Informing the Debate

Michigan Applied Public Policy Brief

A One Health Approach to Information Seeking and Sharing about Antibiotic Resistance among Agriculture Producers and Veterinarians

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Informing the Debate

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Informing the Debate

MAPPR Policy Research Brief

A One Health Approach to Information Seeking and Sharing about Antibiotic Resistance among Agricultural Producers and Veterinarians

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EXECUTIVE SUMMARY

Antibiotic resistance is a complex problem that requires solutions crossing many sectors. One Health is the concept that human, animal, and environmental health are interconnected and that the knowledge and study of these interconnections have benefit. Antibiotic resistance is one example of a One Health challenge.

The policy environment is evolving as there have been many efforts at national and international levels to combat antibiotic resistance. Thanks to advances in computing and communication technology, information about antibiotic use and resistance such as recent development or policy change is available in mass amounts and in many forms. However, we have limited knowledge about what stakeholders' information practices look like when making decisions in relation to antibiotic use.

This research project took the One Health approach by taking human, animal, and environmental health into account in addressing antibiotic resistance. Specifically, this project focused on veterinarians who sit at the nexus of decisions about antibiotic use as they interact with major stakeholders and function as the gatekeepers.

Data from interviews show that veterinarians believed that antibiotics are used appropriately in most farms. However, interviews also revealed concern regarding inappropriate use of over-the-counter and feed grade products. Participants were aware of both opportunities and barriers to reduction in antibiotic use. Most participants argued that veterinarians should become more effective communicators and serve as educators that provide producers with relevant and necessary information to reduce antibiotic use in farm animals. Our data also indicates that veterinarians utilize various online and off-line sources to obtain antibiotic-related information although they prefer human information sources such as coworkers.

Based on our data, we created a knowledge-sharing platform, a one-stop place, where anyone can find relevant and credible online resources on antibiotic use and antibiotic resistance. The platform stores a list of internet resources curated by our research team using specific criteria (i.e., accessibility, relevance, and credibility). It provides key information on each internet resource including URL, topics covered, description, and keywords.

Lastly, we suggest three aspects that may be considered when developing policies related to mitigation of antibiotic resistance; (1) identifying forums and opportunities for communication among stakeholder groups for sharing decision-making strategies and new information about antibiotic use, (2) creating more opportunities for veterinarians and producers to meet in person, and (3) taking a holistic approach that focuses on structural change in food animal agriculture.

INTRODUCTION

This document reviews a project completed with support from the Michigan Applied Public Policy Research Grant Program. It describes the issue of antibiotic resistance as a One Health challenge that holds significant policy dimensions. The report presents insight into veterinarians' decision-making, information-sharing and communication patterns associated with antibiotic use as a basis for the design of a knowledge sharing platform about antibiotic use and resistance. The study focused on a network sample of veterinarians in Michigan, but could be scaled up to other populations. The platform is described as a proposal for its maintenance. Study conclusions and directions for future research are provided.

OVERVIEW OF ANTIBIOTIC RESISTANCE

The introduction of antibiotics has transformed the way human and animal infectious diseases are treated, controlled, and prevented. However, the rapid emergence and spread of antibiotic resistance has become a global problem. The World Health Organization (WHO) defines antibiotic/antimicrobial resistance (AMR) as the ability of a microorganism (like bacteria, viruses, and some parasites) to stop an antimicrobial (such as antibiotics, antivirals and antimalarials) from working against it. Experts suggest that the antibiotic resistance crisis can be attributed to many factors including the overuse and misuse of antibiotics in humans, animals, and agriculture, and limited efforts by the pharmaceutical industry[1] to develop new drugs due to numerous scientific, regulatory and economic barriers[i]. Globalization and urbanization also contribute to the rise of antibiotic resistance because they increase the likelihood of dissemination of resistance through interaction between humans and various environments[ii].

Antibiotic resistance is a growing and urgent health threat to human, animals, and the environment. The WHO has identified antibiotic resistance as one of the greatest threats to global health[iii]. According to the Centers for Disease Control and Prevention (CDC), annually over two million illnesses and 23,000 deaths are caused by resistant bacteria in the U.S.[iv] Studies conducted by RAND Europe and KPMG for the UK's Review on Antimicrobial Resistance estimated that global antibiotic resistance is responsible for over 700,000 deaths annually, and predicted exponential rise in global deaths due to antimicrobial resistant bacteria to above 10 million per year by 2050[v].

Antibiotic resistance is a complex problem requiring solutions that cross sectors. For example, antibiotics used in animals may select for resistant bacteria which could be ingested by humans when they consume food, or may contaminate environments as resistant bacteria from animal production facilities spread through air, water, and soil[vi]. A

[1] Pharmaceutical companies' incentive to develop new antibiotic is limited because a new antibiotic, to which bacteria are susceptible, only will be used in a limited number of patients in which other antibiotics aren't working. This will decrease the companies' earnings because of few doses needed.

recent report from the American Academy of Pediatrics emphasizes a need for judicious use of antibiotics in animals because of the link between antibiotic use in food-producing animals and the occurrence of antibiotic resistant infections in humans[vii]. Figure 1 below demonstrates how human, animal, and environmental health are interconnected in the context of antibiotic resistance.

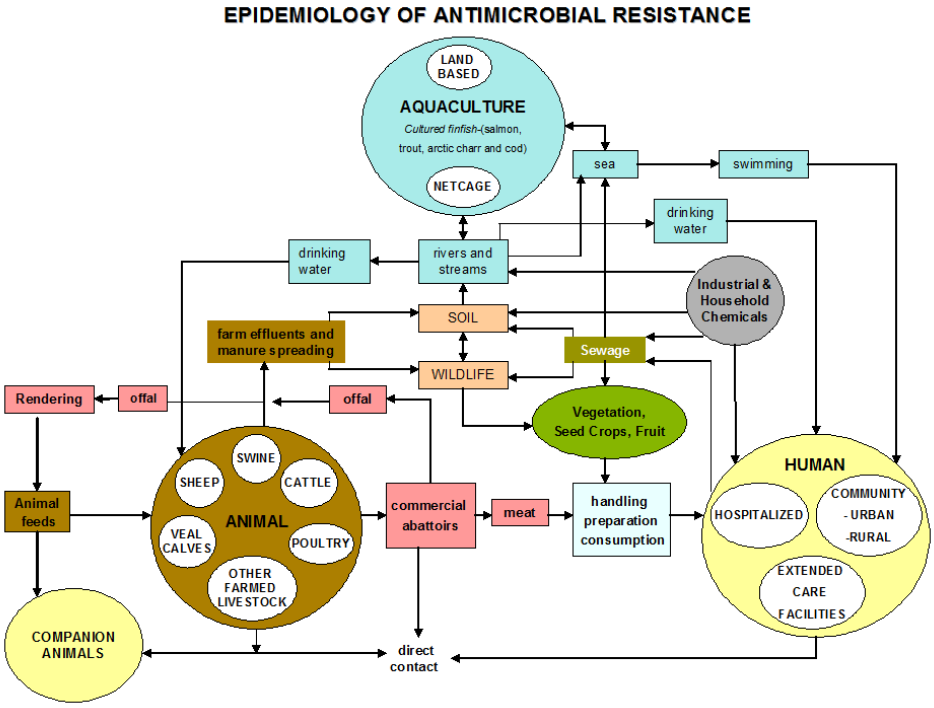

Figure 1. Epidemiology of Antimicrobial Resistance[viii]

National and International Efforts to Combat Antibiotic Resistance

There have been a number of efforts at national and international levels to combat antibiotic resistance. In November 2013, President Obama tasked his President's Council of Advisors on Science and Technology (PCAST) with making practical and actionable recommendations concerning how the Federal Government can best combat the rise of antibiotic resistance that is threatening the health of Americans and people around the world. This report, entitled "Report to the President on Combating Antibiotic Resistance[ix]," was published in September 2014. In March 2015, the administration released the "National Action Plan for Combating Antibiotic-Resistant Bacteria[x]". This is a comprehensive plan that identifies critical actions for key federal departments and agencies to enhance diagnosis and treatment of diseases and limit the spread of antibiotic-resistant bacteria. In addition to the White House administration's action plan, USDA has published "Antimicrobial Resistance, Action Plan[xi]" and in 2013 the CDC released their report: "Antibiotic Resistance Threats in the United States, 2013[xii]". There are also several position statements from the Food and Drug Administration (FDA) on their role in combatting antimicrobial resistance. Most recently, a group of experts including physicians,

veterinarians, and infectious disease researchers convened by the George Washington University Milken Institute School of Public Health released a report dated August 2017. The report, Combating Antibiotic Resistance: A Policy Roadmap to Reduce Use of Medically Important Antibiotics in Livestock, proposes a roadmap to reduce antibiotic use in food-producing animals[xiii].

WHO made antimicrobial resistance a priority, and published a global action plan in May 2015 urging member states to develop national strategic plans to combat antimicrobial resistance[xiv]. A WHO initiative, the Global Antimicrobial Resistance Surveillance System (GLASS supports the global action plan which aims to create standardized, comparable, and validated data on antimicrobial resistance[xv]. During the United Nations (UN) General Assembly high-level meeting on AMR in September 2016, all 193 UN member states agreed to develop national action plans aligned with the WHO's Global Action Plan on AMR and a One Health approach.[xvi] The WHO Interagency Coordination Group on Antimicrobial Resistance was officially established in March 2017 to provide practical guidance in support of the Global Action Plan on AMR[xvii]. In addition, governments and industry leaders publicly committed their support to action to combat AMR. At the 2016 World Economic Forum, more than 90 pharmaceutical, biotechnology, and diagnostic companies and industry associations signaled their collective intent to align priorities and support global efforts to address the threat of AMR by issuing a joint declaration.

Moreover, because of the presence of multi-drug resistant bacteria in food animals and their adverse impact on human health, regulatory organizations around the world have promulgated rules to reduce or cease the use of antimicrobial drugs in animal agriculture. For example, the FDA also has implemented Guidance for Industry #213[xviii], which will remove the use of antibiotics for growth promotion, and the Veterinary Feed Directive (VFD) rule[xix], which increases veterinary oversight of antibiotic use in animals. At the state level, Michigan is investing resources to promote public and healthcare professional awareness of the appropriate use of antibiotics partnering with the Michigan Antibiotic Resistance Reduction Coalition, and providing information regarding the VFD on the Michigan Department of Agriculture & Rural Development website.

Understanding Veterinarians' Information Practices and Decision-Making Process in Relation to Antibiotic Use: A One Health Approach

One Health is the concept that human, animal, and environmental health are interconnected and that the knowledge and study of these interconnections has benefit. Antibiotic resistance, zoonotic disease, and climate change are penultimate examples of One Health challenges. The concept has gained traction globally over the last 10 years, largely in veterinary and human health disciplines[xx], mainly as a way to promote cross-disciplinary training of clinicians. The United States Centers for Disease Control and Prevention (CDCP), World Health Organization, World Bank, Food and Agricultural Organization of the United Nations (FAO), World Organization for Animal Health (OIE) and

others have begun to shape policy and practice in this area[xxi]. More recently, the concept has functioned as a research approach and incubator. In particular, it serves as a framework for studying complex systems and for bringing together diverse academic disciplines to examine these systems[xxii].

The science of antibiotic use and its impact on human, animal, and environmental health is complex and as a consequence, so is the information environment. Advances in the last five years in computing and communication technology make it possible to provide veterinarians and producers with all the information they might desire for making decisions about antibiotic use. This information is available in massive quantities and in many forms. However, we have little knowledge about whether they want it, what they currently use, what they need, how they perceive the existing information environment, and how much of this information is actually utilized by producers and veterinarians when making decisions in relation to antibiotic use. Identifying the most effective ways to communicate complex information regarding AMR such as recent development or policy changes requires a deep understanding of information practices of the people who would use that information.

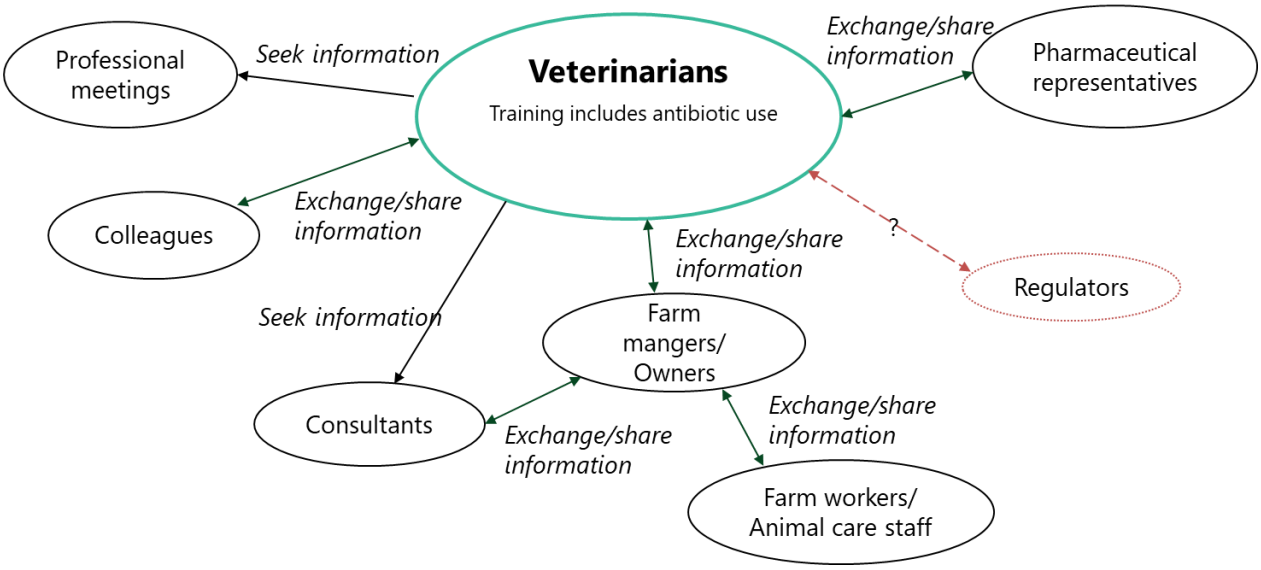

Figure 2. Decision Map: Antibiotic Use in Food Animals

This research project took the One Health approach by taking human, animal, and environmental health into account in addressing antibiotic resistance. In doing so, our focus was on veterinarians in the context of antibiotic use in food animals. As Figure 2 above shows, our key informant interviews indicated that veterinarians play a key role in this context as they are at a position where they interact with major stakeholders and they regularly make decisions about whether and how to use antibiotics. We believed this would be a good starting point to examine how decisions about antibiotic use are made in food animal agriculture and what stakeholders' information practices look like in this context.

Specifically, the goals of this research project included:

(1) examine veterinarians' decision-making process and information practices in the context of antibiotic use,
(2) identify currently available public online resources on antibiotic use and antibiotic resistance, and
(3) create a knowledge-sharing platform that can help stakeholders better understand the AMR problem and optimize their decision-making around the use of antibiotics in animals.

PART 1: INTERVIEW STUDY

To better understand veterinarians' decision-making process and information practices around antibiotic use and antibiotic resistance, we interviewed 14 food animal veterinarians who have been practicing in Michigan and four veterinary students who are currently enrolled in the Large Animal Clinical Science Department at Michigan State University. Through semi-structured interviews, data about factors influencing veterinarians' antibiotic prescribing decisions, their information practices, including sources veterinarians use to seek information about antibiotics, and antibiotic resistance and preferences towards information sources, and veterinarians' perception of antibiotic use were collected. A questionnaire, which was completed by each participant at the end of the interview, was used to capture background information about the veterinarian and their perception of the issue of antibiotic resistance in general.

Description of Participants

Out of 18 study participants, nine (50%) were females. The average age of the participants was 43.2 years with a range of 23 to 71 years (SD = 15.3). Among 14 food animal veterinarians, most participants worked in private practice with eight participants owning the practice. They have been practicing for 22 years on average (SD = 13.8). They reported spending approximately 74.6% of their time on dairy cattle and 9.9% of their time on beef cattle. On average, participants served 26.8 beef farms (SD = 22.0) with 36.8 head (SD = 24.8) per farm, and served 56.8 dairy farms (SD = 52.2) with 785.4 head (SD = 769.2) per farm. As for the four veterinary students, based on their estimate, they spent approximately 37.8% of their time on small animals, 30% on dairy cattle, 19.3% on horses, and 12.5% on beef cattle.

Veterinarians' Perception of Antibiotic Use

The results indicate that veterinarians tend to disagree that antibiotic resistance is a severe threat to domesticated animal health, wildlife, and the environment and believe that antibiotics are used appropriately on most farms. When asked about their perception of antibiotic use in general on a scale of 1-7 (1 = strongly disagree, 7 = strongly agree), participants tend to agree that the amount of antibiotics used in beef and dairy production is appropriate while they tend to disagree that the amount of antibiotics used in human

health is appropriate. Participants also tend to agree that antibiotic resistance is a severe threat to human health while they tend to disagree that antibiotic resistance is a severe threat to domesticated animal health, wildlife, and environment. (See Table 1 below for details.)

Question about perception of antibiotic use in general	Mean	Min	Max	SD
In general, I think the amount of antibiotics used in beef production is appropriate.	**5.1**	2	7	1.3
In general, I think the amount of antibiotics used in dairy production is appropriate.	**5.1**	3	6	0.8
In general, I think the amount of antibiotics used in human health is appropriate.	**3.0**	1	6	1.4
I believe antibiotic resistance is a severe threat to domesticated animal health.	**3.8**	1	7	2.0
I believe antibiotic resistance poses a severe threat to wildlife.	**3.3**	1	5	1.5
I believe antibiotic resistance is a severe threat to human health.	**5.2**	1	7	1.6
I believe antibiotic resistance is a severe threat to the environment.	**4.0**	1	7	1.7

Table 1. Veterinarians' Perception of Antibiotic Use in General

Note: n=18; a 7-point Likert-type scale (1 = strongly disagree, 7 = strongly agree) was used.

When asked about concerns regarding the way antibiotics are used in farms, participants typically indicated that they do not have concerns about the amount of antibiotics used in farms for the majority of animal agriculture farms, and that they believe that producers with whom they work use antibiotics appropriately. They, however, showed some concern regarding inappropriate use of antibiotics especially in relation to over-the-counter products and feed grade products.

For example, some veterinarians stated that as it is easy for producers to obtain over-the-counter products, although it is a small fraction of the total number of producers, there are producers who buy and use them to treat animals rather than using other drugs that are more effective. Moreover, participants indicated that in such cases, producers tend to use antibiotics inappropriately because they administer drugs on their own with no guidance or education from veterinarians, resulting in incorrect dosage including the overuse of drugs. Participants added that it is likely that those producers own small farms with a few animals where veterinarians do not visit on a regular basis, so it is more likely that there is little or no control by veterinarians over the use of antibiotics on those farms.

Policy as an Opportunity for Communication about Antibiotic Use

Many participants mentioned that Veterinary Feed Directive (VFD) changes which took effect in January 2017, have served as a good opportunity to discuss antibiotic-related issues with producers, ultimately helping them educate their clients about appropriate use of antibiotics. As the VFD requires producers to come to veterinarians to use all medically important antibiotics in feed or water for food animals, participants stated that this allows them to have more opportunities to talk with producers in the first place. For instance, one participant (S02) said "we're doing a lot of the VFDs so we've actually had more discussions about resistance and appropriate use of antibiotics in the past month and a half than I've had probably in the past six months." Some participants also stated that they have valued these increased opportunities because they could have conversation not only about treatment (e.g., appropriate use of antibiotics) but also about prevention (e.g., changes in management practices).

Moreover, veterinarians indicated that the VFD changes have allowed them to become aware of the fact that many producers who previously did not use their veterinary expertise to make antibiotic treatment decisions. They tend to use antibiotics out of habit because they cannot get optional drugs over the counter. Participants argued that the VFD is a good first step to help them get more control over the use of antibiotics. The VFD creates opportunities to have discussion with producers and to educate them about the use of antibiotics, especially in places where veterinarians previously did not work often (e.g., small hobby beef producers). For example, one participant (S09) stated that "I think we've been taking steps to address those [small hobby beef producers]. I think the veterinary feed directive is a good first step into that."

Opportunities and Barriers to Reduction in Antibiotic Use

Opportunities to Reduction in Antibiotic Use

When asked about opportunities for reduction in antibiotic use in farm animals, participants suggested several ways to help reduce the use of antibiotics on farms in terms of both treatment and prevention of disease. As for treatment, participants indicated that it is important to educate producers including managers as well as employees who are responsible for administration of drugs on farms about appropriate use of antibiotics. They mentioned revitalization of extension services through universities including producers' meeting, and provision of online educational resources as ways to educate producers.

Veterinarians along with farmers reported that, appropriate use of antibiotics brought prevention of disease and reduced antibiotic use on farms. Many participants stated that better management systems and preventative strategies would ultimately lead to reduction in antibiotic use by preventing diseases in the first place. Veterinarians noted that if producers reduce stocking densities, improve ventilation, bedding, and nutrition, and use vaccines, such changes would decrease the likelihood of disease occurrence, and consequently decrease antibiotic use in farm animals.

Barriers to Reduction in Antibiotic Use

When it comes to barriers to reduced antibiotic use, participants reported that people and money are two major factors that prevent changes that could result in reduced antibiotic use on farms. Many participants mentioned inertia as a barrier to reduction in the use of antibiotics because producers tend to show resistance to change, saying "this is the way we have always done things" or "we have never done this before." To overcome inertia of existing practices of producers, some participants suggested that ways in which veterinarians present decisions to their clients (i.e., producers) matter because veterinarians would need to convince producers to do something new. A few participants also stated that the issue of inertia applies not only to producers but also to veterinarians, as there are veterinarians who resist change in their practices.

Another barrier to reduction in antibiotic use related to financial constraints. Participants said that it is difficult for producers to make management changes for disease prevention due to costs. Moreover, some participants indicated that there are producers who are reluctant to follow the VFD rule and not willing to have discussion with veterinarians in relation to the VFD because of cost.

Role of Veterinarians in Reduction in Antibiotic Use

Given above-mentioned opportunities and barriers to reduction in antibiotic use, participants were asked about the role of veterinarians in reducing antibiotic use in farm animals. Most participants argued that veterinarians need more effective communication skills. They stated that veterinarians could educate and train farmers to promote judicious use of antibiotics, including assessment of disease, dosage, and routes of administration as well as promoting good recordkeeping to avoid human error. Moreover, participants reported that veterinarians need to help their clients participate in due diligence in farm management including nutrition, environment, and vaccination to prevent diseases in the first place. In relation to this, participants emphasized that veterinarians should keep current on relevant information including research and policies about antibiotics because they serve as a primary source of related information. Veterinarians need to be able to interpret scientific information and explain it to producers in layperson's language.

Information Seeking Practices of Veterinarians

Information Sources Used to Obtain Antibiotic-Related Information

These results indicate that participants utilized various sources to obtain antibiotic-related information. Information sources they use include colleagues (e.g., coworkers, other practitioners, and people at universities), pharmaceutical companies (e.g., drug company representatives and company websites), continuing education meetings, professional organizations, peer-reviewed publications, and specialized online resources (e.g., Plumb's Veterinary Drugs and Food Animal Drug Residue Avoidance & Databank (FARAD)). Along with these various sources, participants mentioned that their own experience and daily working knowledge are one of main sources of information.

Depending on types of information they need, veterinarians appear to use multiple sources to obtain information about antibiotics. For example, they look for specific information about a certain drug such as dosage, contradictions, safety, and route of administration using the Plumb's Veterinary Drugs, while they obtain information about extra label use of drugs and relevant withdrawal time from FARAD. They also acknowledged that information from pharmaceutical companies could be biased.

In addition to information sources mentioned above, a few participants said they use industry press (e.g., periodicals), extension services through state governments or universities, university websites, drug labels, and laboratory results. It seems that veterinarians need specific information about antibiotics and treatment rather than general information to choose a medication that work. They place value on evidence-based and unbiased information to support their decisions.

Use of Technology in Seeking Antibiotic-Related Information

When asked specifically about technologies they use to seek information about antibiotics, most participants said that they use face-to-face conversation, phone calls, and emails to seek information, while some participants mentioned the Internet, desktop computers or laptops, or mobile applications. They look for journal articles online regarding which drugs to use for treatment, dosage, side effects, and contraindications.

It appears that participants believe that simple technologies they are currently using (e.g., phones and emails) would be sufficient for their daily work. Most had never thought about new information and communication technologies that may help seek information about antibiotics because they felt no need for it. Although most participants said that they had never wished for any new technology for their work, a few participants stated that a database or application offering convenient access to empirical data based on clinical experiences would be useful.

PART 2: CREATION OF A KNOWLEDGE-SHARING PLATFORM ABOUT ANTIBIOTIC USE IN FOOD ANIMALS

Veterinarians in our sample want to play a role of information intermediary, serving as a primary source of information on antibiotics for their clients, producers, and know the importance of keeping up to date with new developments. Although participants stated that they take little advantage of emerging information and communication technologies in their daily work, we believe that there is a potential for technologies in helping veterinarians make more informed decisions with online resources to obtain specific information on drug treatment. Therefore, as an initial step toward developing new information and communication technologies for agricultural professionals, we have created a knowledge-sharing platform to help people keep up to date by offering a one-stop place where anyone can find relevant and credible online resources on antibiotic use and antibiotic resistance. In short, the knowledge-sharing platform is a website storing useful, curated online resources on antibiotic use in food-producing animals and antibiotic

resistance in human, animal, and ecological health for eXtension and Extension educators and other animal health stakeholders including veterinarians and producers.

Specifically, a knowledge-sharing platform, named "Animal Antibiotic Use," was created to meet the following objectives:

(1) Provide useful, curated online resources on antibiotic use in food-producing animals and antibiotic resistance in human, animal, and ecological health for eXtension and Extension educators and other animal health stakeholders (e.g., veterinarians, producers, etc.)
(2) Promote awareness and understanding of antibiotic resistance
(3) Promote policy-related and science-based decision making about the use of antibiotics

Procedure for Creation of a Knowledge Sharing Platform

We first identified candidate websites that contain relevant information related to topics including decisions about antibiotic use in food-producing animals, antibiotic resistance, antibiotic stewardship, antibiotic use policy, antibiotic resistance policy, and impact of antibiotic resistance on human, animal, and environmental health. For this, a research assistant reviewed websites participants mentioned during interviews, websites researchers found when designing this research, and websites found through Google search using the key words above.

Once identification of candidate websites was complete, an evaluation of each website was performed based on criteria to determine whether to include the website in our knowledge-sharing platform. Each website was assessed in terms of (1) accessibility, (2) relevance, and (3) credibility (See Table 2 below for details).

Dimension		**Inclusion Criteria**
Accessibility		A website/webpage should be written in English. A website/webpage should offer free access to the users. A website/webpage should have an independent URL.
Relevance		A website/webpage should cover relevant topics.
Credibility	Trustworthiness	A website/webpage should lack advertising and commercial content. Thus, a website/webpage will be checked over the following items. • The website's URL • Advertisement on the website • Pop-up windows with ad
	Expertise	A website/webpage should be created by the following entities. • Academic institutions (including extensions)

		• National organizations (both federal and state in case of US) • International organizations • Professional organizations of animal/human/environmental health professionals • Professional news/magazine organizations in animal/human/environmental health • Non-profit organizations affiliated with any entities mentioned above • An individual who is an animal/human/environmental health professional

Table 2. Criteria used to Evaluate Candidate Websites

Lastly, selected websites were categorized based on the author of a website/webpage (i.e., Academic institutions, National organizations, International organizations, Professional organizations, Professional news/magazine organizations, Non-profit organizations, Individual professional in animal/human/environmental health). For each website, a brief description and keywords were created to help users get a quick sense of each resource included in the knowledge-sharing platform. Then, all the content was entered into the WordPress website, hosted on the eXtension website (https://publish.extension.org/animalantibioticuse/). See Figure 3 below for a screenshot of a knowledge-sharing platform.

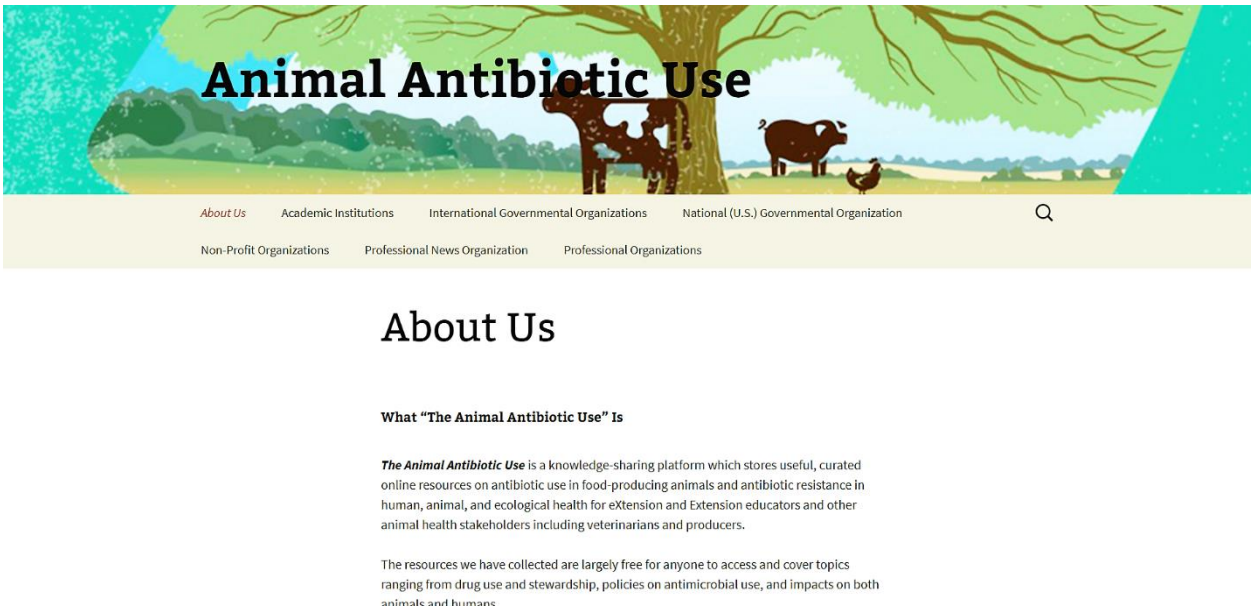

Figure 3. Screenshot of a Knowledge-Sharing Platform

Promotion and Maintenance of a Knowledge Sharing Platform

To ensure that the knowledge sharing platform would serve as a useful tool for any agricultural professionals interested in learning more about antibiotic use and antibiotic resistance, we plan to publicize this platform through various means. Specifically, we will connect with people from the MSU Extension to identify ways to publicize the platform to agricultural professionals they are serving. We also will collaborate with eXtension to publicize the platform as a resource for users of the eXtension website. Furthermore, we may leverage our connections to the veterinary communities including the Michigan Veterinary Medical Association (MVMA), Michigan Department of Agriculture and Rural Development (MDARD), and American Association of Bovine Practitioners (AABP). This would allow us to reach out to potential users, especially those who are animal health stakeholders, not only in Michigan but also in other states. Moreover, we plan to disseminate information about the platform to broader audience including the general public by sharing this work using a blog posting.

Along with promotion of the platform, maintenance to keep content up to date will be important. For this, we plan to prepare a document that describes standard procedures for maintaining the platform including checking of existing content and adding of new content on a regular basis. We are currently in the process of identifying resources available that would allow us to hire a designated person to perform this maintenance work.

Implications for Policy Regarding Mitigation of Antibiotic Resistance

Although our sample size is small, findings from this study indicate that veterinarians, who directly interact with producers on farms, could play an important role in mitigating antibiotic resistance. They could do this by providing specific training to producers, offering relevant and credible information to producers, and lending guidance and consultation to producers not only in relation to animal health, but also in relation to farm management. Therefore, policies designed to facilitate these interactions between veterinarians and producers may serve as an effective way to help address the issue of antibiotic resistance. For this, we suggest that the following three aspects be considered when developing policies related to mitigation of antibiotic resistance.

First, identifying forums and opportunities for communication among stakeholder groups for sharing decision-making strategies and information about antibiotic use is key. Veterinarians participating in this study stated that it is important to have discussions with producers on the use of antibiotics to help their customers understand the rationale for their decision-making. Therefore, any support that would help veterinarians improve communication skills in this regard may be one way to fight antibiotic resistance. For instance, state-sponsored workshops or sessions on communication skills may be held as part of a program of professional organizations' events or meetings.

It is important to create more opportunities for veterinarians and producers to meet in person, ultimately increasing educational opportunities for producers and veterinarians. Participants indicated that there used to be active extension services from universities in Michigan, which they found useful in creating opportunities to discuss antibiotic use with producers. Without these networking opportunities, they have less chance to talk to producers with smaller farms. Given this, identifying ways to extend extension services to facilitate local small-scale meetings would bring veterinarians and producers from smaller farms together.

In relation to this, it is notable that veterinarians mentioned that the implementation of the VFD has served as a good opportunity to have discussion with producers in person, especially with those who tend to seek experts' guidance on antibiotic use less often. States like California[xxiii] and Maryland[xxiv], for example, have stricter rules on antibiotic use by passing a law banning the routine use of antibiotics in healthy livestock and poultry. This policy may offer more chances for veterinarians to meet with producers and talk about appropriate use of antibiotics with them, as producers should visit veterinarians to obtain antibiotics.

Lastly, a holistic approach that focuses on structural change may be required. Participants stated that efforts in terms of disease prevention and farm management are as important as appropriate use of antibiotics to mitigate antibiotic resistance. However, as veterinarians mentioned, even though producers understand this importance of prevention and management improvement, they could not afford to do so due to financial constraints. Veterinarians pointed out that if ways exist to support producers in implementing necessary changes to improve their management, it may lead to reduction in antibiotic use by eliminating chances of disease in the first place. For example, subsidizing or incentivizing financial organizations who lend money to producers would be one possible way to help producers alleviate their financial constraints and prioritize proper antibiotic use.

Appendix A: Interview Protocol

Introduce ourselves and our research
Go through the consent protocol
Start recording

First, I would like to ask you some questions about your antibiotic prescribing practices. We are interested only in your experiences handling beef and dairy cows. In the first question, I would like you to walk me through the factors you take into account when you prescribe antibiotics.

Q1. When you treat a condition with antibiotics, what decisions do you go through and what factors do you consider?

If not mentioned, probe the followings.
(Probe) What is the role of label indications in your decision?
(Probe) What is the role of withdrawal time in your decision?
(Probe) What is the role of resistance of the likely pathogen in your decision?
(Probe) What is the role of financial consideration in your decision? (e.g., value of animal, cost, financial wellbeing of clients)
(Probe) What is the role of farm management skills in your decision?
(Probe) What is the role of your client's expectations in your decision?
(Probe) What is the role of preventive intervention (for the future) in your decision?

Q2. If you develop a protocol for a farm, how would you go about doing that?

Probe: Tell us about the specific steps you go through
Probe: Where do you get information about these issues?
Probe: Are there resources online that you use?
Probe: Or people you call?

Q3. After you developed a protocol, have you ever monitored how the farm was doing with implementing the protocol?

If yes: How did you do that?
If no: How would you do that?

Q4. Could you tell us about your experience with extra-label use of antibiotics? How often do you prescribe or direct extra-label use of antibiotics?

(Probe) When developing protocols, do you include extra-label use of antibiotics?
If yes: Then, in general, what % of antibiotics use is extra-label in protocols you develop?

Q4. What factors do you consider when you decide to prescribe or direct extra-label use of antibiotics?

Q5. Have you ever encountered any problems with residues or other things related to antibiotic use in farms?

If yes:

Probe: How did you find out there had been such problems?

Probe: What did you do to address the problem at that time?

Q6. Do you know what your clients think about your prescribing decisions?

Probe: What makes you think that?

Probe: Do you think that influences your antibiotics prescribing decisions? Why or why not?

Transition phrase: *You mentioned you consider several things when you make antibiotics prescribing decisions.*

Q7. How do you get information about those things? (online or offline strategies)

Probe: How did you know about these sources?

Probe: What kind of information do you look for from these sources?

Probe: Why do you find these sources useful?

Q8. Are there any online sources you use? What are they?

Probe: How did you know about these sources?

Probe: What kind of information do you look for from these sources?

Probe: Why do you find these sources useful?

Q9. What sources do you prefer? Why?

Q10. Do you share the information you find in the process of antibiotics prescribing with anyone else?

Probe: Why or why not?

Probe: How? (online or offline strategies)

Q11. Is there any technology you are currently using to get or share information about antibiotics use?

If yes:

Probe: How did you know about those technologies?

Probe: What kind of information do you look for or share using those technologies?

Probe: Why do you find those technologies useful?

Q12. Then, have you ever wished for any technology that could help you get or share information about antibiotics use?

If yes: What would it be? What would it do?

If no: Why not?

Transition phrase: *I would now like to ask you some questions about how you perceive antibiotics resistance in general.*

Q13. Do you think you have enough information about antibiotics resistance?

If yes: Why?

Probe: Could you tell us more about what you know about antibiotic resistance?

Probe: How do you get this information about antibiotics resistance?

Probe: Are there resources online that you use to get this information?

Probe: Or people you call?

If no: Why not?

Probe: What are some types of information you want to know in order to say you have enough information about antibiotics resistance?

Probe: How would you start out if you want to learn more about antibiotics resistance?

Q13-1. What about antibiotics resistance in relation to human health, animal health, and ecological health? What do you think about it? (added on March 17, asked from S09)

Q14. Have you ever wished for any technology that could help you get information or share information about antibiotic resistance?

If yes: What would it do?

If no: Why not?

Q15. How do you think the issue of antibiotics resistance influences your daily work?

Q16. Do you have any concerns about the way of antibiotics are used in farms?

Probe: Why or why not?

Q17. If there is a need to reduce antibiotics use in farm animals, what are the opportunities for that?

Q18. What are the barriers to that?

Q19. What do you believe is the role of veterinarians in reducing antibiotics uses in farm animals?

Q20. Is there anything else you would like to tell us about this issue?

I am stopping audio-recording. Now, I would like you to fill out this background questionnaire. Hand out a hard copy of background questionnaire. Wait until a participant complete the questionnaire.
Lastly, do you know any food animal veterinarians who you think might be interested?

Thank you for your time. We will send a $25 Amazon gift card to you next week. Please check your email later and let us know if you do not receive it.

APPENDIX B: BACKGROUND QUESTIONNAIRE

1. Please indicate what describes you best.
   ☐ I work in private practice.
   ☐ I am employed directly by farms.
   ☐ Other, please specify _____

2. What is your position?
   ☐ Owner
   ☐ Associate
   ☐ Other, please specify _____

3. What veterinary school did you graduate from? _____

4. What year did you graduate from veterinary school? _____

5. How long have you been practicing/practiced? _____ year(s)

6. Please check **all types of animals** you work with and write down **% of your time spent** on each. Approximates would be fine.
   ☐ Beef cattle: _____ % of my time spent
   ☐ Dairy cattle: _____ % of my time spent
   ☐ Chickens: _____ % of my time spent
   ☐ Pigs: _____ % of my time spent
   ☐ Horses: _____ % of my time spent
   ☐ Small animals: _____ % of my time spent
   ☐ Other, please specify _____ : _____ % of my time spent

Please answer the following questions regarding **beef** farms you serve. Approximates would be fine.

7. How many beef farms do you serve? _____ beef farms

8. How big are those beef farms you serve? Please write down the range and average of farm size below.
   Size of the smallest farm (i.e., number of heads): _____
   Size of the largest farm (i.e., number of heads): _____
   Size of the average farm (i.e., number of heads): _____

Please answer the following questions regarding **dairy** farms you serve. Approximates would be fine.

9. How many dairy farms do you serve? _____ dairy farms

10. How big are those dairy farms you serve? Please write down the range and average of farm size below.
    Size of the smallest farm (i.e., number of cows milking): _____
    Size of the largest farm (i.e., number of cows milking): _____
    Size of the average farm (i.e., number of cows milking): _____

11. How much time do you spend per year on continuing education? _____

12. What do you do for continuing education? Please write down anything you do for continuing education.

The following questions ask you about your perceptions of antibiotic use.

	Strongly Disagree						Strongly Agree
In general, I think the amount of antibiotics used in beef production is appropriate.	☐	☐	☐	☐	☐	☐	☐
In general, I think the amount of antibiotics used in dairy production is appropriate.	☐	☐	☐	☐	☐	☐	☐
In general, I think the amount of antibiotics used in human health is appropriate.	☐	☐	☐	☐	☐	☐	☐
I believe antibiotic resistance is a severe threat to domesticated animal health.	☐	☐	☐	☐	☐	☐	☐
I believe antibiotic resistance poses a severe threat to wildlife.	☐	☐	☐	☐	☐	☐	☐
I believe antibiotic resistance is a severe threat to human health.	☐	☐	☐	☐	☐	☐	☐
I believe antibiotic resistance is a severe threat to the environment.	☐	☐	☐	☐	☐	☐	☐

13. Do you use each of the following technologies? Check all that apply.
    ☐ Email
    ☐ Internet

- ☐ Cell phone calls
- ☐ Cell phone texts
- ☐ Social media like Facebook, Twitter, or LinkedIn
- ☐ Discussion forums like reddit, Digg, or Slashdot

14. Is there any technology you use that is not mentioned above (Q13)?
    - ☐ Yes, please specify _____
    - ☐ No

15. Do you, personally, have or have access to each of the following items? Check all that apply.
    - ☐ A smartphone
    - ☐ A cell phone that is not a smartphone
    - ☐ A desktop or laptop computer
    - ☐ A tablet computer like an iPad, Samsung Galaxy, or Kindle Fire

16. I am:
    - ☐ Male
    - ☐ Female
    - ☐ Other, please specify _____

17. What year were you born? _____

This is the end of questionnaire. Thank you very much for your time.

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