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D5.4 Second Annual Research Prioritisation Report

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1. Executive Summary

The issue of antibiotic resistance is unnecessarily exacerbated by excessive and inappropriate use of antibiotics and improper disposal of antibiotic residues. This necessitates antibiotic resistance management strategies to be developed and implemented. In farming, the need for antibiotic treatments can be reduced by using strategies which promote animal health, prevent disease occurrence and spread, and focus on appropriate medical treatments including targeted use of antibiotics only when necessary.

This second Research Prioritisation Report aims to identify areas to prioritise for future research about antibiotic resistance management in the livestock sector based on results from an online survey based around the key topics selected by the DISARM Community of Practice and adjusted according to findings from the first Research Prioritisation Report. Perceived accomplishments and shortcomings in existing research and policy in the areas of livestock health and antibiotic resistance management are used to recommend areas for further work in sustainable antibiotic usage.

Key areas for attention included; a need for more global cooperation and action regarding antibiotic use in different countries as part of a One Health approach, including improved monitoring systems for antimicrobial resistance and the contribution of livestock (and other sectors) to overall figures. Survey responses indicated a need for greater collaboration between all livestock industry actors for a common goal, facilitated by improvements to policy and legislation, to achieve behavioural change at the farm level to reduce antibiotic usage.

Data from this year's report do not challenge the previous recommendations from the first year report:

- Behaviour change to reduce antibiotic usage at the farm level: how to engage with tenacious high-users and facilitate positive attitudes towards improving animal health and reducing antibiotic treatments?
- Early disease detection and rapid on-farm diagnostics including precision livestock technologies: can more/better/affordable options be developed to allow for early intervention in animal health?
- Disease prevention strategies: what are the most effective interventions, and what is the cost-benefit of implementation?
- Health and antibiotic usage monitoring: can different countries establish suitable monitoring systems to allow for benchmarking between individual farms and compare national averages?

In addition, effective support systems should be investigated so that policy recommendations can be improved.

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1. Introduction

This report is part of the EU Horizon 2020 DISARM (Disseminating Innovative Solutions for Antibiotic Resistance Management) project. The DISARM Thematic Network links together farmers, veterinarians, advisors, industry members and researchers to share and promote best practice strategies to reduce antibiotic resistance in intensive and grazing livestock systems for cattle, sheep, pigs and poultry. The network will focus on strategies which prevent disease and promote good health in livestock, thereby reducing the need for antibiotic treatments and contributing to an overall reduction in antibiotic resistance.

There is a real benefit in the exchange of innovative approaches; different sectors can learn from the approaches to livestock health adopted by farmers in other sectors or countries. DISARM will be facilitating the exchange of ideas through events and workshops, social media channels, and the project website www.disarmproject.eu which will promote examples of best practice in a number of areas relating to animal health and antibiotic use. The DISARM project also aims to inform future research, funding and policy, in part through annually produced Research Prioritisation Reports.

This second Research Prioritisation Report aims to identify areas to prioritise for future research about antibiotic resistance management in the livestock sector based on results from an online survey based around the key topics selected by the DISARM Community of Practice and adjusted according to the first Research Prioritisation Report. Perceived accomplishments and shortcomings in existing research and policy in the areas of livestock health and antibiotic resistance management inform recommendations further work in sustainable antibiotic usage.

2. Antibiotic resistance and the role of livestock farming

Antibiotic resistance and the 'One Health' approach

Since the first antibiotic was discovered by Alexander Fleming in 1928, medical treatments transformed as the number of antibiotics expanded, facilitating advances in medicine and surgery, extending expected lifespans and saving millions of lives. However bacteria are becoming resistant to more and more of the antibiotics we have available, and resistance has been observed against all antibiotics that have been developed[1].

Antibiotic resistance occurs when bacteria adapt to survive in response to antibiotic use. Resistance genes can then spread through populations of bacteria, causing pathogenic bacteria to become 'super bugs' for which our current arsenal of antibiotics are ineffective treatments. Antibiotic resistance is a highly complex problem involving mechanisms which affect both human and animal health, thus requiring action from all sectors[2].

All antibiotic use carries the risk of creating antibiotic resistant bacteria. The issue of antibiotic resistance is unnecessarily exacerbated by excessive and inappropriate use of antibiotics and improper disposal of antibiotic residues. Ultimately, reducing antibiotic usage prevents the selection pressure which causes bacteria to develop antibiotic resistance. These principles apply to both human and animal health and medicine.

European Context

The latest European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) report[3] presents sales data for antimicrobial agents across 31 European countries. Trend data shows that overall antibiotic sales have decreased, with 18 out of 25 countries showing a drop in sales greater than 5% between 2011-2018. However, 5 out of 25 countries showed an increase in sales greater than 5% between 2011-2018 and, as shown in table 1, there is large variation in figures between countries.

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Table 1 Total antibiotic usage for 31 European countries in order (lowest to highest). Adapted from ESVAC report[3]

Country	mg/PCU
Norway	2.9
Iceland	4.9
Sweden	12.5
Finland	18.7
United Kingdom	29.5
Lithuania	33.1
Luxembourg	33.6
Latvia	36.1
Denmark	38.2
Switzerland	40.2
Slovenia	43.2
Ireland	46
Slovakia	49.3
Austria	50.1
Estonia	53.3
Czechia	57
Netherlands	57.5
France	64.2
Croatia	66.8
Romania	82.7
Germany	88.4
Greece	90.9
Belgium	113.1
Bulgaria	119.6
Malta	150.9
Poland	167.4
Hungary	180.6
Portugal	186.6
Spain	219.2
Italy	244
Cyprus	466.3

It is also important to consider the antimicrobial classes used in livestock farming, at there is a need to avoid Critically Important Antimicrobials (CIAs) for human medicine: 3rd- and 4th-generation cephalosporins, fluoroquinolones and other quinolones, polymixins (all AMEG (EU Antimicrobial Advice ad hoc Expert Group) Category B: Restrict) and macrolides. The dosing for various antimicrobial agents varies substantially across treatments and species, and might explain some of the variation in total use across countries.

Table 2 Total antibiotic usage for 31 European countries, including sales data for AMEG Category B antimicrobials. Adapted from ESVAC report[3]

	European country mean 2018 (mg/PCU*)	European country median 2018 (mg/PCU*)	Range (mg/PCU*)
Total Use	103.2	57	2.9 – 466.3
Fluoroquinolones	2.5	1.2	<0.01 – 10.9
3rd and 4th generation Cephalosporins	0.2	0.2	<0.01 – 0.9
Polymyxins (colistin)	3.4	1.6	0 – 12.8

* Rounded to 1 decimal place

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Reducing antibiotic usage in the livestock sector

As part of the European Green Deal, the Farm to Fork strategy outlines key targets for the food sector, including the 2030 target to "reduce the sale of antimicrobials for farmed animals and in aquaculture by 50%".

In farming, the need for antibiotic treatments can be reduced by using strategies which promote animal health, prevent disease occurrence and spread, and focus on appropriate medical treatments including targeted use of antibiotics only when necessary. It is vital that these general principles can be applied in practical ways on farms whilst maintaining or improving animal welfare and farm economic performance.

2.1.1. Internal and external biosecurity

Biosecurity measures help to prevent the entry and spread of infectious diseases on farms, thereby reducing disease incidence and the need for veterinary antibiotic treatments[4]. External biosecurity aims to prevent the introduction of pathogens onto the farm through, for example, controlling movement of animals and people onto and off farms (including wildlife vectors) and the use of quarantine when buying in stock. Internal biosecurity concerns the transmission of pathogens within the farm boundaries, with stocking density, hygiene and disease transmission mechanisms being important considerations.

2.1.2. Vaccination protocols and breeding for robustness

Vaccines are effective preventative measures for a range of diseases, improving the health, welfare and productivity of cattle, sheep, pigs and poultry. Vaccines mimic infection to allow the animal to launch an immune response and develop immunity without succumbing to the disease. This means animals are more resilient to future infections, showing minor or no symptoms of illness and requiring fewer antibiotic treatments.

Genetics also influence animals' susceptibility to disease and their responses to other physical, environmental and social stressors. Selective breeding for favourable traits can make them more common in future generations. Health-related traits like longevity and growth can act as disease resilience indicators, helping to protect the health status of farmed animals.

2.1.3. Water, feed and gut health

Water quality is very important to ensure good animal health. Contamination of the water source, water pipes, or drinking troughs or nipples put animals at risk of infection and reduce the effectiveness of medicines distributed through the drinking water. Regularly and effectively disinfecting water systems can mitigate these risks. Appropriate feed should be stored such that it is protected from pests and moisture to avoid contamination and spoiling, and provided to animals using clean feeding equipment.

Feed composition is another key element in safeguarding animal health and welfare in livestock production. Diet must be adapted for the age of the animal, as nutritional requirements change as they mature and develop. Animal feeds can be formulated with special ingredients like additives, supplements, and active feed ingredients that can assist in supporting the animals' (gut) health and immune function e.g. prebiotics, enzymes, antimicrobial peptides, chitosan, lysozyme, medium chain fatty acids/triglycerides, or plant extracts/phytogenics.

2.1.4. Housing and welfare

An environment that meets the needs of animals, limits stress and inhibits infectious disease is another important factor in reducing antibiotic requirements on farms. Housing systems can be optimized to promote animal health and comfort, reduce the occurrence of injuries and disease, and

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facilitate animal management. Appropriate temperature, ventilation and drainage are key to achieving optimal climate and air quality in a building. It is also important to allow enough space to avoid overstocking and ensure that all animals have adequate access to food and water of good quality, space to move around and rest comfortably with appropriate social contact.

2.1.5. Precision livestock farming

Precision livestock farming is the use of advanced technologies to monitor animal behaviour, characteristics, or other parameters in animals' surroundings in order to determine the health, wellbeing, reproductive, or productive status of animals. Sensor technologies generally measure something about an animal or their environment and feeds this information into a data monitoring system which analyses the data to automatically perform corrective actions or alert the farmer to intervene appropriately. Precision livestock technologies are useful management support tools which provides 24/7 monitoring of the farm and can measure parameters which cannot be detected by even the best farmers' eye. It often provides farms with early-warning systems before any clinical signs of illness appear, allowing for early intervention in health problems to help limit the need for antibiotic treatments.

2.1.6. Neonatal animals

Young animals are particularly susceptible to disease due to their immature immune systems. The health of young animals can be protected by keeping their environment warm, dry, clean, and well ventilated, and feeding them an appropriate diet. Colostrum is very important for acquired immunity in mammals since this first maternal milk feed contains high levels of antibodies as well as growth factors and other elements which set the animal up for life. It is also likely that the early environment, feeding and experiences of young animals have long-term effects on animal health and productivity through epigenetic mechanisms.

2.1.7. Behavioural change

Any antibiotic resistance management strategies require action to be taken by farmers and other industry stakeholders so that solutions can be implemented at the farm and animal level. Motivations and barriers are important considerations in order to enact change. For example, pig farmers in Belgium, France, Germany, Sweden and Switzerland have been found to be more concerned about financial and legal issues related to antimicrobial use than about antimicrobial resistance[5]. Veterinarians are typically responsible for prescribing and overseeing antimicrobial use in animals, but prescribing behavior can be influenced by a range of conflicting interests. For example, the expectation to safeguard public health can be perceived to conflict with the interests of farmers, and veterinarians rely on client satisfaction for repeat business. Furthermore, whilst diagnostic tests can provide valuable insights for prescribing appropriate treatments, they are often considered impractical and are not used due to their cost and the time taken to obtain results, thereby delaying immediate treatment.[6]

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3. Materials and methods

This second report is based on responses to a short online survey hosted on Google Forms. The survey was made available in eight languages (English, Danish, Dutch, French, Greek, Latvian, Romanian, Spanish) and was shared via the DISARM social media channels, newsletter, and the Community of Practice, as well as though the networks and channels of individual DISARM partners. Data was collected from October 2020 – December 2020.

The questionnaire included ten questions which aimed to identify research priorities regarding antibiotic stewardship in livestock farming according to relevant professionals.

Questions included were as follows and responses to each question were not mandatory:

1. What is your primary occupation?
    a. Farmer
    b. Researcher
    c. Veterinarian
    d. Agricultural advisor
    e. Other
2. Which country are you based in (i.e. country of work)?
3. Which livestock species do you work with?
    a. Pigs
    b. Cattle (dairy)
    c. Cattle (beef)
    d. Sheep
    e. Poultry (broilers)
    f. Poultry (layers)
4. Which of the following areas do you think have the most potential to improve animal health on farms? [a]
5. Which of the following areas do you think currently lack research and development relative to the others listed? [a]
6. In your opinion, how important are the following topics for reducing the overuse and misuse of antibiotics in livestock farming? [b]
7. Are there any specific questions you would like answered with regards to slowing the development of antibiotic resistance through improved animal health?
8. In what ways, positive or negative, have policy decisions impacted antibiotic usage and livestock health?
9. What challenges have you faced on farm, or in your daily work, when trying to improve livestock health and thereby reduce antibiotic usage?
10. What new trends do we need to respond to as an industry?
    a. Veganism
    b. Climate change
    c. Anti-science movement
    d. Geo-political issues affecting market access (e.g. Chinese relations)
    e. COVID-19 and future pandemics

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[a] Responses for questions 4 and 5 were collected in a matrix where respondents could select 'Across all species', 'Specific to poultry', 'Specific to cattle', 'Specific to sheep', and 'Specific to pigs' to any/all/none of these options:

- Farm animal welfare improvements
- Feeding and gut health
- Water quality
- Breeding, genetics and genomics
- Youngstock management and rearing
- Biosecurity (internal and external)
- Housing (e.g. stocking rates, ventilation)
- Vaccination protocols
- Precision livestock technology for early disease detection
- Alternatives to antibiotics
- Measuring and monitoring antibiotic use
- Institutional and social aspects of livestock farming
- Farm economics (e.g. cost-benefit analyses)
- Communication and advisory services

[b] Responses for question 6 were collected in a matrix where respondents could select 'Extremely important', 'Important', 'Unsure/indifferent', 'Not important', and 'Not at all important' to any/all/none of these options:

- Appropriate guidance on antibiotic usage (dose, duration)
- Targeting treatments for individual animals
- Alternatives to antibiotics
- Understanding motivations and barriers to changing practices
- Addressing farm-level challenges (e.g. lack of time, labour and money)
- Effective communication / advisory techniques
- Practicality of recommendations
- Cost-benefit analyses of control measures
- Financial situation of farms (i.e. viability and resilience of business)
- Societal / consumer demands
- Methods for early disease detection
- Improved measuring, monitoring and evaluation processes for antibiotic use
- Improving animal resilience (through breeding and immunity)
- Improved water quality and nutrition
- Improved stocking rate and ventilation
- Ways to detect and manage stress in livestock
- Improved management, housing and production systems
- A review of the veterinary business model and selling of antibiotics

Responses were translated into English for analysis. Data were analysed using Microsoft Excel (Microsoft Office 365 Business Version 2011) and open-responses were summarised and grouped according to similar topics to understand trends.

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4. Results

4.1. Responses to closed questions

The survey generated 290 total responses, the majority from veterinarians and farmers, respectively (Figure 1). Participants worked with a range of animal species (Figure 2) and responses were obtained from 14 countries (Figure 3), mainly from Spain (31%), Latvia (19%), Romania (17%), France (10%) and UK (7%).

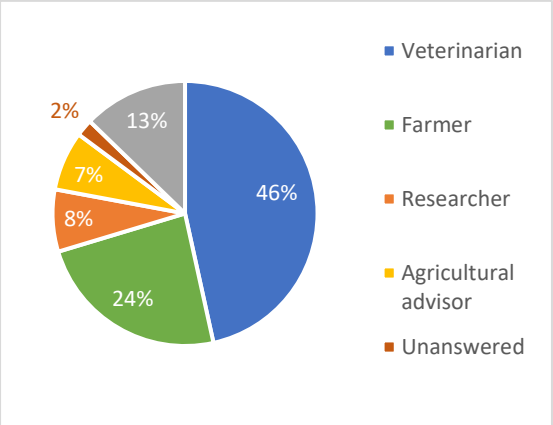

Figure 2 Primary occupation of respondents. "Other" responses included animal health policy makers and industry leaders, journalists, food supply chain actors, students, nutritionists and pharmaceutical company representatives.

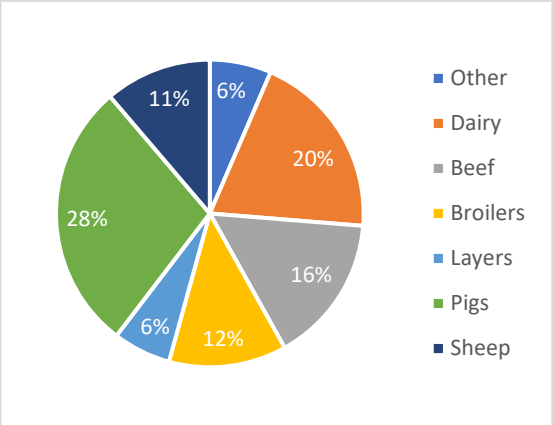

Figure 1 Livestock species respondents worked with. "Other" responses included goats, breeding poultry, rabbits, horses, fish, and human behaviour.

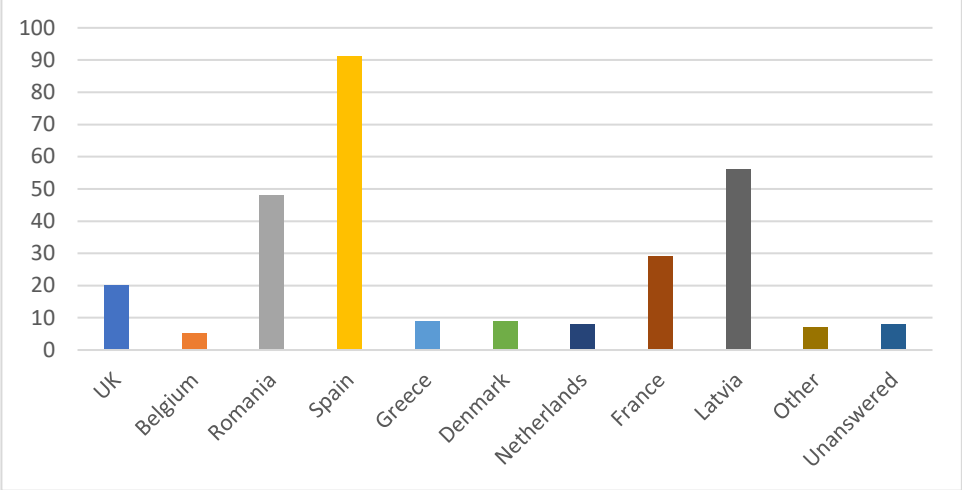

Figure 3 Respondents' primary country of work. "Other" responses included Austria, Ireland (n=3), North Macedonia, Iraq and the Baltics.

Responses were obtained from a range of professions in each country (Figure 4). Every country had responses from farmers, and veterinarian responses were only missing from Greece where there were more frequent responses from researchers. This range in occupation per country may reflect the different types of organisations who were promoting the survey as DISARM consortium partners. For example, AUA in Greece is an agricultural university, which could explain the large number of researcher responses, whereas the UK and Dutch partners, IfA and ZLTO, are largely farmer-facing organisations which might have contributed to the majority responses from those countries being from farmers.

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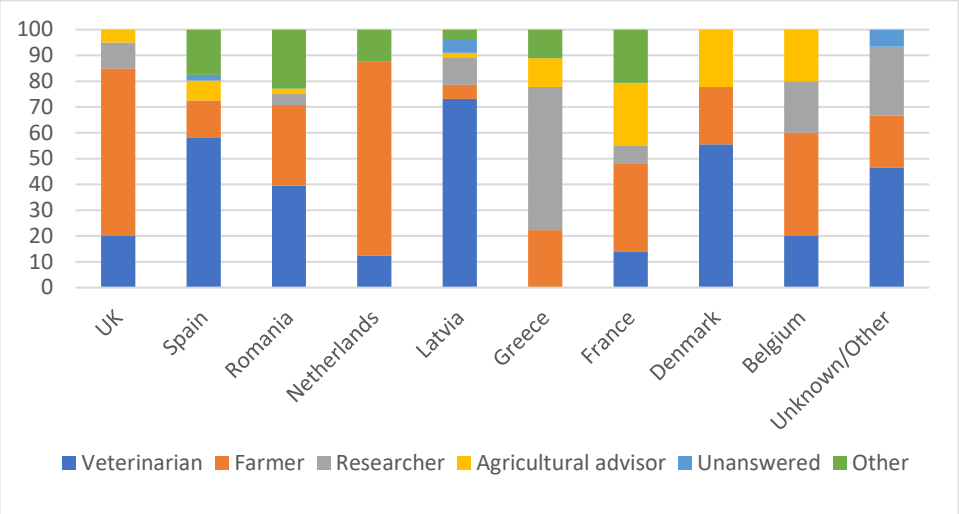

Figure 4 Percentage of respondents' occupations in each country.

All categories provided were considered to have potential to improve animal health on farms (Figure 5). Overall, feeding and gut health, biosecurity, housing and animal welfare were considered the most important contributors to animal health. Institutional and social aspects, and breeding, genetics and genomics were considered least important.

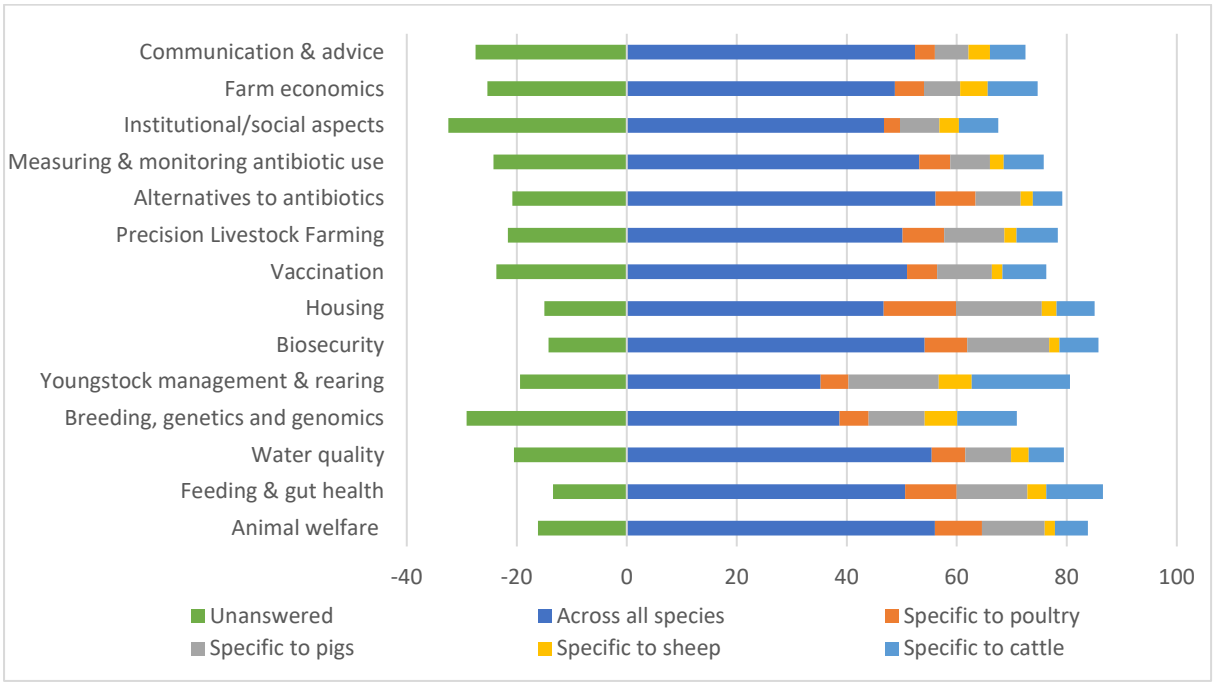

Figure 5 Proportional representation of responses to Q4. Areas with most potential to improve animal health on farms. Where participants did not select one of the five options, the response was classed as unanswered, and counted negatively as it was assumed to indicate a perceived lack of importance for that area.

As shown in Figure 6, current research and development efforts were perceived to be lacking in all areas listed, particularly with regards to precision livestock technology for early disease protection, alternatives to antibiotics, and animal welfare.

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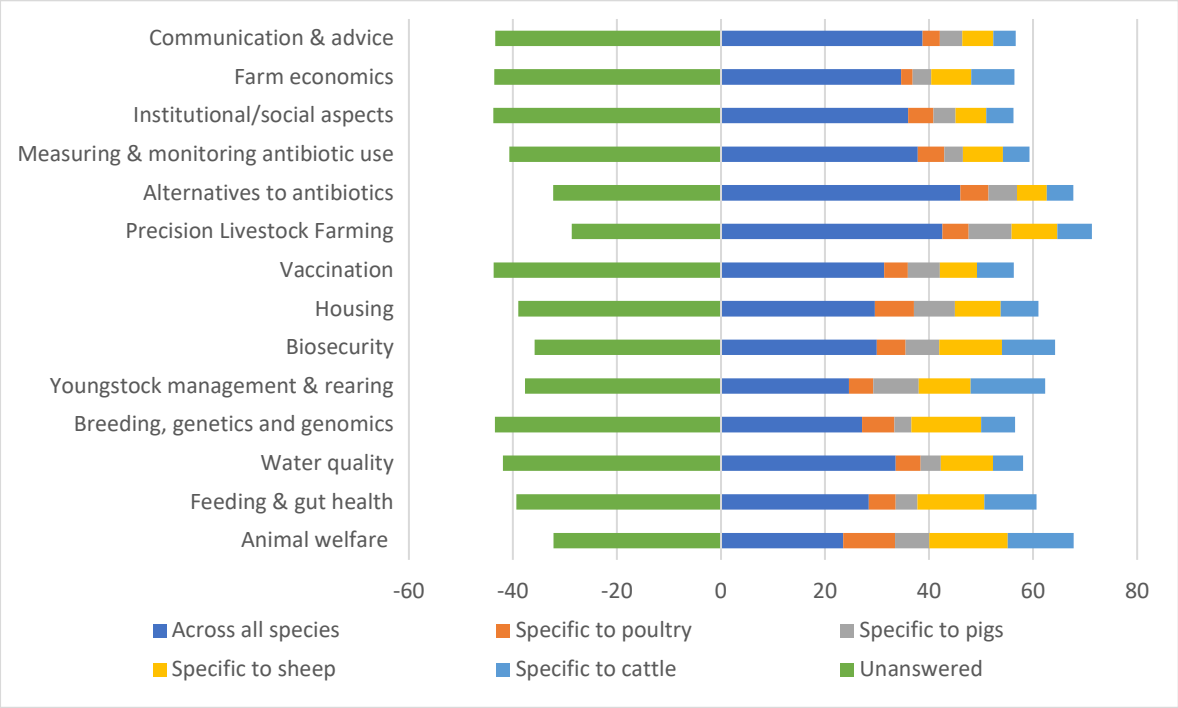

Figure 6 Proportional representation of responses to Q5. Areas which currently lack research and development. Where participants did not select one of the five options, the response was classed as unanswered, and counted negatively as it was assumed to indicate a perceived lack of importance for that area.

The most highly ranked area for reducing the overuse and misuse of antibiotics was early disease detection, whereas the veterinary business model selling antibiotics was rated least important (Figure 7).

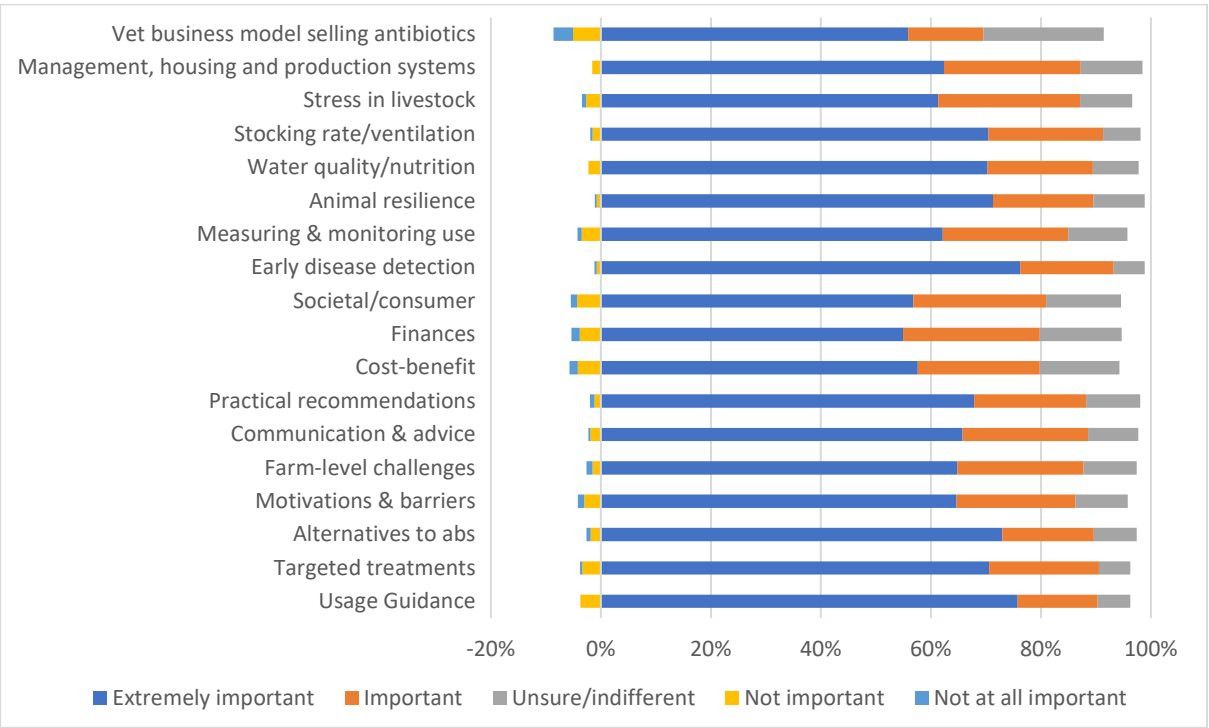

Figure 7 Proportional representation of responses to Q6. Importance of these topics for reducing the overuse and misuse of antibiotics in livestock farming. Non-responses (mean = 27 per topic, range = 20-35) were omitted from the data as this question offered opportunity to express positive, negative, and indifferent responses.

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The final question in the survey took a view beyond just antibiotic resistance, to gain insight into other priorities for the livestock farming industry. As shown in Figure 8, climate change was a key concern for respondents. This could in part be due to concerns around public perception of the industry; "other" responses indicated concerns around the relationship with consumers, particularly regarding animal welfare.

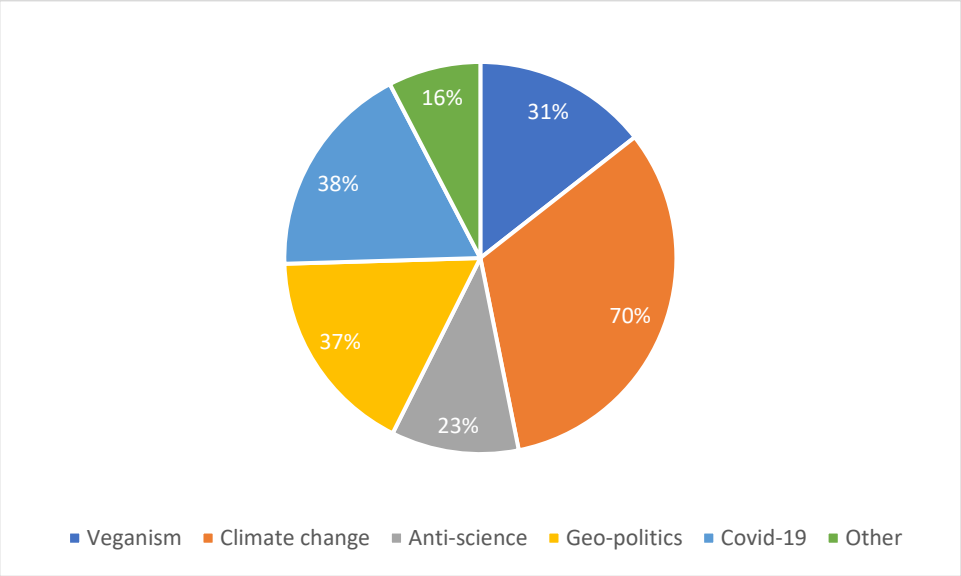

Figure 8 Proportional representation of responses to Q10. What new trends do we need to respond to as an industry? "Other" responses were focused on resource efficiency, sustainable farming and promoting local produce, and improving transparency and communication between consumers and producers to fight misinformation, increase awareness/value of animal welfare, and gain the confidence of consumers.

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4.2. Responses to open questions

4.2.1 Slowing the development of antibiotic resistance by improved animal health

Responses to question 7 regarding slowing the development of antibiotic resistance through improved animal health were grouped into six main categories:

- The effect of specific actions on farm
- Ways to encourage action at the farm level
- Monitoring antibiotic resistance
- Processes involved in antibiotic resistance
- The role of regulation

The effect of specific actions on farm

Respondents were interested to learn more about the impact of farm-level actions on antimicrobial resistance (AMR):

> *"Which specific actions on farms contribute to the spread and development of AMR?"*
> UK ruminant veterinarian.

> *"What are the actual effects of the measures implemented [on farms] on levels of AMR"*
> Irish social science researcher.

There was also interest in how actions taken to reduce the use of antibiotics affected farm performance:

> *"How to reduce the use of antibiotics whilst maintaining the technical and economic performance of farmers?"*
> French agricultural advisor for poultry.

> *"What is the sustainability of measures to reduce antibiotic use?"*
> Spanish ruminant veterinarian.

> *"Can we develop trials to show if increased spend on vaccination can result in lower spend on (and lower usage of) antibiotics?"*
> UK cattle veterinarian.

Ways to encourage action at the farm level

It was noted that control strategies must be implemented by farmers, so using social sciences to understand their actions and motivations is important to offer appropriate support and achieve further reductions in antibiotic usage:

> *"[We need to] understand the barriers and drivers to specific behaviours and tackle these issues pragmatically. [Actions] need to be beneficial – saving time, cost, hassle, and improving farmer, veterinarian and animal wellbeing. Updated knowledge transfer/exchange is needed to ensure messages are reframed to help uptake – not use the same old messages"*
> UK dairy farmer.

> *"What can be put in place to actively support farmers to essentially overhaul their whole farm practices/ behaviours/ habits?"*
> Irish sheep researcher.

The need to improve the availability of information and quality of advice was a concern for several respondents, with suggestions ranging from *"summarizing research results in simple language"*

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(Latvian researcher) to *"better distribution of impartial advice"* (response given by a UK cattle veterinarian, a UK beef farmer, a UK cattle farmer and a UK dairy farmer). Issues of transparency in knowledge sharing, and the expertise and conduct of advisors were also mentioned:

> *"All the large pig companies have launched pilot farms to reduce/eliminate the use of antibiotics in production but the results have not been made public. Sharing this kind of information would make Spain take a giant step in reducing the use of antibiotics"*
> Spanish pig veterinarian.

> *"Insufficient knowledge of farm advisors about udder health"*
> Dutch dairy farmer.

> *"Improve veterinarian guidance to stockmen"*
> UK sheep farmer.

Some also mentioned a need to improve the tools available to veterinarians to diagnose and prescribe appropriate treatments on farm:

> *"If the time between the farm sample, the result provided by the analysis laboratory, and the advice of the veterinarian is significantly improved (shortened), then the systematic use of a broad-spectrum antibiotic could be banned"*
> French ruminant researcher.

> *"How to make a choice for the most suitable antibiotics on farm?"*
> Latvian cattle veterinarian.

Monitoring antibiotic resistance

There were several questions about how antibiotic resistance is measured:

> *"How do we measure resistance at the farm level, and how can we monitor over time to see change?"*
> UK pig and ruminant researcher.

> *"What impact (in figures) does the reduction of antibiotics in animal production that has already been achieved have on the reduction of bacterial resistance to those antibiotics?"*
> Spanish pig veterinarian.

> *"How long is an antibiogram valid for?"*
> Spanish pig veterinarian.

A Dutch goat farmer also questioned the role and availability of monitoring in small scale farming systems:

> *"How can the screening for presence of pathogens and their level of resistance be improved in smaller livestock sectors e.g. no bulk tank milk sampling/screening in goat farming"*

Processes involved in antibiotic resistance

There were some questions regarding how antibiotic resistance is reduced by reducing antibiotic usage:

> *"How does use of antibiotics affect the development of resistance in commensal [bacteria]? How quickly does antimicrobial resistance degrade when antimicrobial use stops?"*
> UK cattle farmer

> *"Does resistance drop as the use of antibiotics decreases?"*
> Spanish pig veterinarian.

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There appeared to be some skepticism about the degree to which the livestock sector contributes to antibiotic resistance as part of a one health approach:

> *"What are the real consequences [of antibiotic use in livestock farming] on antibiotic resistance in humans?"*
>
> French poultry veterinarian.

> *"Is the percentage of responsibility for antibiotic resistance in humans actually allocated correctly?"*
>
> Spanish pharmaceutical company director.

This could be partly due to perceived misuse of antibiotics in human medicine:

> *"What is the relative weight of antibiotics used in animal health versus misuse in humans?"*
>
> Spanish pharmaceutical company representative.

> *"I think it is an exaggeration to blame resistance on the livestock sector, when irresponsible human self-medication is so common"*
>
> Spanish pig veterinarian.

The role of regulation

Several individuals highlighted the importance of regulation in the fight against antibiotic resistance, for example to *"control the use of antibiotics by justifying the need to use them by requiring a prescription"* (Romanian veterinarian). However, one French poultry farmer expressed concern that there was little accountability for others in the supply chain (breeders, feed suppliers), causing farmers to use antibiotics due to poor quality animals or feed:

> *"More traceability is needed on all the players in the sector. [Poor food quality, or contamination] leads to digestive problems/infections which require (antibiotic) treatments when originally the batch did not need it"*
>
> French poultry farmer.

There were some doubts about the effectiveness of policies in practice, both at the farm level, and with regards to international trade:

> *"How does bureaucracy interact with treatment practice?"*
>
> Spanish veterinarian working with pigs and beef cattle.

> *"While the EU is fighting AMR with one hand, with the other it is bringing products to the market from countries where the use of antibiotics is not controlled or regulated, making the product cheaper"*
>
> Latvian Industry Association employee working with poultry.

4.2.2. Impact of policy decisions on antibiotic usage and livestock health

Participants from a range of countries responded to question 8, so responses reflect perceptions about a range of national policies regarding antibiotic usage. Responses were grouped according to whether the impact of policy was perceived positively or negatively, or if ways to improve current policies.

Positive impacts

Many respondents cited the positive effects of policy as demonstrated by an overall reduction in antibiotic use. Reasons for this included increased awareness of AMR and the need to protect Critically Important Antibiotics, which helped to motivate the implementation of improvements to facilities, management and protocols on farms:

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"Thanks to the EU projects to reduce antibiotics, their use has been reduced in Spain without excessive impact on the pig farming economy"
Spanish pig veterinarian.

The support of industry was considered key to achieving changes at the farm level, and to securing a favourable public perception of the livestock sector:

"Retailer/processor demands through farm contracts has made farmers change practices"
UK veterinarian.

"It is the voluntary approach of industry through RUMA which works"
UK cattle and sheep farmer.

"Through coordinated action from government and industry we achieved an enormous reduction [in antibiotic use]. Legislation should focus on end goals rather than means goals, allowing sectors to take the lead rather than adding extra laws and regulations. The success of policy depends heavily on support from the actors; this way support can be achieved."
Dutch animal (pig) health policy officer.

"Better image [for the industry] (if we know how to communicate this to citizens)."
French poultry veterinarian

Danish respondents appeared particularly impressed by the effectiveness of specific policies in Denmark:

"Veterinarians are not allowed to earn money from the sale of antibiotics… registration of [antibiotic] consumption (farm and veterinarian) is required"
Danish cattle veterinarian.

"The Yellow Card (a Danish system) has lowered the use of antibiotic in swine production"
Danish dairy veterinarian.

Areas for improvement

However, despite many positive responses to the impact of policy and regulation, respondents also highlighted concerns that policies were not working as intended. A Danish dairy veterinarian believed that the Danish Veterinary Advisory Service Contracts which prevent veterinarians from profiting from antibiotic sales allowed too much freedom to farmers to access antibiotics:

"Veterinary Advisory Service Contracts have given farmers too much access to antibiotics. It would be okay if the farmer only had the option to treat with simple penicillins and retreatment if the veterinarian has started up with broad spectrum antibiotics"
Danish dairy veterinarian

"That veterinarians profit from selling antibiotics" (UK dairy farmer) was considered problematic by several respondents. In addition, respondents from Latvia and Romania indicated that farmers could too easily access antibiotics without input from their veterinarian:

"At the moment antibiotics are widely available to farmers without consulting the veterinarian"
Latvian veterinarian.

The importance of the farmer-veterinarian relationship, and clear messaging and support strategies was also highlighted by survey participants:

"Animals that have a bacterial disease need treatment and we need to ensure farmers and veterinarians are supported where they have legitimate high use, and provide training for those that have consistently high use. Government is not providing funding for training for support - e.g. industry have needed to fund this. Government is still seen as the stick not the

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carrot. Although there is a move through recent consultations on future farming and Animal Health and Welfare Pathway to change this."

UK ruminant researcher.

"Antibiotic use is partly driven by access, as demonstrated by the reduction in Critically Important Antibiotics, but it's important to also improve the veterinarian-farmer relationship to help identify reasons for antibiotic use, build mitigation strategies and ensure farmers are feeling they're getting a stronger service as a result."

UK beef farmer

However, some still appeared to prefer a system using regulation and penalties rather than support systems:

"Coaching is useless. Give the veterinarian a big stick instead of benchmarking"

Dutch pig veterinarian.

Furthermore, it might be necessary to apply a wider lens to identify and address issues which contribute to ill-health and antibiotic use. For example more focus on the eradication of immunosuppressive viruses like Porcine Reproductive and Respiratory Syndrome (PRRS) or bovine viral diarrhoea disease (BVD), or building regulations to ensure animal housing is fit for purpose:

"The immunosuppressive virus PRRS has generated a very large increase in the use of antibiotics, but there has never been an eradication plan at EU level"

Spanish pig farmer.

"Lack of building design standards is also an area of concern. Ventilation has been understood for decades but new buildings are still built with closed ridges and inadequate ventilation, effectively building the need for antibiotic use into the shed at the design stage"

UK beef farmer.

Negative impacts

A number of negative perceptions about policies were related to their practicality and ease of implementation at the farm level:

"Political decisions usually set a reduction target, but are not involved in the process"

Spanish pig farmer

"Policies have been imposed without managing the real impact on animal health and welfare"

Spanish pig genetics supplier.

"Too many rules developed from behind a desk"

Dutch beef farmer.

"Policy does not account for the huge individual change that needs to happen at farm level – regulation is coming before farms are able/have been prepared to change"

Irish human social and behavioural scientist.

This lack of cohesion between policies and what is happening on the ground might have unintended negative consequences. For example, some felt that restrictions encourage underhanded behaviour:

"Policies encourage the black market for medicines imported from countries without restrictions on antibiotic use"

Romanian agricultural advisor for pigs

"When we get a drug delivery, all of a sudden they expire after two months! In the past this used to be only after one year. We are not allowed to keep drugs older than two months. This is nonsense and destroys working capital. The government wants to be fooled by its own

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rules: everybody keeps a separate, secret, locker on another location on the farm. As long as the inspectors don't find any drugs older than 2 months"
Dutch beef farmer.

Restrictions on the type of antibiotics permitted for use in livestock was also perceived to reduce the effectiveness with which animal diseases could be treated:

"Reduction of very effective antibiotics for mastitis has made it much more difficult to cure"
UK dairy farmer

It is was also considered important to focus on the maxim: as little as possible, as much as necessary, rather than zero tolerance policy for antibiotic use in livestock farming:

"Potentially if we keep pushing a reduction message rather than responsible use messaging we'll end up with poorer health and welfare"
UK ruminant researcher.

Other negative opinions about policy were focused on perceived unfairness, in terms of the attribution of responsibility and cost of antimicrobial stewardship falling on farmers:

"Pressure on farmers who, on the whole, are already working well. Alternative methods are often more expensive without any repercussion on the final price for the consumer"
French agricultural advisor for Poultry

"It criminalises the use of antibiotics in livestock farming, compared to the almost complete lack of control on treatments in humans"
Spanish pig veterinarian.

4.2.3. Challenges to improving livestock health and reducing antibiotic usage

Responses indicated general challenges regarding the facilities and resources available on farms, in terms of animal housing, space available, and time and money to invest in improvements. Several responses indicated that there were negative impacts on animal health and welfare due to reduced antibiotic usage:

"Loss of efficiency, higher mortality and animals in poor health"
Spanish Genetics supplier

"Prolongs the time to heal and treatment is more complex"
Latvian veterinarian

Other challenges were categorized as follows:

- Changing attitudes and behaviours
- Perceived value of interventions
- Using appropriate treatments
- Available treatments/prevention strategies

Changing attitudes and behaviours

A key challenge for advisors was *"To fight against established habits"* (Spanish pig veterinarian) including *"Routine use and fear of disease"* (Irish pig and poultry researcher), and to deal with *"Egos"* (UK cattle veterinarian). An Irish human social and behaviour scientist summarized the complexities of changing behaviours related to animal health and antibiotic usage, and the need for veterinarians, farm advisors and farmers to work together:

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> *"It is not a simple behavior to change - in fact, there are several (tens) of behaviours that need to change to really bring about a reduction in the use of antibiotics at the farmer level - but also change at the level of e.g. veterinarians, farm advisors - this level of change requires a huge commitment from the individual farmer"*

Attitudes and behaviours might be linked to historic practices and experiences, and aversion to change:

> *"Farmers are not ready to accept that times have changed and it is not okay to keep the whole herd/flock on antibiotics for 2 months. Veterinarians are not ready to quit the giving of antibiotics for 3 days, 'just to be sure'"*
>
> Latvian livestock researcher.

> *"The owner of the farms request a particular treatment"*
>
> Danish veterinarian.

> *"Overconfidence in antibiotics. Resistance to evaluating alternatives. Resistance to doing 'different things' e.g. changes in management"*
>
> Spanish veterinarian.

It could also be challenging to continue beyond making an initial change:

> *"Improve and adapt the management, and then sustain and maintain without relapsing into old bad habits"*
>
> Belgium agricultural advisor for pigs.

Perceived value of interventions

There was perceived to be a *"low risk-reward ratio of implementing preventive measures to reduce antibiotic usage"* (Belgian pig researcher). Financial challenges were important considerations:

> *"Rejection by farmers because of the cost of the measures"*
>
> Spanish pig vet

> *"Every element that would increase the comfort of the animals costs a lot"*
>
> Romanian cattle farmer.

This was often attributed to there being *"[immediate] direct costs for the farmer, lack of long-term vision and no guaranteed return on investment"* (Spanish pig veterinarian). There might also be a tendency for farmers to want to solve problems by changing inputs into their system (treatments, feed etc.), rather than altering farm practices:

> *"The farmer almost always believes that things can be fixed from the outside, and not by changing the management"*
>
> Spanish pig veterinarian.

There was also some indication of competing priorities:

> *"Livestock farmers are faced with a great deal of challenges and have to comply with an infinite number of rules, which are constantly changing and which, moreover, regularly conflict with each other. For example, measures are imposed that are good for the environment but bad for animal welfare. Sows must be given more space in the farrowing pen, but piglet mortality must also be reduced. There are many examples. Livestock farmers want to achieve a great deal, but policy must be unambiguous and continuous. Livestock farmers are losing out."*
>
> Dutch animal health policy officer.

> *"Funding - antibiotic reduction is high on the agenda but funding for it is not."*
>
> UK beef and sheep researcher.

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Using appropriate treatments

Due to *"the multifactorial nature of diseases in livestock farming"* (French poultry group director), it can be difficult to establish the best preventative and/or treatment options:

> *"[Lack of] repeatability. Navel infections one year, try to address during the season but weather conditions, stocking density etc. change making it harder to be sure interventions are actually responsible for changes in antibiotic use. Likewise, vaccines one year appear to work well, fail to work (due to different challenge) the following year"*
>
> UK beef farmer

There were also difficulties in practicing prudent use of antibiotics:

> *"The message about 'reduction' rather than 'responsible use' leads to confusion in areas where it is appropriate to use antibiotics. Resulting in, for example, under dosing, delaying treatment or reserving antibiotics for worst cases. This leads to poorer welfare and increases the problem where it is a contagious disease."*
>
> UK beef and sheep researcher

> *"Sometimes we wait too long to treat, in efforts to avoid using antibiotics, but then face big losses so we are more prone to treat earlier, at the first signs of illness in future flocks"*
>
> French broiler farmer.

> *"Choosing the right option between not treating and/or using alternative products (with risks due to lack of proven efficacy) or treat with antibiotics when it could have done without"*
>
> French broiler farmer.

These difficulties in selecting appropriate treatments were sometimes attributed to limited diagnostics and data monitoring:

> *"Lack of an antibiogram as soon as possible"*
>
> Romanian dairy veterinarian.

> *"It is not possible to find the specific pathogen, therefore no specific treatment can be used"*
>
> Danish dairy farmer.

> *"Capturing the reasons for use of medicines on farm is a challenge"*
>
> UK dairy vet

Available treatments/prevention strategies

Another challenge mentioned by respondents was *"Curing disease with a limited armoury of medicines"* (UK dairy farmer). Options for *"feasible and fast-acting economic alternatives [for antibiotics]"* (Spanish pig veterinarian) are limited. Furthermore, alternative treatments/prevention strategies, e.g. nutritional supplements might not be well known by farmers and veterinarians:

> *"Farmers and veterinarians have little knowledge of what probiotic and prebiotic products work to improve health and immunity"*
>
> Spanish nutritionist.

In addition, although vaccines can be useful in safeguarding animal health and reducing antibiotic requirements, there are some limitations to their use:

> *"Lack of effective vaccines against some pathogens"*
>
> Spanish pig veterinarian

> *"Small doses of vaccines are not available for poultry in Latvia, there are no registered vaccines for combating sheep respiratory and foot diseases"*
>
> Latvian veterinarian.

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5. Discussion

The survey responses covered a range of countries, sectors and professions, obtaining a good spread of opinions. Feed and gut health, biosecurity, housing and animal welfare were most commonly selected as most important elements of animal health. Precision livestock technology for early disease detection, alternatives to antibiotics and animal welfare were the most common areas seen to require more research and development efforts, and early disease detection was considered by most respondents to be a key areas to reduce overuse and misuse of antibiotics. However, there was little difference between rankings of all areas listed, so insights are limited due to the survey design. Although it was considered important to allow an option to highlight areas of importance in different livestock sectors, most respondents selected "across all species", and use of a Likert scale to rank the importance of listed areas might have given more clear delineations. These results are similar to those from the First Research Prioritisation Report, in which precision livestock technology and feeding and gut health were both considered in need of further work and to have the greatest impact on antibiotic resistance management in livestock systems.

Responses to open questions provided additional insights into the perspectives of respondents. These qualitative answers indicated a demand for more information about how specific actions taken the farm level (to improve animal health) affected farm performance and levels of AMR. Improved monitoring of antibiotic resistance, and research investigating processes involved in its development and reduction were considered necessary to prove the degree to which livestock farming contributed to AMR as part of the 'One Health' approach. Participants appeared sceptical about the impact of livestock farming on overall AMR, and felt that the livestock industry was being scapegoated whereas antibiotic usage in human medicine was poorly regulated by comparison. Unfairness was also perceived to stem from trade agreements that allowed import of cheaper food produced in countries without restrictions on antibiotic usage.

The need to influence attitudes and behaviours was highlighted in both last year's report, and this year's survey. Farmers and veterinarians must be convinced of the need to reduce antibiotic use for farm animals before taking action. Behavioural change strategies, cost-benefit analyses, antibiotic use and animal health surveillance/monitoring and policy may all play a role. Collaboration between government, veterinary organisations and other important stakeholders within the livestock sector resulted in significant reduction in antimicrobial usage of farms in the Netherlands through a combination of compulsory and voluntary actions with clear reduction goals[7]. In some cases, preventing disease (thereby reducing antibiotic requirements) might require changes to infrastructure e.g. newer buildings with easily disinfected materials to house animals, or other long-term investments to protect against the need for short-term antibiotic solutions to animal health problems. These changes are not easy to achieve and greater support systems are needed to encourage changes towards improved animal health and reduced antibiotic reduction. Any solutions must be feasible, affordable and practical at the farm level, and policy regulations must be realistic and achievable for farms.

Respondents also appeared to be concerned about public perception, and many respondents indicated that improved communication was needed between producers and consumers/the general public. In addition to antibiotic resistance, climate change was most commonly selected as a priority concern for the livestock sector.

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6. Conclusions

The data presented in this report are indicative of some key areas for attention. Firstly, there is a demand for more global cooperation and action regarding antibiotic use in different countries as part of a One Health approach, including improved monitoring systems for antibiotic use and trade policies which avoid penalising local producers who are held to higher standards than for imported products. All livestock industry actors should work together towards a common goal which might be facilitated by improvements to policy and legislation. A key area of interest was in achieving behavioural change at the farm level to reduce antibiotic usage, by showing farmers the cost-benefit of suggested solutions, the most effective interventions for their farm, and development of effective preventive measures, early disease detection methods, rapid on-farm diagnostics and alternative treatments. To avoid disillusionment of actors in the livestock sector, evidence of the contribution of different sectors to antimicrobial resistance, and clearer regulation on use of antibiotics in human medicine are needed.

7. Recommendations

The key areas of interest for antibiotic resistance management in livestock farming that were highlighted in the First Research Prioritisation Report were:

- Behaviour change to reduce antibiotic usage at the farm level: how to engage with tenacious high-users and facilitate positive attitudes towards improving animal health and reducing antibiotic treatments?
- Early disease detection and rapid on-farm diagnostics including precision livestock technologies: can more/better/affordable options be developed to allow for early intervention in animal health?
- Disease prevention strategies: what are the most effective interventions, and what is the cost-benefit of implementation?
- Health and antibiotic usage monitoring: can different countries establish suitable monitoring systems to allow for benchmarking between individual farms and compare national averages?

The data from this year's report do not challenge the previous recommendations. Results indicate that effective support systems should be investigated so that policy recommendations can be improved.

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