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Foodborne antimicrobial resistance (AMR) research and surveillance in the UK: priorities identified through the Food Standards Agency's AMR programme review (2023)

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The significance and burden of antimicrobial resistance (AMR) has been well documented. The 2016 O'Neill report highlighted the enormous risk that AMR poses to human health and made recommendations to address this global challenge [1]. The report prompted the UK's 20 year vision for AMR [2], highlighting how the UK will contain and control antimicrobial resistance by 2040. Alongside this vision, a 5 year National Action Plan (NAP) [3], 2019–2024, was created; laying out how government departments would deliver co-ordinated action to mitigate the impact of AMR.

Since its formation in 2000, the Food Standards Agency (FSA) has funded AMR research and surveillance to understand the impact and burden of AMR in the food chain and promote good hygiene practices to reduce consumers' exposure to pathogens and AMR via food. The FSA's AMR Research and Evidence Programme, guided by the Areas of Research Interest [4], continues to commission AMR-related research and surveillance to generate evidence and meet its departmental commitments in the UK's AMR NAP (the FSA is the lead department for AMR in food). Given the extensive portfolio of work completed by the FSA's AMR programme (all publications available on food.gov.uk) and the completion of the current NAP, the FSA held a 2 day event to firstly, review the work completed under its AMR programme, and secondly, to identify and prioritise new and emerging challenges in food-related AMR, with the express intention of informing the new NAP 2024–2029.

This article outlines the areas identified and prioritised from the Programme Review event, which was attended by government experts, academics, and other specialists in the field of food-related AMR research and surveillance and included presentations and breakout discussions to prioritise future work (more information on the FSA's AMR programme can be found on the website: Antimicrobial resistance | Food Standards Agency). The theme for day one was 'surveillance', in which experts were provided with a list of retail food types to vote on, but also had the option to suggest categories not listed. The theme for day two was 'research' in a free format, to enable open discussion.

Continued surveillance on poultry meat, specifically chicken and turkey, was identified as the top priority (Fig. 1). Whilst data collected by the FSA from 2016 to 2020 shows a decrease in antimicrobial-resistant *E. coli* contamination of chicken [5, 6], the group felt this food product, due to high production and consumption, required further surveillance to track any future changes. This would also improve understanding as to why certain AMR-carrying organisms, and particularly *E. coli,* were persisting. Fresh produce was ranked second, primarily due to challenges in agricultural practices and the risk of AMR spread, particularly when the product is consumed uncooked. Fish, followed by beef, pork and lamb were next in the priority order. The increasing concern over farmed fish has been driven by evidence from the recent VARSS report (2020) [7], that has highlighted an increased use of antibiotics in salmon farming in recent years. Raw pet food was ranked as the fifth highest priority area, especially due to the increased popularity of raw pet food and the potential risk this product poses to human health due to handling. The FSA is currently running a raw pet food survey [8]. Bivalve molluscs and crustacea were identified as priority six and seven, respectively. Other food categories that received a lower number of votes included other poultry (e.g. duck and other game birds), minced meats, offal, dairy, animal feed, animal-free alternatives (e.g. plant-based vegetarian/vegan products), imported foods, especially where antimicrobials, including antibiotics, are routinely sprayed on crops (e.g. citrus trees), game ruminants and ready-to-eat (RTE) foods.

The FSA started a rolling surveillance programme to monitor AMR in 2015. This has primarily focused on meat on retail sale, which established baselines and provides monitoring data of AMR trends. A key finding has been a significant reduction of

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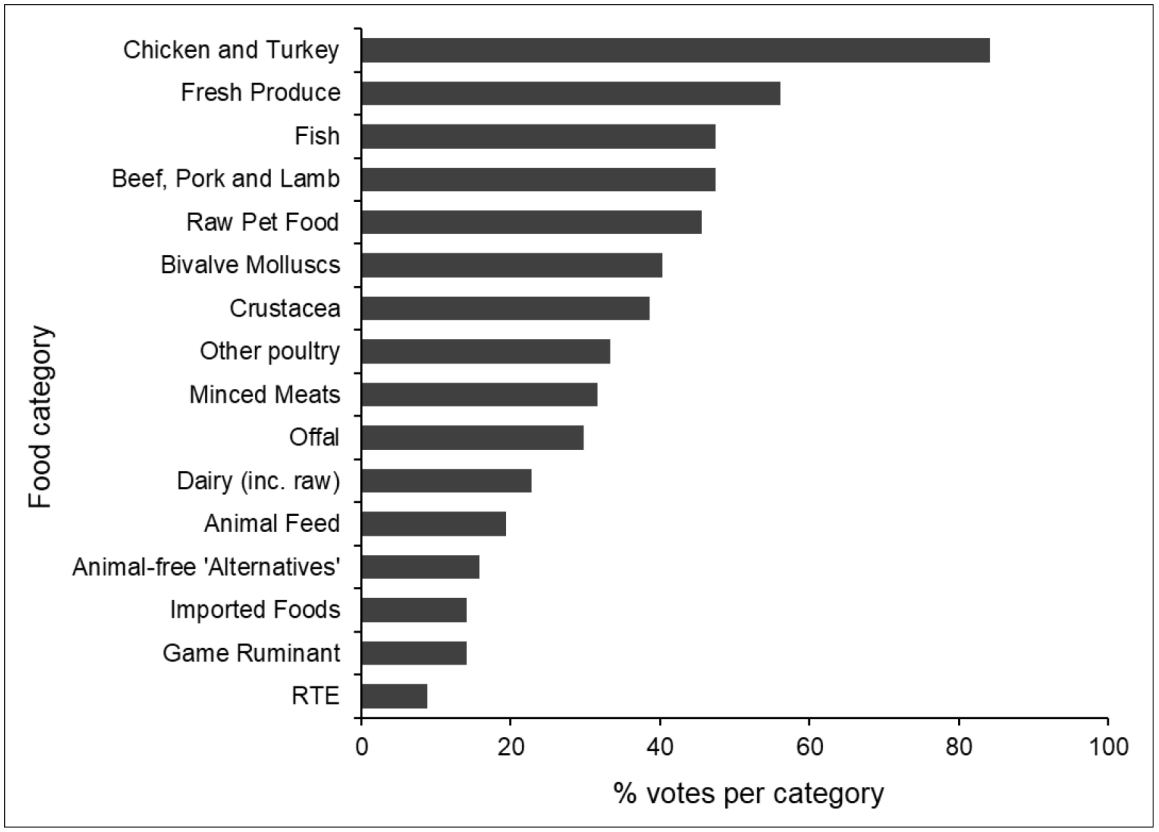

Fig. 1. Prioritised surveillance of antimicrobial resistant food categories at retail. Each expert had a total of five votes and could vote on each food category once. The figure displayed represents the percentage of total votes each category could receive. A total of 57 experts voted during the surveillance session.

ESBL/AmpC-producing *E. coli* detected in fresh UK chicken at retail (45% in 2016, 13% in 2020) [5], suggesting that tighter controls on antimicrobial usage, including antibiotic usage in the poultry industry, is reducing AMR in retail chicken. Beef, pork and lamb have also been included in previous FSA surveys with the prevalence of ESBL/AmpC *E. coli* being very low [9, 10].

Under the theme of 'research', the breakout sessions were less prescriptive to enable open discussion and were followed by experts voting on discussed areas (Fig. 2). There was some overlap between the identified themes and topics. Most votes centred around the need for cross-government capability and use of genomic technologies, and improved sharing of datasets and harmonisation of analysis methods, that would enable collaborative analysis of sequencing datasets. Omics has and will continue to advance AMR research, and with the emergence and potential use of artificial intelligence in the AMR field, the sharing of datasets generated by these technologies can enable a cross-government approach to interrogating data at a greater level. This is particularly true for adopting a genuine 'One Health' approach to tackling AMR, with a better focus on the agri-food-environment system and how that then interacts with human health.

The application of genomics would further our understanding of the uptake and flow of AMR genes from the environment and farming through to humans (via the food chain); this topic was the third top research priority – understanding the movement of genetic material and associated critical factors would provide better evidence-based control of AMR spread. Omics also has utility in understanding the co-selection factors for AMR (ranked fourth), along with understanding the link between AMR genotype and phenotype (seventh). The use of social science to understand and track awareness and behaviours including interventions such as hygienic food handling to prevent the spread of AMR was ranked fifth. The use of modelling to predict the spread of AMR through microbial communities and to identify evidence gaps was eighth. Other topics fell broadly into the environment category. These included the need to research the implications of changing farming practices, particularly the impact of these practices on fresh produce, the effect of climate change that could increase the AMR load on imported foods (mainly seafood), and the impact of increasing frequency of extreme weather events, resulting in discharge of raw sewage into surface waters and flooding. Other areas discussed included the shift in human dietary habits

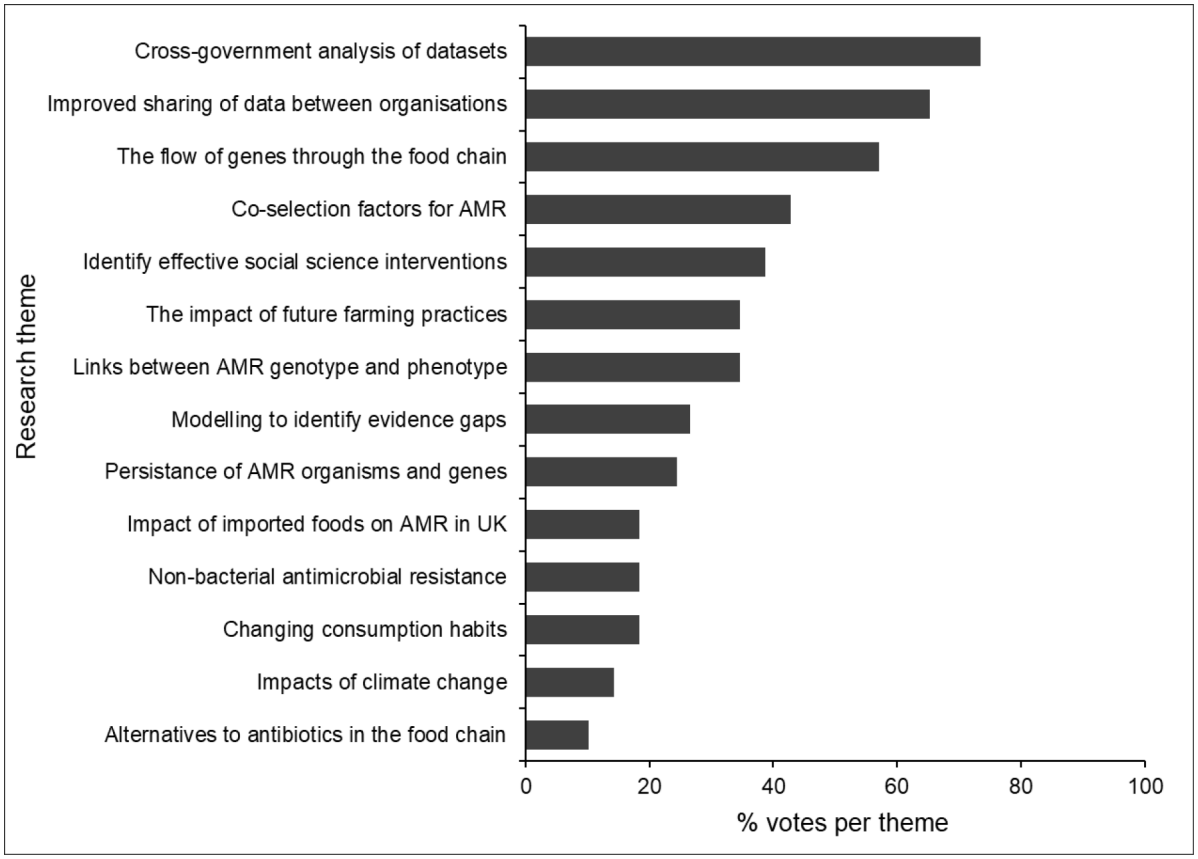

Fig. 2. Prioritised AMR food research themes. Each expert had a total of five votes and could vote on each research theme once. The figure displayed represents the percentage of total votes each category could receive. A total of 49 experts voted during the research session.

(e.g. increased vegetarian/vegan foods), AMR that is encoded by organisms other than bacteria, and the impact of using alternatives to antimicrobials and particularly antibiotics.

To date, FSA's research has focussed on several areas, including the potential transfer of AMR bacteria during the processing of chicken meat [11], understanding the burden of AMR in ready-to-eat foods [12], developing tools to help quantify the risk of AMR exposure via chicken and lettuce [13] and surveying food handlers' awareness of AMR. Furthermore, FSA leads the Pathogen Surveillance in Agriculture, Food and the Environment (PATH-SAFE) programme [14], a £19.2 m Shared Outcomes funded programme (2022–2024), which has developed a four-nation, cross-government 'One Health' approach to tackle issues relating to foodborne disease (FBD) and AMR and has collaborations across government, academia and industry. PATH-SAFE aims to pilot a national surveillance programme for FBD and AMR using whole genome sequencing (WGS) and environmental sampling, aligning closely to the existing AMR NAP, and contributing to the development of the new NAP. Better data sharing is core to PATH-SAFE's goals.

To summarise, the independent experts (who were invited to assess the AMR programme) concluded that the FSA has delivered against its NAP commitments to strengthen the evidence around AMR in the food chain. The AMR programme review was timely given the next AMR NAP is in development and the outputs from the review's prioritisation exercise provided a collective expert opinion to inform the development of the next set of food commitments and deliverables in the 2024–2029 NAP. The FSA will continue to play a strong role in the AMR space and will strengthen cross-governmental and research community coalitions, to better align and deliver AMR agri-food-environment priorities, and build on existing networks, such as those developed under PATH-SAFE.

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Conflicts of interest
The authors declare that they have no competing interests.

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