Antibiotic-resistant E. coli on supermarket meat – a serious threat to human health

Summary

This briefing reports on the very high levels of antibiotic-resistant E. coli found in testing of British supermarket pig and poultry meat. Resistance was frequently found to three families of antibiotics that are particularly important for treating human E. coli urinary-tract and blood-poisoning infections.

The study, commissioned by The Alliance to Save our Antibiotics was carried out by scientists at Cambridge University. It looked at 189 UK-origin pork and poultry-meat samples from the seven largest supermarkets in the UK, ie. ASDA, Aldi, Coop, Morrisons, Sainsbury's, Tesco and Waitrose.

It found that 24% of chicken-meat samples tested positive for ESBL E. coli, a type of E. coli resistant to the 'critically important' modern cephalosporin antibiotics which are used for treating serious E. coli blood-poisoning and kidney infections.

A total of 51% of the E. coli from pork and poultry samples were resistant to the antibiotic trimethoprim, which is used to treat over half of lower urinary-tract infections (infections of the bladder). In addition, 19% of the E. coli were resistant to gentamicin, a very important human antibiotic widely used to treat more serious upper urinary-tract infections (infections of the kidney or the ureters[1]).

These findings are a major concern as scientific evidence increasingly suggests that the overuse of antibiotics in intensive farming is contributing, via the foodchain, to the increasing levels of resistance being found in human E. coli infections. While antibiotic consumption in human medicine is also a major reason for the increasing resistance, some scientists argue that the farm contribution is so important that for antibiotic-resistant E. coli, "We are what we eat".

Antibiotic resistance in human E. coli infections in the UK and across Europe has increased dramatically this century. The European Centre for Disease Prevention and Control has called the increase "remarkable". Higher resistance is leading to more treatment failures, record levels of serious blood-poisoning infections and increasing numbers of deaths.

Data from Public Health England shows that E. coli now kills more than 5,500 people a year in England alone, which more than twice as many people each year as MRSA and Clostridium difficile combined.

The Alliance study is the first comprehensive study of the levels of antibiotic resistance to key antibiotics in E. coli from UK supermarket meat. The findings add to the scientific evidence that some of the resistance to key antibiotics in human E. coli infections is of farm-animal origin.

[1] The tubes connecting the kidneys to the bladder.

As no genuinely new antibiotics have been for treating E. coli infections have been discovered for over 35 years, the need to protect the available antibiotics is now greater than ever. Supermarkets must now take urgent action to reduce antibiotic use in their supply chains, and publicly commit to polices which prohibit the routine mass-medication of groups of healthy animals and dramatically curb the use of antibiotics classified as critically important in human medicine.

1. Large and increasing burden of E. coli infections

E. coli is commonly present in the intestines of humans and other mammals, usually without causing any disease. Certain strains of E. coli, which have acquired an ability to produce toxins, can cause a serious form of food poisoning. E. coli food poisoning, however, is not usually treated with antibiotics.

However, extra-intestinal E. coli infections (non food-poisoning infections), particularly urinary-tract and blood poisoning infections, are far more common infections. E. coli can also cause meningitis in newborn babies and skin and soft tissue infections [1]. All of these types of extra-intestinal infections usually need to be treated with antibiotics.

Urinary-tract infections (UTIs), which are infections of the bladder and sometimes, kidneys, are the second most common infections (after respiratory infections), affecting up to 15% of women each year [2], and causing an estimated 150 million cases globally per year [4]. In the UK, approximately 70-80% of all UTIs are caused by E. coli [4], and over 700,000 cases of E. coli UTIs were tested for antibiotic resistance in 2014 [5]. The overall incidence of E. coli UTIs is likely to be significantly higher than 700,000, since many UTIs are not tested for antibiotic resistance if the infection is not complicated, and even when testing is done, the species of bacteria is not always identified [5].

High levels of antibiotic resistance in UTIs, can lead to treatment failure and the E. coli bacteria, via the kidneys, can get into the bloodstream and cause a bacteraemia (blood infection) [5][6]. According to Public Health England, the UTIs are the predominant underlying infection in over 50% of E. coli bacteraemia, and the level of antibiotic resistance in UTIs can therefore contribute to the number of bacteraemia [7][2].

Increasing resistance to key antibiotics is likely, therefore, to be a major reason for the ever increasing number of E. coli bacteraemia infections in the UK (another is the aging population). This has been confirmed by a 2012 Oxfordshire study which found that the increasing incidence of E. coli blood infections from 1999 to 2011 was essentially confined to resistant E. coli, whereas susceptible E. coli blood-poisoning infection rates were not changing. The increase in resistance was greatest around 2006-7, when there was a similar increase in resistance in urinary infections. The scientists concluded that the increasing resistance in E. coli blood poisoning infections was “alarming” [8].

Data compiled by the Alliance to Save Our Antibiotics from shows that in 2015, the number of E. coli bacteraemia infections in the UK reached 45,666, an all time high. See Table 1 and Graph 1.

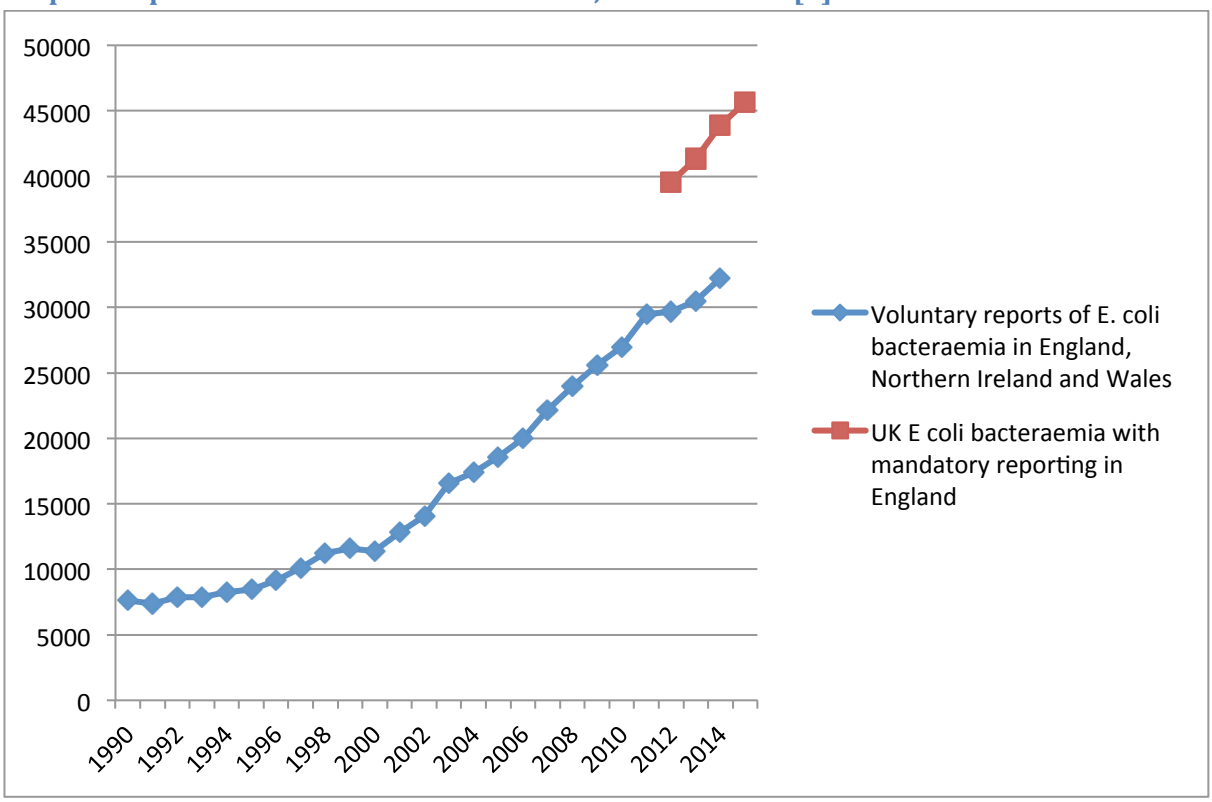
[2] Public Health England says: “Data from the mandatory surveillance of E. coli bacteraemia indicate that when underlying foci of infection are reported, the urogenital tract predominates, with over half of such reports listing this site. Hence, an understanding of the incidence and epidemiology of UTIs, together with an assessment of the proportion of such infections caused by antibiotic-resistant strains, may not only give greater insight into the burden of UTIs per se, but may lead to interventions that could impact on the occurrence of associated E. coli bloodstream infections” (ESPAR 2016)

Table 1 Number of E. coli bacteraemia in UK in 2015 [9]

England	Northern Ireland	Scotland	Wales	Total
37,273	1,486	4,596	2,311	45,666

The number of reported E. coli bacteraemia has increased nearly every year since 1990, when just 7,610 cases were reported in England, Wales and Northern Ireland[3], see Graph 1. The introduction of mandatory reporting of E. coli bacteraemia in England in June (up until then it had been voluntary) increased the number of reports by about 20% [10].

Graph 1 Reports of E. coli bacteraemia in UK, 1990 to 2015 [9]



2. E. coli is by far the largest bacterial cause of mortality in the UK

In March 2016, Public Health England published its first-ever report with statistics on 30-day mortality in England from several bacterial infections: E. coli, Clostridium difficile, MRSA (methicillin-resistant Staphlococcus aureus) and MSSA (methicillin-resistant Staphlococcus aureus) [11].

Existing data from the Office of National Statistics for MRSA and Clostridium difficile are based on death certificates, but as PHE points out, such statistics can be of a subjective nature. The PHE's data collection, on the other hand, simply records whether the patient died within 30 days of E. coli or S. aureus bacteraemia infection or of C. difficile infection, and involves no judgment as to the cause of death.

[3] In 1990, there were 7,610 reported infections and in 2015 45,666. However, reporting was voluntary until 2011. In June 2011, mandatory reporting of E. coli bacteraemia was introduced in England, and mandatory reporting has been introduced in Scotland in 2016.

Table 2 Thirty-day all-cause fatality subsequent to E. coli, MRSA and MSSA and bacteraemia and C. difficile infection, year to March 2015, England

E. coli	MRSA	MSSA	C. difficile
5,574	223	1,879	2,267

As can be seen from Table 2, E. coli bacteraemia is associated with far more mortality than the three other bacterial infections for which the PHE provides data. In fact total E. coli bacteraemia 30-day mortality is more than twice as high as C. difficile and MRSA combined.

Furthermore, the same PHE publication reports that while C. difficile and MRSA mortality is falling, E. coli bacteraemia mortality is increasing: see Table 3.

Table 3 Increasing 30-day day all-cause fatality subsequent to E. coli, England

2012/2013	2013/2014	2014/2015
5,243	5,348	5,574

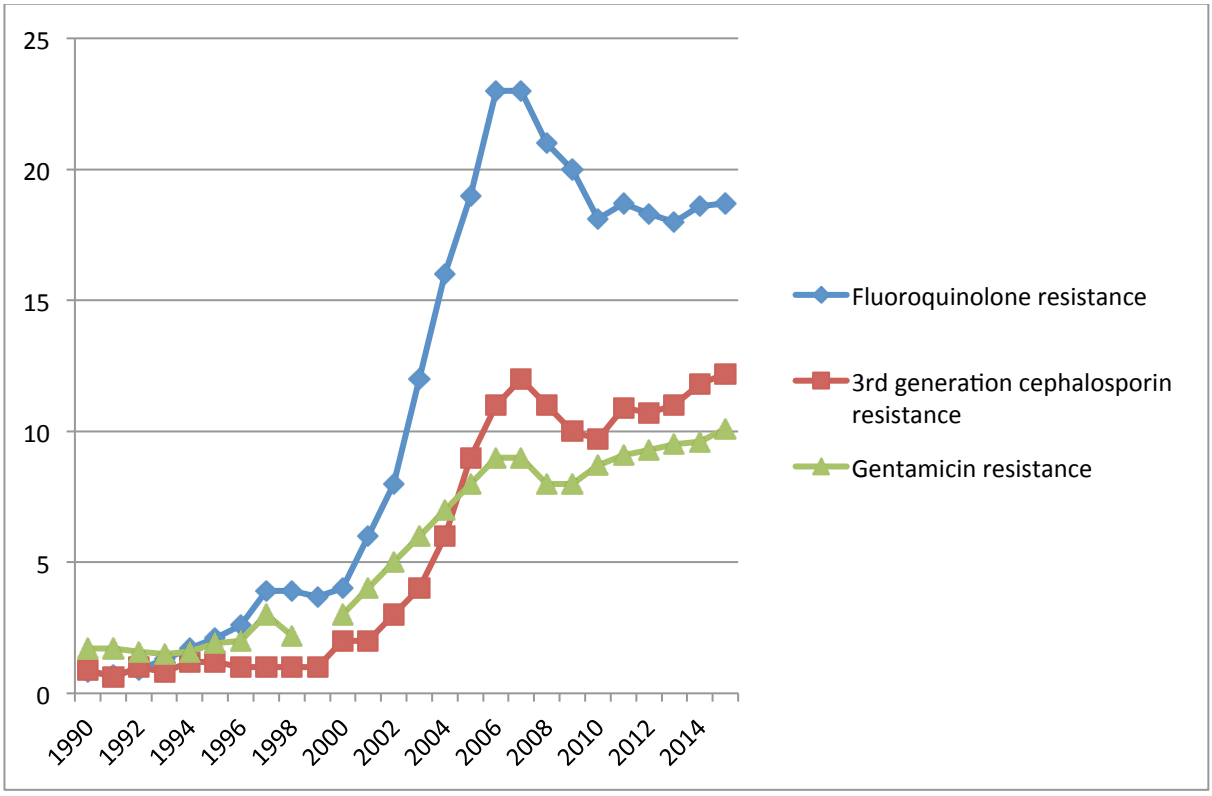
In Northern Ireland, Scotland and Wales there were 8,393 E. coli bacteraemia in 2015, in addition to the 37,273 in England (see Table 1). So, if we assume that the 30-day all-cause fatality rate for E. coli bacteraemia in the rest of the UK is similar to that in England (ie. 14.95%), it follows that approximately 1,255 fatalities will have occurred in the rest of the UK in 2015.

This means that the total number of deaths in the UK in 2015 within 30 days of an E. coli bacteraemia is likely to be well over 6,500.

3. Dramatic increase in antibiotic resistance of E. coli infections

Data collected by the former Public Health Laboratory Service and subsequently by the Health Protection Agency and then Public Health England show that resistance in E. coli blood-poisoning infections to some of the antibiotics most widely prescribed by hospital doctors for treating these serious infections has been increasing for past twenty five years, and has increased particularly sharply in the last fifteen years. See Graph 2.

Graph 2 Increasing rates of resistance (%) to key antibiotics in E. coli blood-poisoning infections in England, Wales and Northern Ireland [12]



Data on the levels of resistance in E. coli urinary-tract infections are not as readily available. However, in recent years Health Protection Scotland has published resistance rates, and some data has also been published by Public Health England. Table 4 summarises some of the data, and shows that resistance to trimethoprim is very high (about 35%), while resistance to modern cephalosporins, fluoroquinolones and gentamicin also occurs.

Table 4 Antibiotic resistance in urinary-tract infections in England and Scotland in 2014 [5][13]

	Modern cephalosporin	Fluoroquinolone	Gentamicin	Trimethoprim
England	5-7%*	11-13%*	unavailable	35-37%
Scotland	5.1	12	5.1	35%

*Figures read from a graph.

The lower levels of resistance found in UTIs compared with bloodstream infections is partly explained by the fact that the more highly resistant UTIs are more likely to develop into bloodstream infections.

Increasing resistance in E. coli infections has not been just a British phenomenon, but has occurred Europe-wide, and in many non-European countries. In 2010, the European Centre for Disease Prevention and Control (ECDC) described the ongoing increase in antibiotic resistance in E. coli infections as 'remarkable' [14], and the latest ECDC data shows that between 2011 and 2014 resistance to antibiotics like the modern cephalosporins, fluoroquinolones and gentamicin has remained at high levels or even increased further still [15].

4. Why antibiotic resistance threatens human health

The human-health consequences of antibiotic resistance can be severe, as frequently doctors have to treat before they know whether the bacteria are sensitive to the antibiotic chosen.

As explained by Professor David Livermore, formerly of the Health Protection Agency: "It takes two to three days to culture the blood and find out what it is sensitive to. So treatment is started blind, started empirically" [4].

He points out that if the antibiotic chosen is ineffective, the chances of dying are significantly increased: "There are numerous studies now to show that if you are given an ineffective antibiotic for a bacteraemia caused by one of these multi-resistant gram-negatives [such as E. coli][4] you are twice as likely to die as if you are given an effective antibiotic". He goes on to explain that this creates a pressure to use the last few effective antibiotics, such as the carbapenems, which in turn is increasing the rate at which resistance develops to these too.

Increasing resistance to modern cephalosporins and fluoroquinolones, both classified as critically important in human medicine by the World Health Organization, is a major health concern, as they have been standard treatments for E. coli kidney and blood infections [4]. Scientists are also extremely concerned about resistance to gentamicin, due to its importance in treating E. coli infections, and recently described the possibility that resistance might be transferred from farm animals as a "great concern" [16].

Although trimethoprim is only used for uncomplicated, lower urinary-tract infections, and not for blood infections, resistance to the antibiotic can still have a clinical impact: a study in West Gloucestershire showed that patients with UTIs caused by trimethoprim-resistant organisms had "significantly worse clinical outcomes than those with trimethoprim-susceptible organisms" [17]. Patients with resistant organisms had longer duration of disease (7 days versus 4 days), greater reconsultation, more subsequent antibiotics and higher rates of significant bacteriuria (bacteria in urine) at one month (42% versus 20%).

4. Resistance to key antibiotics found in E. coli from supermarket pork and chicken

The Alliance to Save our Antibiotics testing was carried out by scientists at Cambridge University.

It looked at 189 non-organic UK-origin pork and poultry meat samples from the seven largest supermarkets in the UK: ASDA, Aldi, Coop, Morrisons, Sainsbury's, Tesco and Waitrose. A total of 97 pork samples and 92 chicken-meat samples were tested.

E. coli bacteria were isolated from 186 (98%) meat samples.

A remarkable 24% of chicken-meat samples tested positive for ESBL E. coli (extended-spectrum beta-lactamase E. coli), a type of E. coli resistant to the modern cephalosporins (3rd and 4th generation cephalosporins). This was a fourfold increase on Alliance testing of 50 poultry-meat samples in 2015, which found just 6% of samples were positive for ESBL E. coli.

No pork samples tested positive for ESBL E. coli.

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[4] All bacteria are classified as Gram-positive or Gram-negative. E. coli, like salmonella, are Gram-negative. MRSA and Clostridium difficile, for example, are Gram-positive.

In addition, 19% of meat samples tested positive for resistance to gentamicin. Resistance was found in both chicken meat (20%) and pork (18%).

Resistance was highest, at 51%, for trimethoprim. This included a resistance rate of 52% for pork and 50% for chicken meat.

No resistance to fluoroquinolones or to the antibiotic colistin was found in any of the E. coli.

Full details of the retail-meat findings can be found in the Annex.

5. Resistance on meat is linked to farm antibiotic use

Some of these findings of resistance in E. coli on supermarket meat may, at first sight, appear surprising since, in the UK, modern cephalosporins are not licensed for use in poultry, although they are licensed for use in other farm-animal species. Furthermore, gentamicin is not licensed for use in any farm animals either.

However, even when particular antibiotics are not licensed for use in an animal species, under certain circumstances vets can be nevertheless be permitted to prescribe the antibiotics for use in that species "off label" when, in their judgment, this is the only way to treat animals or groups of animals effectively. This is the so-called 'prescribing cascade', where vets are required to first look to antibiotics licensed in the species in question for the condition being treated, then if no suitable antibiotics are available, to antibiotics licensed in that species but for other conditions, then to antibiotics licensed only in other animals and finally to antibiotics licensed only for human use.

Routine off-label prescribing of modern cephalosporins occurred in day-old chicks in many breeding flocks up until the end of 2011, when the British Poultry Council announced a voluntary ban on the use of the antibiotics [18].

The ESBL E. coli that emerged in poultry during the period when the modern cephalosporins were used can be maintained through the use of other beta-lactam antibiotics like amoxicillin: a Danish study showed that the use of amoxicillin in pigs exerted a selective pressure in favour of ESBL E. coli, even though it wasn't as large as that exerted by modern cephalosporins [19]. A similar effect is likely in poultry. Data on antibiotic use published this year by the British Poultry Council shows that amoxicillin is the most widely used antibiotic in poultry after the tetracyclines [20].

Nevertheless, BPC data shows that total antibiotic use by their members, who represent about 90% of poultry-meat production in the UK, has fallen significantly in recent years, by 44% between 2012 and 2015. The increase in the incidence of ESBL E. coli is therefore unexpected, although the presence of the resistant bacteria is not.

Although gentamicin is not licensed for use in farm animals in the UK, it too could possibly be used off-label. In particular, it could be used in day-old chicks as a replacement for the modern cephalosporins, since modern cephalosporins and gentamicin are the two types of antibiotics known not to harm the Marek's vaccine given to day-old breeding birds [21]. However, the Alliance have been told that this is unlikely to be happening in the UK and we have no evidence it is happening.

On the other hand, aminoglycoside antibiotics (gentamicin is an aminoglycoside) are very widely used for mass medication in British farm animals: about 20 times more aminoglycosides are used for

in veterinary medicine than in human medicine in the UK [22], and it is likely that such use is contributing to the spread of gentamicin resistant E. coli. The use of the veterinary aminoglycoside, apramycin, is known to be the cause of the emergence of a particular type of apramycin/gentamicin resistance [16][23][24], and the use of this antibiotic for mass medication may partly explain the levels of gentamicin resistance found.

Trimethoprim, is commonly used to mass-medicate whole groups of animals via their feed or water, and significantly more trimethoprim is used in animals than is used in human medicine. The government's One Health report published in 2015 showed that the total use of trimethoprim and sulphonamides (antimicrobials often given in combination with trimethoprim, particularly in farming) was more than three times higher in veterinary medicine than in human medicine [22].

An alternative explanation for the presence of antibiotic-resistant bacteria on supermarket meat might be human contamination at the abattoir. However, contamination on this scale appears highly unlikely. Furthermore, studies carried out on E. coli taken directly from the animals have in the past found high levels of resistance to many of these antibiotics [25].

The absence of any fluoroquinolone-resistant E. coli is surprising as fluoroquinolones are used in farm animals. According to the British Poultry Council, use of fluoroquinolones in broilers was cut by 96% in 2015 by its members [20], so this may partly have contributed to the lack of resistance.

6. Evidence that resistance in human infections is linked to farm antibiotic use is growing

It is increasingly being said that antibiotic resistance is the "quintessential One Health issue" [26]. As explained in a recent scientific review article, the One Health approach "recognises that the health of people is connected to the health of animals and the environment. Antimicrobial resistance has clear links to each of these three domains" [26].

The authors of the review also said "misuse of antimicrobials in animal production is a clear and substantial driver of antimicrobial resistance, and there is a growing body of evidence linking antimicrobial consumption in livestock to antimicrobial resistance in the clinic" [26].

The Antimicrobial Resistance Review, appointed by then Prime Minister David Cameron, and chaired by the economist Jim O'Neill, published a report in 2015 on the topic of farm antibiotic use and resistance in human medicine [27]. It reviewed 139 scientific papers by academics and found that 72% supported a link between farm antibiotic use and resistance in human medicine, whereas only 5% opposed such a link. The review said this suggests that "antibiotic use in animals is a factor in promoting resistance in humans and provides enough justification for policy makers to aim to reduce global use in food production to a more optimal level".

Historically, the strongest evidence for resistance transfer from farm animals to humans has been for food-poisoning bacteria like Salmonella and Campylobacter, and in 2008 the European Food Safety Authority (EFSA) said that most resistance in human infections caused by these bacteria is in fact of farm-animal origin [27]. However, there has also long been evidence that resistance in human E. coli infections was partly of farm-animal origin, and the same EFSA reported said that for E. coli that it was "highly probable that food is a vehicle for the spread of resistance genes".

A review article published in 2015 by a Danish government scientist argued that for antibiotic-resistant E. coli, the livestock reservoir "has a more significant impact on human health than was estimated 10 years ago" [29]. An Australian scientist has warned that the evidence now suggests that for antibiotic-resistant E. coli "we are what we eat" [30].

Part of the reason why it is taking scientists longer to determine where resistance in E. coli is coming from in comparison with Salmonella and Campylobacter is because we all have resident E. coli in our intestines, which usually do not cause disease, but can do so in some people if, for example, they become established in the urinary-tract. This makes it more complicated to determine where an E. coli causing disease has come from: food, or our own resident population? It has also been known since the 1960s that farm-animal strains of E. coli can transfer their antibiotic resistance to resident human E. coli in the human gut, through a process called "horizontal gene transfer"[5] [31]. This means that even when ingested farm-animal E. coli do not become established in the intestines or go on to cause infection directly, they may nevertheless survive in the gut for long enough to pass on their resistance genes to the resident E. coli bacteria.

The recent emergence of resistance to colistin, an antibiotic of last-resort in human medicine, in bacteria, including E. coli, in farm animals and humans, is an example of this complexity. The new resistance gene, called mcr-1 ("mobile colistin resistance 1"), is a mobile gene which can move between different strains [32][33]. Scientists believe it is likely that the main reason for the emergence of colistin resistance in human infections is linked to the widespread use of the antibiotic in farming. This is partly because it is used much more widely in farming than in human medicine: in China, for example, where the mcr-1 gene was first found in human and animal E. coli, it is not yet used at all in human medicine, so there is no other credible explanation for its emergence. Furthermore, other known veterinary-origin genes have been found on some of the mobile genetic elements, called plasmids[6], that carry the mcr-1 gene between bacteria [34].

Similarly, numerous studies have been carried on comparing the strains of ESBL E. coli in found in humans with those found in farm animals, as well as their resistance genes and their resistance plasmids. While new findings are still being published, at present many scientists believe that the evidence suggests that ESBL resistance genes and resistance plasmids are likely to be transferred between farm-animal and human E. coli, possibly in both directions [24][35][36][37], whereas the E. coli that actually cause the infection are more likely to be of human-origin. Some major ESBL E. coli strains, like E. coli ST131, are also believed to be due to human antibiotic use alone, and there is only limited evidence of an animal link.

The links between the use of the veterinary aminoglycoside antibiotic apramycin and resistance to the human aminoglycoside antibiotic gentamicin are well established. Apramycin was licensed for veterinary use in the UK in 1980, and by 1983 the first-ever case of highly apramycin-resistant E. coli was found in humans in the UK [38][39]. Highly apramycin resistant E. coli possessed a new gene,

[5] 'Horizontal gene transfer' between bacteria occurs when donor bacteria, carrying a particular gene, make more copies of the gene and transfer them to other bacteria. If the gene is, for example, an antibiotic-resistance gene, the receiving bacteria become antibiotic-resistant.

[6] Plasmids are small pieces of DNA in bacteria, which are separate from the bacterial chromosome. Plasmids often carry antibiotic-resistance genes, such as ESBL genes, and can replicate inside the bacteria, and copies of the plasmid, with its resistance genes, can be passed by horizontal gene transfer to other bacteria, thus spreading the resistance.

called AAC(3)IV, which also made the bacteria resistant to gentamicin. By 1994, scientists working for the then Central Public Health Laboratory found that 27% of gentamicin-resistant E. coli from humans were apramycin-resistant, produced the AAC(3)IV enzyme, and their apramycin resistance gene was on a transferable plasmid. They concluded that their findings 'support the view that resistance to gentamicin and apramycin in clinical isolates of E. coli results from the spread of resistant organisms from animals to man, with subsequent inter-strain or inter-species spread, or both, of resistance genes on transferable plasmids [40]. In 1986, French scientists had found similar results after apramycin was introduced into French farming in the early 1980s [41].

In addition to antibiotic-resistance genes being transferred from farm-animal E. coli to E. coli which cause disease in humans, scientists are also uncovering increasing evidence that some farm-animal E. coli may directly cause infections in humans, including blood poisoning, urinary-tract infections and meningitis. E. coli are the most common bacterial pathogen in poultry, and extraintestinal E. coli infections in poultry, such as colibacillosis, are a frequent occurrence in intensively farmed birds. These are caused by E. coli strains referred to collectively as 'avian pathogenic E. coli' (APEC). Studies have compared APEC with E. coli causing urinary-tract infections in humans using a typing method known as multilocus sequence typing (MLST). One American study found that at least some of them are highly similar, and the scientists concluded that their data 'supports the possibility that a food-borne link between some APEC and uropathogenic strains exists' [41]. A German study found that faecal E. coli from chickens, which were most virulent in chicken-infection experiments, belonged to MLST sequence types that were almost exclusively associated with extraintestinal diseases not only in birds but also in humans (this included diseases like septicemia, urinary-tract infection, and newborn meningitis). They concluded that some faecal E. coli strains from chickens can infect humans [43].

American researchers also compared APEC strains from poultry with E. coli which had caused meningitis in newborn babies. They found that 'they were not easily differentiated on the basis of multilocus sequence typing, phylogenetic typing, or carriage of large virulence plasmids', and that using a rat model of human neonatal meningitis, some of the APEC strains were able to cause meningitis. They concluded that some findings supported the hypothesis that some, but not all APEC strains had 'zoonotic potential', ie. they can be passed from animal to human and cause disease in humans [44].

A series of studies published by Danish scientists has provided "solid evidence" and even "proof" that E. coli urinary-tract infections are sometimes a zoonosi (a disease which can be transmitted to humans from animals) [45][46][47][48][49][50]. The studies involved comparing strains found in farm animals, with those in human infections, and found that some of them were "clonally related". They suggest "contaminated meat" may be the source of some of these E. coli.

The occurrence of outbreaks of urinary-tract infections caused by a single E. coli strain, with unrelated people being affected, sometimes over a large geographical area, has also led many scientists to suspect a foodborne origin for at least some of these infections [50][52]. The likelihood of some UTIs being foodborne as been described by American scientists as "a new paradigm for antimicrobial-resistant foodborne illness", although they say that further research is required to accurately quantify the food contribution to antibiotic resistant UTIs [53]. A recent review article said that there was now "compelling" evidence linking E. coli from poultry meat to human UTI, and

said that E. coli pork might also be implicated, but not E. coli from other meats. It concluded by saying that “If the increase in antimicrobial-resistant extraintestinal infections caused by E. coli is attributable to the introduction of new multidrugresistant ExPEC [Extraintestinal pathogenic Escherichia coli] lineages through contaminated food product(s), then the relevance to public health, food animal production and food safety would be significant” [54].

Further evidence for a link between farm antibiotic use and resistance in human E. coli infections has been provided by scientists from Australia, Denmark and Canada who analysed the association between resistance to four antibiotics, or families of antibiotics, in E. coli from pigs, poultry and cattle and E. coli from blood-poisoning infections in humans. They also compared rates of resistance in the human bacteria, with antibiotic usage in humans in the different countries. The antibiotics examined were ampicillin, aminoglycosides, 3rd generation cephalosporins and fluoroquinolones. In all four cases, they found strong and statistically significant correlations between resistance rates in E. coli from poultry and resistance rates in E. coli from humans, as well as similar strong and statistically significant correlations for ampicillin, aminoglycosides and fluoroquinolones for the pig and human E. coli. For cattle, only resistance to ampicillin was statistically significantly correlated with resistance in humans. Human antibiotic use was only significantly correlated to human resistance rates for the fluoroquinolones and the 3rd generation cephalosporins.

They concluded ‘these findings exclude [human] antimicrobial usage as the only explanatory variable for the observed resistances in E. coli from humans. They suggest that, in addition to the contribution of antimicrobial usage in people, a large proportion of resistant E. coli isolates causing blood-stream infections in people are likely to be derived from food animal sources’ [55].

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Annex: Findings from antibiotic resistance testing of supermarket pork and chicken meat

Samples

In total 189 samples were tested. Of these 174 were from England, from London, the South of England, the South-West of England, the Midlands, and the North-East. A further 15 samples were tested from Scotland.

The meat tested included 97 pork samples (chops, loin, steak, belly, shoulder, mince, rashers and sausages) and 92 chicken samples (whole, legs, thighs, drumsticks, breasts, sausages). Samples were non-organic.

The supermarkets were the seven largest supermarkets in the UK: ASDA, Aldi, Coop, Morrisons, Sainsbury's, Tesco and Waitrose.

A total of 27 samples were bought from each supermarket chain.

Testing carried out

All meat samples were tested for resistance to:

- beta-lactam antibiotics (including ampicillin, amoxicillin and several cephalosporin antibiotics)
- ciprofloxacin (a fluoroquinolone antibiotic)
- aminglycoside antibiotics (including gentamcin)
- colistin (a polymixin antibiotic)
- carbapenem antibiotics (human-only antibiotics)
- trimethoprim
- tigecycline (a human tetracycline).

Presence of E. coli on meat samples

E. coli was found 186 of 189 samples (98%).
E. coli was found on all 92 chicken samples (100%) and on 94 of 97 (97%) pork samples.

Resistance found

Resistance to modern cephalosporins (ESBL resistance)

Modern cephalosporins are classified by the World Health Organization as critically important in human medicine and are used for treating human E. coli blood-poisoning infections and upper urinary-tract (kidney) infections.

E. coli resistant to modern cephalosporins (3rd and 4th generation cephalosporins) are called ESBL E. coli (extended spectrum beta-lactamase E. coli).

Of the 92 chicken samples, 22 tested positive for ESBL E. coli (24%). No pork samples tested positive for ESBL E. coli.

ESBL-positive samples were found from all supermarkets:

- 5 from ASDA
- 4 each from the Coop and Sainsbury's
- 3 from Aldi
- 2 each from Morrisons, Tesco and Waitrose.

ESBL positive samples included chicken thighs, legs, drumsticks, diced breasts, wings and sausages.

In total 134 of 189 (71%) of all meat samples had antibiotic-resistant E. coli.

- 61 of 97 (63%) of pork samples had antibiotic-resistant E. coli
- 73 of 92 (79%) of chicken meat samples had antibiotic-resistant E. coli.

Scotland-only results:

15 samples, 9 chicken, 6 pork

100% had E. coli
2 of 9 chicken samples had ESBL E. coli (22%)
No pork samples had ESBL E. coli
2 of 15 meat samples had gentamicin-resistant E. coli (13%)
3 of 15 meat samples had trimethoprim-resistant E. coli (20%)
7 of 15 meat samples had E. coli resistant to at least one antibiotic (47%)

England-only results:

174 samples, 83 chicken, 91 pork

171 (98%) samples had E. coli
20 chicken samples had ESBL E. coli (24%)
No pork samples had ESBL E. coli
33 of 174 meat samples had gentamicin-resistant E. coli (19%)
94 of 174 meat samples had trimethoprim-resistant E. coli (54%)
127 of 174 meat samples had E. coli resistant to at least one antibiotic (73%)

Gentamicin resistance

Gentamicin is very widely used for treating E. coli upper urinary-tract infections in humans.

In total 35 meat samples (19%) were positive for gentamicin-resistant E. coli.

This included 18 of 92 (20%) chicken-meat samples and 17 of 97 (18%) pork samples.

Gentamicin-resistant E. coli was found on meat from all supermarkets:

- 9 from Tesco
- 7 from Aldi
- 6 from Waitrose
- 4 each from ASDA and the Coop
- 3 from Morrisons
- 2 from Sainsbury's.

Trimethoprim resistance

Trimethoprim is the most common treatment for lower E. coli urinary-tract infections in humans, used in over 50% of cases.

In total 97 (51%) meat samples were positive for trimethoprim-resistant E. coli.

This included 50 of 97 (52%) pork samples and 47 of 92 (51%) chicken-meat samples.

Trimethoprim-resistant E. coli was found on meat from all supermarkets:

- 16 from ASDA and Morrisons
- 14 each from the Coop and Tesco
- 13 each from Aldi and Sainsbury's
- 11 from Waitrose.

Resistance to other beta-lactam antibiotics

Ampicillin used to be routinely used for treating human urinary-tract infections, but is no longer used because of high levels of resistance. Similarly, amoxycillin is being undermined as a suitable treatment for urinary infections due to resistance. As a result, amoxicillin is often given in combination with clavulanic acid which helps combat the bacterial resistance.

In total 54 (29%) meat samples were positive for ampicillin-resistant E. coli.

This included 33 of 92 (36%) chicken-meat samples and 22 of 97 (23%) of pork samples.

Just one chicken-meat sample was fully resistant to amoxicillin/clavulanic acid, and one further chicken-meat sample showed intermediate-level resistance.

No resistance found to fluoroquinolones, carbapenems or colistin

Fluoroquinolones are classified by the World Health Organization as critically important in human medicine, and are a treatment for E. coli infections, although efficacy is being undermined by rising levels of resistance.

Carbapenems are antibiotics used only in human medicine, which are used for treating highly resistant E. coli blood-poisoning infections.

Colistin is a last-resort antibiotic used for treating highly resistant E. coli blood-poisoning infections. It is used for mass medication in pigs and poultry. However, it is not nearly as widely used in UK farming as it is in many European countries.

No resistance was found to any of these antibiotics in E. coli from supermarket meat.