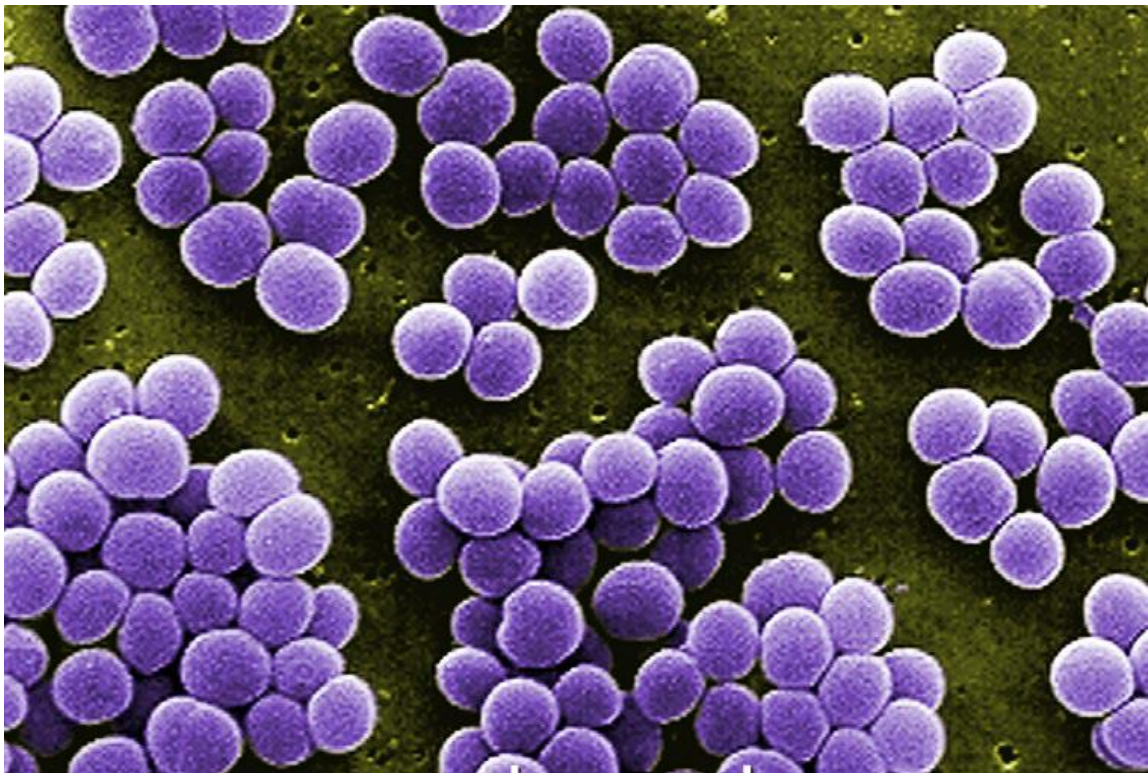# Evaluation of the implementation of the UK Antimicrobial Resistance Strategy in the Food Chain

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Acronyms

AB	Antibiotic
ABR	Antibiotic resistance
ABU	Antibiotic use
AHDB	Agriculture and Horticulture Development Board
AMR	Anti-Microbial Resistance
APHA	Animal and Plant Health Agency
BVA	British Veterinary Association
CVMP	Committee for Medicinal Products for Veterinary Use (of the EMA)
DEFRA	Department of Environment, Food and Rural Affairs
DfID	Department for International Development
DH	Department for Health
EC	European Commission
EMA	European Medicines Agency
FAO	Food and Agriculture Organisation of the United Nations
FSA	Food Standards Agency
HCAI	Healthcare Associated Infections
ILRI	International Livestock Research Institute
NHS	National Health Service
OIE	World Organisation for Animal Health
PCU	Population-corrected Unit
PHE	Public Health England
RUMA	Responsible Use of Medicines in Agriculture Alliance
VMD	Veterinary Medicines Directorate (executive agency sponsored by DEFRA)
WHO	World Health Organisation (United Nations)

Executive Summary

Background

The Policy Innovation Research Unit (PIRU) was commissioned to undertake an evaluation of the implementation of the UK Antimicrobial Resistance (AMR) Strategy 2013-2018 and evidence underpinning the key mechanisms of change, with a view to contributing to the refresh of the Strategy taking place in 2018. This report offers findings from interviews with policy officials and professionals involved in implementation of the Strategy in the animal source food chain, undertaken in order to explore national and international policy level responses to the AMR Strategy initiatives within the food chain, to understand workings of the Strategy in a governance context.

Methods

This report primarily draws on 15 semi-structured interviews conducted in summer and autumn of 2017 with informants based in organisations selected as relevant to animal source food chains. This comprised staff from 8 UK organisations and 7 European/international organisations, including government departments, international bodies and independent sector organisations. These were supplemented with 6 interviews conducted as part of other data collection within the wider PIRU evaluation of the implementation of the UK AMR Strategy that had sections relevant to food chains. Publically available reports and websites, as well as the *Overview of evidence of antimicrobial use and antimicrobial resistance in the food chain*, prepared as part of the PIRU evaluation, informed the context and the analysis.

Findings

The 2013-18 AMR Strategy was described as focusing predominantly on domestic work but respondents commented on the international and global nature of the AMR challenge and suggested putting more emphasis on the international dimension of the refreshed Strategy and actions to address AMR.

The UK was described as a global leader in addressing AMR in the food chain, with the Strategy being seen as a fundamental part of this response. Informants stated that the UK must maintain the pressure for continued action across sectors and its international prominence on the issue by developing its work and increasing action. This was of particular concern to informants given the hard to predict potential impacts of Brexit, both in the sense of a risk of reduced collaboration between the UK and the European Union and reduced authority of the UK as a lone voice if it were to become more internationally isolated.

Respondents observed a relative lack of research and data on AMR and AMU within the livestock sector, including a lack of consistency around measurements, compared with human health. In particular, informants commented on the lack of integrated surveillance systems i.e. systems that conduct surveillance planning and implementation, or use of surveillance outputs across relevant sectors, which inform and measure the implementation of the goals in the UK AMR Strategy. Surveillance systems were deemed essential to track progress, but also aid livestock sectors and individual producers to assess and compare their own progress and actions on ABU against others, for comparison and motivation. Furthermore, an evidence gap was described regarding the environmental and ecosystem factors that contribute to the emergence, sustaining and spread of AMR, particularly on farms.

Informants explained that each animal sector had been developing and implementing its own changes in antibiotic use (ABU) with a bottom-up approach. This was described as effective and should be encouraged to continue. However, respondents believed that in the future, the focus should shift

further to improving animal health through better husbandry and production practices, thereby reducing the need for and reliance on antibiotics. These changes will require support from industry and government to achieve as economic investments are likely to be considerable.

While progress in One Health collaboration, in particular between human and animal health, was praised, respondents felt that a One Health approach needed to become more embedded in the Strategy and that there is some way to go to harmonise activities. Informants claimed that there needed to be greater consensus and collaboration across sectors on the main areas of concern within AMR, bringing together human medicine, public health, food, veterinary medicine, agriculture and environmental agencies.

1　Introduction

1.1　Background

The UK Antimicrobial Resistance Strategy 2013-2018 was released by the Department of Health (DH), with the Department for Environment Food and Rural Affairs (DEFRA) and Public Health England (PHE), in September 2013. The primary objective of the Strategy is to slow the development and spread of antimicrobial resistance (AMR). The Policy Innovation Research Unit (PIRU) was commissioned to undertake an evaluation of the implementation of the Strategy and evidence underpinning the key mechanisms of change, with a view to contributing to the refresh of the Strategy, planned for 2018.

The extent to which antimicrobial agents are used in food producing animals for infection prophylaxis, metaphylaxis, and treatment, and their impact on human resistance through the food chain, is hotly contested and more evidence is needed on this aspect of AMR. There are concerns that antimicrobial agents used in the food chain could be a direct or indirect source of AMR in humans and that excessive use and misuse of antimicrobials could contaminate food for human consumption with resistant bacteria or genes.

The food chain is the system of organisations, people, activities and information describing the linkages, flows, governance and values between primary food producers, processors, manufacturers, retailers and consumers including waste management. In this report, only animal sourced foods are considered because the information available on antimicrobial usage and resistance in other foods is currently too limited to be assessed. The analysis of implementation of the UK AMR Strategy in the food chain consists of two parts: i) a review of the literature; and ii) analysis of interviews undertaken with policy officials and professionals involved in implementation of the Strategy; this report provides the qualitative analysis of the interviews.

The review of the literature is provided in a separate report entitled *Overview of evidence of antimicrobial use and antimicrobial resistance in the food chain* (Bennani et al, 2018). It highlights several key factors regarding AMR in the food chain. Evidence on the link between antibiotic use (ABU) in livestock for food production and AMR in people is neither abundant nor particularly clear, partly due to a lack of an integrated surveillance system. There is some evidence from specific substance-livestock species-combinations to suggest that reducing ABU and AMR in livestock production has a positive effect on AMR levels in humans. Antimicrobial resistant bacteria can be present in the human food supply chain, which presents a potential exposure route for consumers. Food can be contaminated by AMR pathogens or resistance genes in different ways including contamination of food during agricultural production, presence of resistance genes in bacteria added during food processing, or cross-contamination with resistant bacteria during food processing. However, it is not clear what fraction of resistant bacteria found in humans originates from animal-derived food. Food processing and preservation techniques can extend the shelf life of food products. The effects of these techniques on bacteria present in food vary but, in general, the number of bacteria is reduced when these techniques are applied. In general, food processes that kill bacteria in food products decrease the risk of transmission of AMR, possibly to the degree where exposure becomes negligible.

The ABU practices used by livestock production professionals (farmers, veterinarians, feed providers) are influenced by guidelines, incentives, trends, personal beliefs, attitudes and other drivers (see the case study reports for insights – *Evaluation of national and local implementation of the UK Antimicrobial Resistance Strategy*, Eastmure et al 2018). Many guidelines and requests come from industry schemes (e.g. farm assurance, certification), national government policies and international policies with implementation by a range of bodies and various levels of collaborations. Whereas the evaluation of implementation of the Strategy in the pig, poultry, and companion animal sectors

provide insights from the perspective of the farmers and veterinarians, this report focuses on the views of governmental and industry bodies with regards the broader picture of ABU and AMR in relation to the food chain in the UK.

1.2   Research questions

The food chain interviews aimed to address the following research questions:

1. What are the domestic laws and international agreements regulating (or policies advising/guiding) actions on anti-microbial use in the food chain in the UK and its major trading partners? What are current or planned policy commitments or advice guiding action on anti-microbial use in the food chain, from organisations such as the WHO? Are these covered by the actions listed in the UK AMR Strategy?
2. What is the progress in the implementation and the current evidence for the effectiveness of the mostly non-regulatory approach policies in both UK and elsewhere in the EU, particularly among key trade partners?
3. What are the potential gaps in the UK AMR Strategy in terms of addressing actions relevant to AMR and the food chain in the UK and internationally?

2   Methods

A series of fifteen semi-structured interviews were undertaken to explore national and international policy-level responses to the AMR Strategy initiatives within the food chain, to gain in-depth understanding of workings of the Strategy in a governance context. This report draws principally on findings from those fifteen interviews. The informants were based in organisations selected as relevant to animal source food chains, involved directly or indirectly in livestock production and ABU policy and regulation. Eight of the interviewees were based in UK organisations and seven in European/International organisations, including government departments, international bodies and independent sector organisations. These interviewees are detailed below in Table 1 (with interview reference codes beginning FC).

In addition, sections from six interviews conducted as part of other data collection within the wider PIRU evaluation of the implementation of the UK AMR Strategy were included in the analysis, generally from human and public health. These sections of content were identified and labelled as being relevant to food chains during the coding process by colleagues analysing them for other aspects of the evaluation, in order to check for convergence and divergence between the different data sets. Interviews identified by this mechanism are also listed in Table 1, with interviewee references codes beginning FCX. Findings were also considered and compared in conjunction with the findings from the *Local implementation of the Strategy in Norfolk and East Anglia in the poultry and pig sub-sectors* report (Häsler et al 2018). This report refers only to food chain statements for animal source foods. Publically available reports and websites, as well as the *Overview of evidence of antimicrobial use and antimicrobial resistance in the food chain*, prepared as part of the PIRU evaluation, informed the context and the analysis.

Interviews were conducted in summer and autumn of 2017, and were face-to-face, by phone or by Skype. Most interviews lasted around one hour. The organisations and professional roles of these informants are listed below (

Table 1). When recruiting informants, the aim was to include representation from different types of organisations and roles within ABU and AMR reduction in livestock production. Information has been limited in

Table 1 to ensure the anonymity of the participants. In the findings, the relevant interviewee code is referred to, and information about their organisation where appropriate.

Table 1. Informant descriptions for all people interviewed

Interviewee reference	Organisation	Role of interviewee	Level
FC1	VMD, DEFRA	Senior Officer	UK
FC2	DEFRA	Senior Policy Officer	UK
FC3	FSA	Senior Policy Official	UK
FC4	EMA/VMD, DEFRA	Technical Expert	EU
FC5	BVA	Academic, Senior Officer	UK
FC6	RUMA	Senior Staff	UK
FC7	WHO	Policy Official	Global
FC8	FAO and ILRI	Senior Scientist	Global
FC9	WHO	Senior Officer	Global
FC10	FAO	Technical Expert	Global
FC11	OIE	Senior Officer	Global
FC12	EC	Senior Staff	EU
FC13	Department of Agriculture and Rural Development, Northern Ireland Government	Senior Policy Officer and Technical Expert	UK
FC14	Welsh Government	Senior Advisor	UK
FC15	APHA	Scientist	UK
FCX1	VMD, DEFRA	Senior Officer	UK
FCX2	PHE	Policy Official	UK
FCX3	DH England	Senior Officer	UK
FCX4	DH England	Senior Officer	UK
FCX5	NHS England	Senior Scientific Officer	UK
FCX6	DH	Policy Manager	UK

After consent, all the interviews were digitally recorded and subsequently transcribed. The transcripts were read by members of the research team, who met and discussed early inductive themes that were identified in the interviews. This food chain report builds on this work and explores the key thematic findings. This early analytical work aids a 'constant comparison' approach to qualitative data interpretation (Glaser 1965) that enables early findings to be discussed amongst the wider research group.

A largely inductive coding approach was favoured to explore the key themes shaping approaches to ABU and AMR reduction, and their relationship to the Strategy. The findings are therefore presented thematically by heading. Direct quotes from the transcripts are used to illustrate points.

3 Findings

3.1 Advocacy, pressure and key drivers

Having established the importance of AMR as a public health threat in the UK (indeed, interviewees commented that the UK had led on raising the profile of AMR more internationally), it was felt that the Strategy had brought a great deal of pressure for action, which needed to be maintained: *"the first Strategy… the pressure to deliver was very, very high, very much pressure"* (FC6). This was generally seen as a positive situation, in helping to mobilise action across many sectors. Furthermore, it provided arguments to support the various changes in practice taking place and needing to take place. One interviewee noted that the Strategy had helped in "*making sure that the pressure is felt and maintained*" and that it had "*given space for a transition and that's important, but what needs to be maintained is the pressure for change, because change carries a cost*" (FC2). Given the UK's prominent international role, the interviewees noted the importance of keeping up the pressure, building on work so far, and carrying through with further action, leading as an example to other nations not only in advocacy but also action on reducing ABU.

Besides the Strategy itself, there were numerous mentions of the O'Neill Report that was published in summer 2016 (https://amr-review.org/), which some were more familiar with than the Strategy itself. The O'Neill Report provided a review on AMR, commissioned in July 2014 by the UK Prime Minister, who mandated the economist Jim O'Neill with the analysis of the global problem of rising drug resistance and to propose concrete actions to tackle it internationally. The Review engaged widely with international stakeholders to understand and propose solutions to the problem of drug-resistant infections from an economic and social perspective in order to produce its final report and recommendations.

The sustained impact of this report was acknowledged by several interviewees: *"the O'Neill Report and the associated material that went along with that, was very influential in terms of international advocacy and policy pushing"* (FC8), and: *"the UK has been leading in this, so it's not because of the strategy, but what O'Neill did, and all the big fuss about AMR a few years ago did was to absolutely focus our minds"* (FC6). The O'Neill Report also shaped some of the ways that action was taken*: "in our government response to O'Neill, we said the sectors had to come up with things by the end of this year, forget the targets – with a sector plan"* (FC2).

The increase in importance of AMR, and subsequent pressure for action, was seen to have had a positive overall effect on attitudes within organisations involved in the food chain. One interviewee noted: *"we've seen over time, for example, an obligation on our profession to use antibiotics responsibly as embedded in the code for the profession"* (FC1). The sense of obligation and duty within the food chain had shifted towards a reduction in ABU. There is more about the role of targets in addressing AMR and the sector-lead approach in Section 3.4.

3.2 National, international and global perspectives

It was echoed throughout many of the interviews that the importance of ABU and AMR had been clearly established in recent years, and that the topic had moved up the political agenda prominently: *"what we've seen is that AMR has come up the agenda, the visibility has gone up; we've seen the sectors start to engage to a greater extent"* (FC2).

This was attributed in part to the Strategy: *"there's been a step-change during the course of the five-year Strategy actually in the UK"* (FC2), which was seen to have raised the profile of and political pressure to addressing the risk of AMR in the food chain.

In an international context, the UK was perceived to be a particularly strong leader on the issue of AMR and advocating for its place on the international agenda: *"the UK was taking a lead in trying to keep things going, stir up a bit of activity"* (FC8). The Strategy was seen to play an important role in this by providing a justification to engage. This is illustrated by the UK leading on some of the European and global AMR initiatives: *"the Government had gone to the UN and said, 'we want to lead on this'… we decided as a country we were going to lead on this"* (FC6). However, this comes with responsibility and consequences: *"so the pressure's then on, isn't it? We have to then match that up with action"* (FC6). There were many comments about the need to follow through with action.

In addition, interviewees acknowledged the unknown possible consequences of Brexit, with the potential for the UK to be a less prominent voice without the clout of the EU. It was stressed that it should aim to stay as a global leader in the context of the control of AMR risk in the food chain, and furthermore, that it should use its high food safety and animal welfare standards as a selling point in trade negotiations.

Although the Strategy's scope is limited to the UK, one of the criticisms of the Strategy was its almost exclusive focus on the UK, at the expense of the wider international context of AMR. The latter was described as particularly relevant in the context of food as many food chains are international. *"I felt the strategy was very UK centric, and a problem like AMR... the focus of the strategy was very, very much towards the UK, and I would certainly like to see it take a much, much, much more international perspective"* (FC11). Another interviewee remarked that the Strategy provided a good understanding of the UK position on the use of AB, but did not help to understand use in countries that formed part of the international supply chains.

In relation to this, a respondent acknowledged that the Strategy needed to reach out beyond national food chains and consider international food chains in its actions on AMR: *"we need international partners; this is not something the EU could do on its own, and certainly the UK – this is definitely a global resource challenge"* (FC2). This was, perhaps not surprisingly, particularly prominent amongst interviewees who worked in international organisations: *"it's the global nature of the problem that's not really dealt with adequately by the UK strategy"* (FC8). Whilst the Strategy is about and for the UK, and the UK has little control beyond domestic issues, some interviewees stressed the importance of including ways to strengthen collaboration with partners integrated in the international food supply chain and ABU governance in other countries.

Leading on from the highly UK-centric focus of the Strategy, there were numerous comments on the global nature of AMR, and, therefore, the inherent global challenges and need for greater international integration. As one interviewee put it: *"antibiotic resistance… it's a global threat… so the global challenge is a challenge for the UK. If you understand that, then everything we do at UK level is dwarfed by the international challenge"* (FC2). However, the details of what kind of international integration and with whom were not discussed and could be looked into.

Respondents commented on the root causes of AMR, which went beyond UK borders, and how resistant bacteria cannot be segregated by national borders: *"the problem of AMR in very, very highly developed countries like the UK is that the improvements there will go on anyway... That's not where the investment is needed, it's dealing with the real root of the problem, which is in these low and middle income countries, and if we're ever going to put a serious halt on AMR, then that's where we need to be working… The UK dealing with the problem in the UK is not going to solve the problem at all, because there'll be a constant threat from antimicrobial resistant bugs that are being churned out of other situations, so, they'll be able to contain AMR when it arrives in the UK, but you know, the root cause has to be dealt with if we're to make any progress at all"* (FC9).

Considering that much of the food consumed in the UK is imported (the country's food production to supply ratio was 60% in 2017, (DEFRA, 2017a)), there was particular mention of developing countries as sources of food: *"the link to the Sustainable Development Goals is quite strong, because when you look globally, the places where the biggest problems lie are the places that have a lot to do in terms of their fundamental capabilities"* (FC2). This implied that bodies like the Department for International Development (DfID) needed to have a more prominent role in the Strategy. In addition, it was implied that international development-focused organisations should have greater presence in international AMR collaborations. However, interviewees also noted that successful food chain actions in the UK cannot necessarily be translated successfully elsewhere, and therefore actions needed to be developed according to local contexts: *"the international discussions, we need to be very sensitive to the need to make real progress, and we need to avoid presenting the rest of the world with the UK or the European template that we care to force them into, because it won't work"* (FC2).

3.3   Implementation of a One Health approach

The term "One Health" was used many times during interviews, and is stated in the Strategy as a key principle for addressing AMR. Some interviewees did not mention it at all, whilst others referred to it as an approach which positively shaped the Strategy, although they only spoke about it in the context of human and animal health sectors communicating, neglecting the environmental dimension. This reflects a lack of true understanding and embodiment of a One Health approach.

The Centers for Disease Control define One Health as "a collaborative, multisectoral, and trans-disciplinary approach — working at the local, regional, national, and global levels — with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment" (CDCP 2017). In short, One Health focuses on holistic approaches for the benefit of people, animals and the environment. The following quote reflects some of the opinions and understandings of the way One Health is employed and hints at an imbalance in the representation and engagement of the different sectors: *"[the Strategy] is also rather public health centric, and I would like to see it take a much stronger One Health approach... it's not that it doesn't pay service to One Health, pay lip service to it... it's mentioned and then it proceeds without it"* (FC8).

Despite this perceived imbalance, the interviewees confirmed that the Strategy had brought together many sectors that had previously not collaborated, which was described as a positive development. What was generally positively discussed was greatly improved communication and collaboration between human and animal health sectors. Some tensions and misunderstandings were still mentioned, but on the whole, these were reported to have diminished, and there were stories of professionals working together across human and animal health, sharing and comparing practices. One interviewee praised a UK cross-sectoral One Health meeting that had taken place in 2017: *"And then the audience, because we had the CVO and the CMO chairing, we managed to get an audience that included people like the Chief Pharmaceutical Officers, and some Senior Medical Microbiology Consultants, and a range of people that were Heads of veterinary professions. And it was a very dynamic interested courteous professional meeting, and it was exactly what One Health should be"* (FC1).

In the past, it was reported that blame and responsibility was pushed to others by both veterinary and public health sectors. There remained some residual debate regarding the main responsibility for AMR emergence and spread: *"odd dynamic where you could debate, because of... the lack of the evidence base, the relative importance of AMR in the human field and the animal field, as relates to threats to human health, and that got in the way, and actually there was an almost one element of denial with*

the animal sector feeling that proportionately, it wasn't sufficiently important to do more than they were already doing and the human sector feeling that it was important, regardless, and there was not enough being done, and that pressure or tension wasn't really very healthy" (FC2).

However, in general, the debate on responsibilities in the context of AMR was felt to have been resolved: *"we're working quite closely with human medicine, because how this started was that the human medicine started to blame farmers for the problems… the last thing we need is to start blaming each other, because we're all in this together… now that we've engaged with them, they now understand farming a lot better"* (FC5). This was partly attributed to the need to work together across sectors to address AMR, which was called for in the Strategy. One informant further explained that a lot of the (perceived) mistrust and blaming in the past had been related to a lack of knowledge of what the other sectors were doing, and that sharing and learning from each other had helped to move towards a better mutual understanding. However, in the next stages, it was generally felt that this needed to extend further, to engage also groups and people that operate in parallel and do not buy into the agreed One Health approach, such as those still pursuing disciplinary approaches, and those not yet connected to the health communities, e.g. environmental specialists.

While there were positive observations on the progress made in human and animal health sector collaborations, some interviewees argued that there was a distinct lack of discussion regarding the role of environmental and ecological factors within AMR and the Strategy: *"thinking about our focus on animal health, well we mustn't forget the environment and the One Health agenda"* (FC2). This was both reflected in the absence in interviews of a mention of environmental factors, or remarks in interviews drawing attention to the lack of knowledge and work on it: "*the livestock sector and what that means for the environment, and a whole area that needs to be better understood about the environment as an ecosystem… there's a body of work to do, to strengthen our evidence base as well, our understanding of what is happening in the environment"* (FC2). This is a clear gap as a considerable proportion of food originates from plants. It was felt that even with limited knowledge, aside from increasing research on the topic, more could be done to incorporate environmental factors into the Strategy and subsequent actions on AMR.

Frequently, interviewees called for ways to strengthen the collaboration on AMR activities across sectors and to pursue a One Health approach. Informants mentioned a need to improve methods to measure, analyse and generally understand AMU across animal sectors. On the topic of AMR in the environment, one interviewee remarked that the Strategy "*has helped an ongoing dialogue and understanding across animal and human health of where we are and our differing responsibilities"*, and now, *"including the environment, where there is more to do, again on both the evidence and evidencing what action's been taken"* (FC2). Again, this is relevant for the food chain, both for animal and plant-derived foods, given the shared ecosystems that provide inputs for food production systems.

Many interviewees commented on the complexities of different ways to measure and record ABU in food chains, and even ways to understand resistance: *"we need to harmonise our gathering and measurement of resistance in the human and animal populations… [human and animal health are] not measuring resistance in the same way, so our definition of what antimicrobial resistance means varies, and it will vary between country and it also varies between animal and human health... there's definitely some things to do in that area"* (FC1). Whilst this is at a broader level across human, animal and environmental sectors, it relates to integrated surveillance systems (see Section 3.4), at the scale of species sector.

3.4 Changes in ABU and AMR action

This section outlines some of the main changes in ABU and AMR management in relation to food chains that interviewees identified to be a result of the Strategy.

It was widely acknowledged that there were considerable differences between the different food animal industries in terms of the form and extent of policy implementation. For example, the meat-poultry sector was mentioned to *"have very good data"* (FC6) and to be *"ahead of the game"* (*"it's almost now overquoted and the withdrawal of fluoroquinolones for day-old chicks in our meat-poultry sector was a really good example of that"*), but that *"not all sectors are the same"* (FC2). Data is seen as an important part of ABU reduction actions, as they can help measure and monitor changes, and were referred to as evidencing reductions. The poultry sector was noted to possess data that demonstrated the reduction in use. The pig sector was perceived as being similarly progressive: *"pigs are only collecting the data now since AHDB… we've set up at AHDB the pig Electronic Medicine Book"* (FC6). The dairy, beef and sheep sectors were seen as less advanced: *"Cattle and sheep, there's no data; dairy, there's no data to speak of"* (FC6). Although, positive progress was noted also in these industries*: "We're starting to see...the behavioural change and the willingness to change, not only the use of antibiotics but also the system that surrounds it, so to get that change in the dairy sector you need good hygiene, you need good monitoring, you need to understand your cows at most risk"* (FC2).

The role of targets was mentioned in many of the interviews. Targets refer to set numbers relating to quantity and types of ABU within the food chain. Some have already been set, some are being developed and others are being proposed as a way to reduce ABU. In 2016 DEFRA committed to reach the target to multispecies average of 50mg/kg ABU by 2018 in livestock and fish (BMJ 2016). There is some debate as to the potential of broad targets for positive impact.

The main ones set have been taken from the O'Neill Report, and they seem to be generally accepted: *"O'Neill said he'd like to see everyone down to 50 milligrams… we were given until 2018 to meet these targets… and we accepted that challenge, and we think we'll get there because we're well on the way"* (FC6). The overall target of 50mg/PCU was agreed in the DEFRA response to the O'Neill report. Livestock sectors were then charged with agreeing their own targets with the Veterinary Medicines Directorate. This process was supported by RUMA (see RUMA 2017 report for details).

However, the main felt concern was the perceived simplicity of the targets. An interviewee from RUMA remarked: *"from the agricultural side, I'd like to see us be more sophisticated on targets… we're saying, 'not only do we need you to get to the target, we want to see the critically important ones reduced as well'… We need a more holistic approach to what we're doing, you could just simply have a number, but I think we can do better than that"* (FC6). The challenge of target setting is related to the complexity of ABU in animal health. Within the food chain, there are specific AB substances, some of which are used in human health. However, they all differ in terms of what is given, how it is applied, dosage, the way it is measured, and which substances are considered critically important. Furthermore, many of these attributes differ by animal species, and thus can vary widely across the livestock sectors. This means that having only simple targets does not serve the specific needs of each sector adequately, although they can help to focus everyone on a single idea.

The following quote reflects this complexity: "*I don't particularly like these target numbers, because they're too easy, and they're crude… Also, there's a big argument – is it milligrams per kilogram? Is it DCD (defined course dose)? Is it DDD (defined daily dose)? And, most people don't even know what you're talking about, because it's so complicated, and different sectors use different things, and then you've got a WTO (World Trade Organisation) for medicines, EMA (European Medicines Agency) list, all these lists – it's just so confusing*" (FC6). Another interviewee echoes similar sentiments and

remarks on concerns about even broader global targets: *"understanding the animal sector, it's quite clear that global targets could drive not necessarily the right behaviours… weight-based targets, milligrams, antibiotic used per kilogram production on a PCU (population-corrected unit) basis…"* (FC2).

It was felt that basic, vague, blanket targets not adjusted to each sector were too simplistic, difficult to follow and hard to measure. They missed out nuances such as which type of antibiotic (e.g. critically important ones or not), how they are administered and when/why (e.g. prophylactically). This could encourage practices that make it easiest to reach the target, rather than improving the overall husbandry practices, animal health, and particular uses of antibiotics.

However, there was general consensus that targets have some role to play, mainly in focusing everyone, working out what to measure and how, and setting some benchmarks, even where the context changes and new targets are needed: *"the target's had its function, but the target isn't the end, so I think "targetry" will remain interesting"* (FC2).

The advantage of targets was seen in the fact that the sectors were encouraged to respond to them with a great deal of autonomy, whereby they developed more particular targets suitable to each sector, and measures to implement them: *"in the meantime, we were then challenged to set targets for each sector in agriculture, which we decided, it would be better if the industry did it for itself, to avoid regulation, and that's what we've been doing for the last year is, we've got a targets taskforce"* (FC6).

Many interviewees commented on how the private actors in the agricultural sector had assumed leadership in the introduction of measures for reducing ABU and managing AMR, and how this had generally been very positive and well received. This contrasts with other countries such as the Netherlands and France, which have taken a more top-down, regulatory approach to ABU, as commented by one interviewee. For example, the Netherlands brought in mandatory reduction targets (defined as 20% reduction in 2011 and 50% in 2013, renewed in 2012 to 70% reduction for total livestock production). Measures included transparency in use, a full ban of new antibacterial drugs in animals, and changes in the animal drug law (Mevius and Heederik 2014). This is not to say whether one approach is better than the other (top-down regulation versus more voluntary sector-led), only that the UK is taking the latter approach and it was felt that this was positive and effective. Where referring to 'sector-lead', this is in reference to different animal species sectors.

Upon receiving targets, the livestock sectors in the UK were encouraged to take charge of their own ABU reduction, monitoring and necessary changes in practices. This shaped the approach in the food chain, and it is discussed from the pig and poultry producer perspective in our evaluation of the national and local implementation of the Strategy (Häsler et al. 2018). One interviewee described it thus: *"a dialogue with our sector... if you don't want a heavy-handed regulation, which we can deploy if really necessary, 'cos this is very politically important, but take control for your sectors on a sector-by-sector basis and deal with those targets, which was a dialogue led by VMD, but with a positive role played by RUMA"* (FC2).

This had required careful coordination, which RUMA had led: *"RUMA stepping into the coordinating position… they've taken on that challenge to assist the sectors with the sectors' willingness, to seek to coordinate that, of course with VMD working very closely, so, this is very partnership working, that then engages the sector leaders, it also engages the veterinary associations that work with those sectors, and they're crucial"* (FC2). Overall, it was felt to have been a successful approach, encouraging

and sharing good practice, healthy competition between farmers and sectors to reduce their ABU, and a sense of autonomy and agency amongst producers.

Of course, it was not without its challenges, particularly relating to communication. However, this seems to have been managed appropriately by each sector: *"I've been amazed how the sector representatives – we had a leading farmer and a vet from each sector, and we made them all meet together in the same room, and then we had observers from the VMD, from the FSA and from Red Tractor, and then we had senior RUMA staff there, and they've all helped each other and challenged each other, and it's been really great… Communication is quite difficult, but when you've got a leading farmer and a leading vet who then consults with their group, in species group, of leading people, that's enough, that will do the trick... There is a big change of attitude, they know that things have got to be different"* (FC6).

When considering future developments of the Strategy, one interviewee cautioned against taking a more prescriptive approach: *"I would hate to see the new Strategy seek to dictate to the sectors and the veterinary profession that relates to them how to do this, because actually the policy that we have pursued is to make them feel responsible and take their own action"* (FC2). It was noted that more dogmatic regulatory approaches (such as seen in the Netherlands) are also effective, but were not the preferred approach in the UK, where the sector-led style was helping the transition to be a more positive experience for farmers, vets, etc. and helping buy-in of the changes.

As noted in the systematic review of evidence in the food chain carried out as part of the wider evaluation of the implementation of the Strategy (Bennani, et al., 2018), and as stated at numerous points in the interviews, the quality of the current surveillance data in terms of completeness, comparability and attribution of use to livestock species remains limited (Al-Haboubi et al, 2018). For example, when discussing use of antibiotics in the meat-poultry sector, one interviewee explained: *"measuring is really important and our measure is limited, because we only have sales data, we don't have prescription data, and it's very hard to attribute use necessarily to a particular species"* (FC2). For the pig sector, AHDB had made substantial progress with its Electronic Medicines Book, which was mentioned multiple times in relation to its success and usefulness. However, it was still relatively new and similar initiatives, or the same but adapted for other species, had not so far been put in place. One interviewee explained: *"We need a proper national database… And, then we have to make sure it's all integrated… We've got all the data on the farm already, because everybody has to keep it for Red Tractor, farm assurance, but nobody collects it"* (FC6).

The necessary changes in production systems and livestock husbandry were mentioned by numerous interviewees. As one explained, "*it's a combination of using less, using it correctly, responsible use, and then only using it when it's necessary, and then preventing, preventing the need to use any at all by having healthy animals, proper facilities, which means investment and all the rest of it"* (FC6).

At the policy level, a focus on general improved animal health was perceived to be a win-win situation, whereby healthier animals would require less treatment and ABU, minimising costs, increasing productivity and therefore profit. However, it is not necessarily that simple, as the costs in making these changes are often great, and most farmers are already ensuring the best animal health within their means (see *Local implementation of the Strategy in Norfolk and East Anglia in the poultry and pig sub-sectors* report). Therefore, the changes that should lead to further ABU reduction are complex and far-reaching: *"not only the use of antibiotics but also the system that surrounds it… There is the whole package of good practice that goes with withdrawing your use of antibiotics"* (FC2).

3.5   Costs, drivers and incentives

Informants emphasised that ABU reduction in animals will require improved animal husbandry and management practices that will help prevent disease, prioritise animal health and thereby reduce the need for ABU. For example, optimised ventilation, lighting and bedding; precision feeding practices including use of probiotics; and high quality water systems can improve animal health overall and prevent infections (see Case Study reports for examples). Such management changes have been shown to reduce the need for ABU. Some specific ideas for future developments in ABU and AMR reduction were identified by interviewees, for farming and veterinary medicine. Namely, faster and cheaper diagnostics for use in animals (pen-side tests), recognition and rewards for good practice and reduced ABU, financial support for improved husbandry practices such as those mentioned (especially regarding housing and feeding), and awareness raising among farmers and veterinarians.

However, as one informant noted, *"Change carries a cost"* (FC2). There were some comments and suggestions on the costs, drivers and incentives needed to make the necessary change to reduce ABU. Adequate facilities were identified as one of the challenges: *"there's a lot of farmers who haven't got good enough facilities, and they're using too much antimicrobials, but sometimes they can't borrow the money, and even if they can borrow the money, they're too frightened to invest, because if they invest and then the market turns, they'll go bust, so, they're sitting there using too much antimicrobials because they haven't got a choice"*, to which one proposal was: *"I'm trying to persuade Government, they need some tax breaks – help us help them to get rid of this"* (FC6).

The role of the Government and finance challenges came up multiple times as a way to encourage, support and facilitate this change: *"we need to combine financial assistance or tax breaks, or something, in order to improve circumstances where animals are kept, because the more healthy animals we have, the less we're going to use, automatically, and everybody wins"* (FC6). Farm profits can be irregular and precarious in the UK (see for example DEFRA 2017b, especially pig and dairy farms). Whilst the hope is that better facilities and overall animal health to reduce ABs will also benefit farmers, the initial investments needed to implement the changes and improvements are substantial and it is not clear where they will come from.

Apart from government, there are other actors within the system, such as retailers and consumers, civil society groups, integrators[1] within the profession. Each of these can exercise influence, some with a direct economic impact on producers. One interviewee highlighted: *"There's a whole issue of your relationship to retailers and the actions of retailers and we need to avoid actions by anybody, including retailers, that have perverse outcomes or mislead the consumer, so there's a complex issue here around driving forward best practice without creating perverse incentives or the wrong impression"* (FC2). For example, some supermarkets tried to bring in an 'antibiotic-free' meat label, with Karro, one of the leading pork processors in the UK, registering an 'antibiotic-free' trademark with the Intellectual Property Office (see IP0 2016). However, this was met with criticism, especially animal welfare bodies, who saw it as incentivising farmers to not use antibiotics therapeutically to treat sick animals when they needed it. It was also seen as promoting a simplistic and confusing label to the public regarding the role of antibiotics in farming, and whether unlabelled meat meant they were consuming antibiotics. This is not true, as current regulations and enforcements on ABU stipulate withdrawal times and food chain inspections to ensure that animal source foods are not contaminated with AB residues. This highlights the need to be aware of unintended consequences.

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[1] Integrated production is increasingly common, where production stages are combined into large vertically integrated firms, usually overseen by one common owner who controls the supply chain.

3.6 Research, data and funding

Finally, there was a sustained call for more research funding to allow analyses leading to better understanding of ABU, AMR and trends over time. This need relates to almost all the points discussed above. As one interviewee put it: *"more than half of the antibiotics consumed globally are in animal production, so proportional to that consumption, there's very, very, very little work going on to understand that, to understand how transmission occurs with the environment, and to understand ways in which that can be dealt with and addressed"* (FC8).

For example, the role of targets was deemed irrelevant when, *"the biggest problem has been [regarding targets], we've got very little data"* (FC3). This was also seen as posing a problem in collaborating with environment-focused bodies and understanding the environmental factors in AMR: *"there's a body of work to do, to strengthen our evidence base as well, our understanding of what is happening in the environment"* (FC2).

Data and research not only help to direct and monitor change, but were also seen as contributing to advocacy and maintaining pressure for change: *"We need to continue to have an element that researches and gives a good evidence base, because we need it not only to direct what we do, but also to convince people of the need for change… In relation to animal systems, we need to take delivery of sector-specific plans, consider their strength or otherwise, and keep the momentum"* (FC1).

4 Discussion

In general, there were positive perceptions of the UK's as a global leader in addressing AMR in food producing animals, and actions taken to reduce ABU. The leadership and engagement among the different livestock sub-sectors were deemed effective in implementing the Strategy' goals in this field and promoting change. Several concerns were communicated, including insufficient consideration of the international and global dynamics of the AMR challenge, the heterogeneity in surveillance activities, limited understanding of the links between AMU in animals and AMR in people, and the role of food chain actors other than primary producers in ABU and AMR. Calls were made for further research to understand transmission of resistant bacteria through the food chain to people, promotion of integrated surveillance systems, better One Health collaboration that includes environmental specialists and sectors and incentives (financial and recognition) for best practice in ABU.

ABU reduction in animals will require improved animal husbandry and management practices that will help prevent disease, prioritise animal health and thereby reduce the need for ABU. However, they often require substantial changes in management and husbandry practices as well as investments into building and infrastructure. Consequently, there are concerns, including from the interviewees, that improving sanitation may lessen the effects that reduced ABU has on animal productivity, but will likely add costs, which could reduce revenues if improved husbandry is not accompanied by an increase in prices. While literature on the economic performance related to changes in management practices and resultant reduced ABU is still sparse, first results in pig sub-sectors in various European countries (not including the UK) show that the implementation of alternative management measures does not affect technical performance and, that their costs are outweighed by sustained productivity and improved animal health (Levy 2014; Rojo-Gimeno et al. 2016; Collineau et al. 2017). However, further work is needed to explore the impact the reduced ABU would have on farm profits in a range of production systems operating under different management structures and further downstream in food chains.

In fact, few informants talked explicitly about the food chain when questioned about "*specific policies on AMR in the food chain*", but talked about sectoral collaborations in general and specific people or groups of people in the food chain. Many informants talked about (livestock) primary producers in particular, veterinarians and "public health" people. Often, quite vague statements were made in reference to the food chain using phrases such as "*the vets and the rest of the food chain*". Also, people pointed at the sectoral allocation of tasks with animal health sectors being responsible for primary production, and harvesting and public health agencies being responsible for the retail level and consumers. Some informants commented on the lack of a whole food chain approach and neglect of AMR issues in parts of the food chain other than primary production.

These observations are closely linked to comments made about the lack of integrated surveillance systems. The WHO and Centers for Disease Control in the US define surveillance integration as harmonising different methods, software, data collection forms, standards and case definitions in order to prevent inconsistent information and maximising efforts among all disease prevention and control programmes and stakeholders (WHO 2010). Calls for such integrated surveillance approaches are not new; in 2004 the *Development of a new paradigm for health protection surveillance in the UK* was outlined, calling for the use of integrated surveillance at key points in pathways that can lead to adverse health effects, engagement of relevant agencies from multiple fields and targeting efforts at points in the (food) chain where the biggest impact in terms of risk mitigation could be achieved (Sopwith & Regan 2004). Despite substantial progress in surveillance harmonisation, sectoral differences prevail and further progress in surveillance integration may be hindered by sector-specific metrics and measurements tools and the wide range of (sector-specific) institutions involved in data collection, recording, and reporting (Al-Haboubi et al, 2018). The problem of confusing metrics was also mentioned with regard to target-setting and questions came up about the arbitrary nature of targets (Al-Haboubi et al, 2018; Staerk et al, 2018). Consequently, there is a tension between a desire for sectoral autonomy and harmonisation in surveillance and intervention.

Such cross-sectoral tensions are well-documented in the One Health literature. Integrated approaches to health (such as One Health, Ecohealth, Planetary Health) emphasise the commonalities of human, animal, plant and ecosystem health and call for systems thinking (Lerner and Berg 2017; Rüegg et al. 2018). In the last two decades, there has been a re-emergence of the recognition that a combined approach to health issues is needed, together with an increasing awareness that environmental health affects the health and livelihood of humans, domestic animals and wildlife, and is an important component for sustainability and resilience of people, animals and ecosystems (Destoumieux-Garzón et al. 2018). Antimicrobial resistance is a common challenge for health, agri-food and environmental sectors. A large quantity of antibiotics used is poorly absorbed in the gut of animals and humans, and excreted in faeces and urine. Land application of animal waste as a form of fertiliser is a common practice in many countries and there is increasing concern about the impact of AB residues in fields, feed and plant food production, recreational environments and waterways (Kümmerer 2009; Tasho & Cho 2016; Sarmah et al. 2006). Despite calls for urgent attention to be given to the investigation of the effects of residues in waste and their impact on ecosystems for more than a decade (Sarmah et al. 2006), environmental stakeholders and specialists were described as a neglected part of the One Health Strategy for AMR. Given this awareness among respondents, it crystallised that the next Strategy should make active efforts to broaden participation and support integrated research to make sure that AMR is understood and addressed not only in the food chain, but also in ecosystems.

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