30 aphA (aminogly), 30 out of 30 had sul (sulfanomide), none had penA (carba)	Potential risk of bivalves posed by Lm	(17)
2002 to 2019	China	Food, livestock and humans	NA; 369 Lm isolates analysed	Ampicillin (2.1%) Gentamicin (2.4%) SXT (2.9%) Meropenem (0%)	NT	AMR is varied over years and covers wide geography and food products	(18)
2006 to 2013	Poland	RTE meat products	70 out of 44,141 (0.16%)	Ampicillin (83%) Amoxicillin (6%) Gentamicin (0%) SXT (0%) Meropenem (0%)	NT	Continued surveillance recommended to ensure effective antibiotic treatment	(19)
2008 to 2016	Iran	Clinical, livestock, RTE food, dairy, fresh produce and fruit	44 out of 1,150 (3.8%)	Ampicillin (62%) Gentamicin (50%) No SXT or carbapenems tested	NT		(20)
2009 to 2019	Poland	Soil, fruit, veg, RTE, meat, fish, salad and enviro swabs	262 out of 2,495 (10.5%)	Penicillin (0.4%) Gentamicin (0%) No SXT or carbapenems tested	NT	Proportionally more resistance in atypical Lm than Lm, so need to id non-haemolytic Lm	(21)
2010 to 2021	Australia / New Zealand, Asia, Europe, North America, South	All sources, including human	NA; 35,753 Lm isolates analysed	NT	Genes conferring to ampicillin or gentamicin resistance not found in 35,753 sequence strain data	Large scale study puts other smaller studies into context – however, not all data is submitted into NPDIB and there are gaps	(22)

Year of study	Country	Sampling source	Isolation rate (%)	Phenotypic antibiotic resistance (%)	AMR genes present (%)	Other comments	Reference
	Africa, and UK / Ireland						
2012 to 2013	Turkey	Raw water buffalo milk and milk products	13 out of 188 (6.9%)	Penicillin (85%) Gentamicin (0%) SXT (15%) No carbapenems tested	NT	Lm had developed resistance to many frequently used medical antimicrobial agents	(23)
2012 to 2020	Finland	Game meat (Moose, deer, mallard, teal, pheasant, wild boar)	Between 3% (teal) and 40% (wild boar)	NT	Only fosX and lin detected	Hunted game do not have access to feed contaminated with resistant Lm strains	(24)
2012, 2017, 2022	Japan	raw chicken samples	17 Lm isolates	Ampicillin (0%) Gentamicin (0%) SXT (0%) Imipenem (0%)	NT	AMR rate lower in 2022 than 2012 and 2017	(25)
2013	Spain	Poultry processing	50 out of 347 (14.4%)	Penicillin (2%) Gentamicin (0%) SXT (0%) Meropenem (0%)	NT	In poultry-associated Lm, AMR is low	(26)
2014 to 2015	Italy	Pig carcases and processing samples	98 out of 1,131 (8.7%)	Ampicillin (0%) Gentamicin (0%) SXT (3%) No carbapenems tested	NT	Low resistance to main ab to treat listeriosis but concern of high resistance to other Gram-pos antimicrobials	(27)
2014 to 2022	Montenegro	Various food, meat and dairy products	160 out of 22,593 (0.7%)	NT	WGS. fosX and lin genes detected in all strains. No acquired ARGs were detected	Only looked for fosX and lin genes, which are intrinsic	(28)
2014 to 2022	Portugal	Meat preparations, cheese, raw milk, food-processing environment	13 out of 227 (5.7%)	Penicillin (23%) Gentamicin (8%) SXT (38.4%) Meropenem (8%)	WGS found norB (fluoroquinolones) in 5 isolates, tetM in one isolate	Res to first-line treatment ab. Need to educate all about handling practices, hygiene and antimicrobial overuse. Comprehensive surveillance essential	(12)
2015 to 2016	Brazil, Columbia, Uruguay, Argentina, Romania	Beef carcases	53 out of 518 (20.3%)	Ampicillin (100%) Gentamicin (51%) No carbapenems and SXT tested	NT	Resistance identified in imported meat may have impact in several countries	(29)

Year of study	Country	Sampling source	Isolation rate (%)	Phenotypic antibiotic resistance (%)	AMR genes present (%)	Other comments	Reference
2015 to 2020	USA	Cattle, sheep and goat infections	NA; 73 Lm isolates analysed	NT	Only one isolate harboured gene qnrB19-quinolone res. All other known res genes absent in isolates	Very low resistance and highly clonal	(30)
2015 to 2020	China	retail meat and meat processing	123 out of 1,914 (6.4%)	Penicillin (18%) SXT (12%) Meropenem (0%) Gentamicin not tested	NT	Long term surveillance is needed	(31)
2015 to 2022	China	Aquatic products, baked good, catering food, cooked meats, edible fungi, raw meat and poultry	NA; 72 Lm isolates analysed	Ampicillin (5.5%) SXT (11%) Meropenem (0%) Gentamicin not tested	tet(M) and blaZ in 7 isolates, mef(A) in 2 isolates, one isolate had 5 res genes.	Shown diverse resistance patterns posing public health threat	(32)
2016*	Turkey	RTE foods	15 out of 300 (5%) Lm 70 out of 300 (23%) L. spp	Lm and L.spp: Ampicillin (14%) Gentamicin (3%) SXT (8%) Imipenem (0%)	NT	Shows presence of AMR Lm in RTE foods which may lead to consumer health risks	(33)
2016 to 2018	Morocco	Beef	10 out of 140 (7.1%)	Amoxicillin (100%) Gentamicin (10%) SXT (50%) Imipenem (0%)	NT	Lm becoming increasingly res to abs, so need to develop more effective abs against Lm	(34)
2016 to 2019	Greece	Myzithra cheese, processing surfaces	NA; 54 Lm isolates analysed	Ampicillin (0%) SXT (0%) Meropenem (1.8%)	Only fosX, mdrL and mdrM detected	Potentially acquired resistance along the food production	(35)
2017	Mexico	Ham, hotdog	NA; 4 Lm isolates analysed	NT	All had same multidrug resistance pattern: fosX, norB (quinolone), mprF and lin	Observed genes associated with alternative treatments for Lm	(36)
2017	Brazil	unpasteurised cheese	9 out of 170 (5.3%)	Ampicillin (0%) Gentamicin (0%) SXT (67%) Meropenem (0%)	NT	Important to monitor the raw milk cheese processing and develop microbial safety strategies	(37)
2017	Argentina	Meat and meat products	25 out of 270 (9.3%)	Penicillin (48%) Gentamicin (0%) SXT (0%) No carbapenems tested	None had blaZ or mecA genes	Concerned of penicillin resistance	(38)

Year of study	Country	Sampling source	Isolation rate (%)	Phenotypic antibiotic resistance (%)	AMR genes present (%)	Other comments	Reference
2017 to 2018	Morocco	Raw milk and products, raw bovine, poultry meat and products, raw fish, salads	15 out of 520 (2.9%)	Ampicillin (33%) Gentamicin (17%) SXT (17%) Imipenem (0%)	NT	Although at a small presence of 2.9% in food, there is high resistance seen	(39)
2017 to 2018	Poland	RTE meat products	52 out of 848 (6.1%)	Ampicillin (0%) SXT (0%) Meropenem (0%) Gentamicin not tested	NT	Isolates were sens, but emergence of res highlights need for continual surveillance	(40)
2017 to 2019	South Africa	Clinical, raw seafood, raw meats, RTE food and processing environment	NA; 177 Lm isolates analysed	Ampicillin (0%) Gentamicin (1.7%) No carbapenems or SXT tested	NT	No isolates were res to AMP (current ab for clinical treatment). However, high level of MDR and res in ERY causes concern. Due to TB and HIV/AIDS in SA, could increase fatalities due to Lm in immunocompromised individuals	(41)
2017 to 2019	Spain	Dairy cattle	211 out of 424 (54%)	Only 45 isolates tested Ampicillin (15.5%) Gentamicin (0%) Meropenem (11%) Did not test for SXT	Only fosX, lin, norB and mprF detected	Antimicrobial resistance among L.m isolates is still low	(7)
2017 to 2020	Romania	RTE meat products, raw meat, dairy	17 out of 221 (7.7%)	Penicillin (100%) Gentamicin (0%) SXT (29%) Imipenem (53%)	NT	Recommending clinicians to treat listeriosis cases with gentamicin	(10)
2018	Iran	beef and chicken meat	45 out of 90 (50%)	Penicillin (100%) Gentamicin (100%) SXT (100%) Did not test for carbapenems	NT	Need continuous surveillance and taking preventative control measures	(3)
2018 to 2019	Poland	Smoked and raw salmon	NA; 17 Lm isolates analysed	NT	No clinically relevant resistance genes detected for Lm, although all had tetA_3 and tetC genes	Tetracyclines used in fish industry, which explains acquisition of tet resistance genes	(42)
2018 to 2020	USA	Meat products (for example, ground beef, chicken, sausage, ox tail), egusi ground, saffron powder	15 out of 326 L. spp (4.6%)	Ampicillin (0%) Gentamicin (0%) SXT (0%) Meropenem (6.7%)	NT	*Campylobacter*, *E.coli* and *Salmonella* also isolated, so *Listeria* only briefly discussed	(43)

Year of study	Country	Sampling source	Isolation rate (%)	Phenotypic antibiotic resistance (%)	AMR genes present (%)	Other comments	Reference
2018 to 2020	China (import study)	frozen meat, fresh fish, dairy food	101 out of 1,797 (5.6%)	89 isolates tested Ampicillin (0%) Gentamicin (0%) SXT (0%) Imipenem (1%)	ErmC, aph(4)-Ia, tetK and tetM genes found	Concerned about salmon isolates and resistance, as this is from most regions of world	(44)
2018 to 2022	South Africa	salmon, smoked trout, fresh hake, oysters, processing enviro, clinical isolates	NA; 38 Lm isolates analysed	Ampicillin (0%) Gentamicin (0%) SXT (5.2%) Meropenem (0%)	Intrinsic genes found, plus aacA4 (aminoglycosides) found in 3 isolates but not phenotypic GEN R	Also looked at benzalkonium chloride resistance; paper focuses on persistence and genetic diversity	(45)
2018 to 2023	Russia	Clinical, meat and fish	7 isolates from human, 9 from food	NT	Only clinical isolates harboured genes for penicillin-binding protein and beta-lactamase	Resistance only observed from clinical isolates	(46)
2019	Greece	raw meat, preparations, RTE meat products, processing, handlers	12 out of 303 (4%) Lm 22 out of 303 (7.3%) L. spp	L.m only: Penicillin (100%) Gentamicin (8%) SXT (0%) No carbapenems tested	NT	The rate of Lm MDR is low, but an increase in the emergence of antibiotic-resistant strains for reasons not yet clearly defined	(47)
2019	USA	Faeces from dairy cows	18 out of 20 (90%)	Ampicillin (84%) Gentamicin (20%) SXT (4.5%) Did not test for carbapenems	NT	Due to res to clinically important abs, may require a modified drug regimen. A larger study is needed on many farms to assess ab res.	(48)
2019	South Africa	RTE	100 out of 239 (41.8%)	Amoxicillin (42%) Gentamicin (9%) SXT (14%) Ertapenem (36%)	NT	High resistance observed, suggested a campaign against ab misuse and search for novel ab to treat Lm	(49)
2019	South Africa	Raw and pasteurised milk, cheese	21 out of 65 (32.3%)	Amoxicillin (33%) Gentamicin (23.8%) SXT (14%) Imipenem (9.5%) 8 isolates MDR	Presence of β-lactam genes blaTEM, blaSHV, blaTEM variants (TEM-1 and TEM-2) and blaZ and tet genes (tetA, tetD, tetG and tetM and tetK) in resistant strains.	Recommended to limit and prevent rapid spread of AMR by adopting organic farming and introduce strict polices against ab use in animal husbandry to achieve safe milk and milk products	(50)
2019	South Africa	apple, cabbage, carrot, mushrooms, spinach, tomato	60 out of 140 (42.9%), although 103 Lm isolated	Amoxicillin (58%) Gentamicin (12%) SXT (3%) Ertapenem (20%) 88 isolates MDR	20 different genes detected	High resistance rates indicate antibiotic selection pressure or drug misuse in the region. Advocate surveillance monitoring to ensure food safety	(51)

Year of study	Country	Sampling source	Isolation rate (%)	Phenotypic antibiotic resistance (%)	AMR genes present (%)	Other comments	Reference
2019	South Africa	RTE foods	194 out of 239 (81.2%)	Amoxicillin (41%) Gentamicin (10%) SXT (15%) Ertapenem (36%) 162 isolates MDR	NT	Recommend adequate hygiene practices during food production and good storage to avoid spread of MDR Lm in RTE food	(52)
2019	India	Milk, soil, feed, sewage, beef	10 out of 474 (2.1%)	Penicillin (100%) Gentamicin (10%) No carbapenems or SXT tested	PCR revealed tetM in 70% isolates, 50% mefA, 40% msrA, 10% lnuA	Need to regularly monitor to ensure food safety and well-being of animals	(53)
2019 to 2020	South Korea	Raw beef, abattoir environment	15 out of 444 (3.4%)	Penicillin (53%) Gentamicin (0%) SXT (0%) No carbapenems tested	NT	Penicillin most frequently used in livestock farms, which could be causing the resistance	(54)
2019 to 2020	Zambia	RTE and re-heat meat products, dairy products	18 out of 304 (5.9%)	Penicillin (5.5%) SXT (5.5%) Meropenem (0%) Did not test for aminoglycosides	Intrinsic AMR genes detected, as expected	Stated the importance to improve hygiene conditions in food processing plants and to compare available WGS data for clusters with clinical strains	(55)
2019 to 2021	China	Raw chicken, goose, duck and pigeon	41 out of 236 (17%)	Penicillin (2.4%) Gentamicin (0%) SXT (0%) Imipenem (0%)	NT	Ab use in poultry farming warrants monitoring	(56)
2019 to 2021	South Africa	Beef and beef products	37 out of 400 (9.3%)	Penicillin (62.2%) Gentamicin (2.7%) STX (5.4%) Did not test for carbapenems	NT	89% Lm were MDR. High AMR and MDR in Lm from beef and beef products may enter human food chain and cause listeriosis with potential therapeutic failure	(57)
2019 to 2021	Spain	Food, clinical and animal isolates	NA; 132 Lm isolates analysed	Ampicillin (0%) Gentamicin (0%) SXT (0%) Meropenem (0%)	ermG, mefA and msrD present in 2 Lm strains (ERY res), aphA found in one Lm strain (aminoglycoside)	Although clinically relevant res not found in Lm, was found in Lspp - need for ab surveillance	(58)
2019 to 2022	Romania	RTE – dairy, bovine, poultry, pork and fish	26 out of 8,151 (0.3%)	Ampicillin (19%) Gentamicin (3.8%) SXT (27%) Did not test for carbapenems	NT	Needs to continue monitoring of AMR in food	(59)

Year of study	Country	Sampling source	Isolation rate (%)	Phenotypic antibiotic resistance (%)	AMR genes present (%)	Other comments	Reference
2019 to 2023	Poland	Sterile site clinical, meat dumplings, pielmieni, ravioli, smoked salmon, camembert	NA; 16 isolates analysed	Ampicillin (0%) Gentamicin (0%) SXT (0%) Meropenem (0%) However, resistance to CIP and TET seen	NT	Res seen in food isolates, not in clin isolates. Emergence of CIP and TET res requires surveillance in clinical isolates.	(60)
2019 [note]	Greece	Bulk tank bovine milk	5 out of 138 (3.6%)	Penicillin (100%) Gentamicin (0%) SXT (0%)	NT	Highlights importance to monitor Lm in farm animals	(61)
2019 [note]	China	Pig slaughter factory	37 out of 320 (11.6%)	Ampicillin (2%) Gentamicin (3%) No carbapenems or SXT tested	PCR revealed tetA 61%, tetM 45%, ermA 17%, ermB 14%, ermC 15%	Dominant ST5 Lm had high AMR and invasion characteristics, illustrating a potential risk	(62)
2020	Spain	Horsemeat	4 out of 19 (21%)	Ampicillin (100%) Gentamicin (0%) SXT (0%) Meropenem (50%)	NT	Horsemeat can be a source of multi-resistant bacteria	(63)
2020	South Africa	River and irrigation water	NA; 41 Lm isolates analysed	Ampicillin (100%) Gentamicin (32%) SXT (100%) No carbapenems tested	sulI 71%, tetA 63%, blaTEM 66%, blaOXA-1 17% covering sulfonamides, tetracyclines and aminoglycosides	Yes, clinically relevant resistance	(64)
2020	Jordan	Goat and sheep milk	116 out of 948 (14.4%)	Ampicillin (83.6%) Gentamicin (28.4%) No carbapenems and SXT tested	NT	Restrict the use of abs and chlorinate and monitor water sources for sheep and goats (sig factor in multivariable analysis)	(65)
2020 [note]	Egypt	Minced meat, fish fillet, sausage, milk	17 out of 250 (6.8%)	Amoxicillin (29%) Gentamicin (29%) SXT (76%)	NT	Recommend continuous education for food workers	(66)
2020 [note]	Saudi Arabia	Camel meat	8 out of 50 (16%)	Ampicillin (25%) SXT (25%) No carbapenems or GEN tested	NT	High susceptibility of Lm, possibly due to use of natural grassland to feed camels	(67)
2020 to 2021	Poland	Food and food processing environments	NA; 40 isolates analysed	Penicillin (2.5%) Gentamicin (intermediate 2.5%) SXT (12.5%) Meropenem (2.5%)	PCR: aadB in 1 isolate sulI in 4 and sulII in 2	Recommend monitoring virulence and antibiotic resistance of Lm from food and industry	(2)

Year of study	Country	Sampling source	Isolation rate (%)	Phenotypic antibiotic resistance (%)	AMR genes present (%)	Other comments	Reference
2020 to 2021	Egypt	Cattle, milk, faeces, environment	48 out of 360 (13.3%)	Penicillin (96%) Gentamicin (42%) SXT (100%) Imipenem (92%)	NT	The existence of MDR Lm represents a hazard to animal and human health	(4)
2020 to 2021	Poland	raw and processed meat and environment	NA; 153 Lm isolates analysed	Ampicillin (0%) Gentamicin (0%) SXT (0%) No carbapenems tested	NT	Limitation of paper: used own breakpoints to define sens or res, using different zone diameter to EUCAST	(68)
2020 to 2021	Zambia	Broiler chickens, and enviro swabs	NA; 17 Lm isolates analysed	Penicillin (35%) Gentamicin (9%) SXT (33%) Imipenem (0%)	NT	Yes, clinically relevant resistance	(69)
2020 to 2021	India	dairy products, juices and veg	2 out of 92 (2.2%)	Ampicillin (50%) Gentamicin (0%) SXT (50%) No carbapenems tested	NT	Important to increase hygienic measures and surveillance	(70)
2020 to 2022	South Korea	Pig carcass swabs and pig slaughterhouse swabs	22 out of 260 (8.5%)	Ampicillin (0%) Gentamicin (0%) SXT (0%) No carbapenems tested	NT	Continuous monitoring will be helpful in predicting food safety risks	(71)
2020 to 2022	China	12 food categories, including raw meat, fish, poultry, RTE meat, drinks, bakery products, veg, berries	46 out of 1,243 (3.7%)	Penicillin (6.5%) Gentamicin (2.2%) SXT (0%) No carbapenems tested	NT	Resistance to local foodborne Lm is relatively low, but emergence of PEN, AMP and GEN res, requiring monitoring	(72)
2020 to 2021, 2023	Serbia	Raw and pasteurised cheese, kajmak	6 out of 302 (2%) Lm 6 out of 302 (2%) L. spp	Penicillin (33%) Gentamicin (17%) SXT (17%)	NT	Maintain food hygiene throughout the production process	(73)
2021	Iran	Raw milk	NA; 47 Lm isolates analysed	Penicillin (97%) Gentamicin (51%) No SXT or carbapenems tested	No AMP genes found by PCR	Yes, clinically relevant resistance	(74)
2021	South Africa	Enviro samples, faeces and carcass	110 out of 990 (11.1%),	Penicillin (68%) Gentamicin (1%)	13 res genes detected. Tet(M) 30%, dfrG 8.2%, mphB 4.5%. 10 AMR gene patterns with 2-7 res genes per pattern.	High AMR gene presence for tet(M) and fosX in livestock suggests that use of Ab in husbandry should be reviewed	(75)

Year of study	Country	Sampling source	Isolation rate (%)	Phenotypic antibiotic resistance (%)	AMR genes present (%)	Other comments	Reference
		swabs, meat from beef	*L. innocua* only	SXT (8.2%) No carbapenems tested			
2021	South Africa	Beef production chain	60 out of 990 (6%)	NT	All 60 have fosX and vga(G) No acquired ARGs were detected	High AMR gene presence for fosX in livestock suggests that use of Ab in husbandry should be reviewed	(76)
2021	South Africa	Beef and beef-based products	NA; 24 Lm isolates analysed	NT	Only intrinsic ab genes detected in strains. Detected plasmids did not carry AMR genes	No resistance seen with first-choice Abs	(77)
2021	Germany	Fresh and frozen berries, and FNAO processing plants	8 out of 123 (6.5%)	Penicillin (100%) Gentamicin (12.5%) SXT (0%) No carbapenems tested	Using WGS, genes for PEN res not found, but fosX, mprF, lin and norB found in all 8 isolates	Periodical sampling could provide more insights	(78)
2021 to 2022	Turkey	Cattle carcasses and slaughterhouse enviro samples	89 out of 720 (12.4%)	Penicillin (2.2%) Gentamicin (5.6%) SXT (3.4%) Meropenem (2.2%)	NT	No resistance seen with first-choice Abs	(79)
2022 [note]	Spain and Portugal	Chicken mince	NA; 70 Lm isolates analysed	Ampicillin (0%) Gentamicin (5%) SXT (15%) No carbapenems tested	NT	Occasionally, treatment for listeriosis is undertaken with rifampicin, tetracycline, and chloramphenicol, which did see resistance	(80)
2022 to 2023	Turkey	Beef, fish, raw cow milk, cheese	39 out of 400 (9.8%), *L. innocua* only	Penicillin (41%) Gentamicin (2.5%) SXT (69.3%) Meropenem (2.5%)	NT	Non-pathogenic microorganisms can serve as reservoirs of potential resistance genes	(81)
2023	Turkey	Raw milk, curd, cream, butter, yoghurt, cheese	4 out of 185 (2.2%), L. spp only	Penicillin (0%) Gentamicin (100%) SXT (50%) Meropenem (25%)	NT	Not Lm, but resistance seen in other Lspp	(5)
2023 [note]	Mexico	Hass avocados, lettuce, parsley, cilantro, broccoli, cucumber	17 out of 132 (12.9%)	Ampicillin (100%) Gentamicin (0%) SXT (0%)	lde, tetM, msrA	High AMR due to inadequate use of agents in vet medicine and accumulation of residues in soil and irrigation wate	(82)
2023 [note]	Poland	raw meat, RTE food (meat), food production enviro	NA; 283 Lm isolates analysed	Ampicillin (0%) Gentamicin (0%) SXT (0%) No carbapenems tested	NT	Continued study of AR is required to select effective treatment for listeriosis [only studied serotype IIa and IVb Lm]	(83)

Year of study	Country	Sampling source	Isolation rate (%)	Phenotypic antibiotic resistance (%)	AMR genes present (%)	Other comments	Reference
2023 [note]	Spain	Poultry	15 out of 30 (50%)	Ampicillin (0%) SXT (20%) No carbapenems or GEN tested	NT	First line ab still sus, but an increase in AMR cft 1993 and 2006 - need to maintain correct hygiene practices in poultry processing	(84)
2023 [note]	Egypt	Poultry carcasses, hygiene swabs from handlers	24 out of 250 (9.6%)	Penicillin (70.9%) Gentamicin (29.1%) No carbapenems or SXT tested	NT	STREP, TET and B-lactams used in poultry production including growth promotion and prophylactic. Poultry can be vector for Lm disease in humans.	(85)
2024 [note]	Mexico	Seafood, past and raw milk, cheese, beef, chicken	17 out of 300 (5.7%)	Ampicillin (0%) Gentamicin (0%) SXT (78.9%) Meropenem (21%)	NT	Monitoring is recommended	(86)
2024 [note]	Italy	Meat products, seafood, dairy products, sauces, confectionary products, RTE rice dishes, food-processing	NA; 269 Lm isolates analysed	Ampicillin (45%) Gentamicin (1.5%) SXT (37.5%) Meropenem (13%)	NT	High level RES found - could pose a sig risk to public health. Info essential for prescribing treatment for listeriosis, due to evolving ab patterns	(11)

Abbreviations
NT = not tested
NA = not available
SXT = trimethoprim/sulfamethoxazole
AST = antimicrobial sensitivity testing
Lm = *Listeria monocytogenes*
AMR = antimicrobial resistance
RTE = ready-to-eat
[note] = year of publication; date of sampling not stipulated in original manuscript

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UKHSA is an executive agency, sponsored by the Department of Health and Social Care.

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Prepared by: Shona Neal
For queries relating to this document, please contact: fwe.nrl@ukhsa.gov.uk

Published: November 2026
Publishing reference: GOV-21487

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