Preventive Veterinary Medicine 194 (2021) 105428

Contents lists available at ScienceDirect

Preventive Veterinary Medicine

journal homepage: www.elsevier.com/locate/prevetmed

New York State dairy veterinarians' perceptions of antibiotic use and resistance: A qualitative interview study

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ARTICLE INFO

Keywords:
Interview study
Veterinarian perceptions
Antibiotic use
Antimicrobial resistance
Dairy farming

ABSTRACT

Antimicrobial resistance (AMR) limits the ability to prevent and treat infection, making AMR one of the foremost threats to human and animal health. Animal agriculture's large use of antibiotics in food animals is an important factor in AMR. As such, policies to reduce antibiotic use and combat AMR in animal agriculture in the United States (US) have been in place or are developed. One key to the success of these policies in the US is understanding how a major stakeholder - veterinarians treating dairy cattle - perceive the scale of antibiotic use, the threat of AMR and the utility of antibiotic use policies. We interviewed 9 dairy veterinarians in New York State and conducted an iterative thematic analysis of their responses, through which five themes were identified: 1. veterinarians' views of the frequency and reasons for antibiotic misuse, 2. their ideas on reducing antibiotic use, 3. perceptions of AMR within the dairy industry, 4. view of organic farming and how it relates to animal welfare, and 5. the impact of consumers' beliefs on the dairy industry. Participants viewed antibiotic overuse as largely due to farmers' concern for the welfare of their cattle and desire to treat ailments swiftly. Interviewees believed that it was possible to reduce antibiotic use through regulation, such as the Veterinary Feed Directive and improved herd management activities, such as better colostrum management, culture-based mastitis treatment, and improved housing conditions. They did not view the dairy industry as a significant contributor to AMR, particularly when compared to the human medical industry. Interviewees also offered their (unsolicited) opinion on organic dairy farming in the US and expressed frustration with the limited treatment options available in organic dairy farming and how this dynamic may potentially compromise animal welfare. Finally, they commented on the impact of consumers' beliefs on the dairy industry, expressing frustration with how misinformation about the dairy industry has led to consumer driven changes. As consumer beliefs have an impact on the dairy industry, this influence could be leveraged to further decrease antibiotic use. These findings can help guide future efforts in veterinarian-client communication and the development and implementation of effective policies in New York State. These results also highlight the need for more quantitative research on antibiotic use in the dairy industry, as without this data it will be difficult to ascertain the true impact of policy interventions.

1. Introduction

The Centers for Disease Control and Prevention (CDC) and World Health Organization (WHO) recognize antimicrobial resistance (AMR) as one of the foremost threats to public health. Annually in the United States (US), over 2.8 million illnesses and 35,000 deaths in people are attributable to antibiotic resistant bacteria and fungi (CDC, 2019). One of the current strategies to combat AMR is the development of antibiotic stewardship programs to optimize antibiotic use in human medicine, veterinary medicine, and animal agriculture (Fair and Tor, 2014; WHO, 2018; Jayarao et al., 2019).

The agricultural industry has had to respond to intense scrutiny over their current use of antibiotics as a result of their historic use of antibiotics to promote the growth of food animals (livestock and poultry) (Fair & Toy, 2014; Jayarao et al., 2019). Animals treated with antibiotics, and their subsequent food products, may contain bacteria

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https://doi.org/10.1016/j.prevetmed.2021.105428
Received 11 January 2021; Received in revised form 30 June 2021; Accepted 7 July 2021
Available online 9 July 2021

possessing antibiotic-resistant genes (Kirbis and Krizman, 2015; Scott et al., 2018). A rapid review of studies on antimicrobial use in food animals found that increased antibiotic use in these animals was associated with increased AMR (Scott et al., 2018). Research has also indicated that limiting antimicrobial use in food animals was associated with decreased AMR for particular bacteria in those animals (Tang et al., 2017; Scott et al., 2018). Specific to dairy, previous research suggests that it is possible to implement strategies to reduce antibiotic use while upholding husbandry standards. A 2010 study in Denmark determined that an intervention, Stable Schools, that sought to minimize the disease level in dairy herds while optimizing selection criteria for their treatment, resulted in a 50 % decrease in antimicrobial use by participating dairy farm in one year (Bennedsgaard et al., 2010).

In response to growing concerns over AMR and antibiotic overuse in agriculture, the US Food and Drug Administration (FDA) has instituted policies aimed at reducing antibiotic use in food animals. In 2017, the FDA implemented the Veterinary Feed Directive (VFD) final rule, with the goal of "judicious use of medically important antimicrobials in food-producing animals" (US Food & Drug Administration, 2020). The VFD specifies that medically important antibiotics (antibiotics essential to human medicine) in feed or water require a veterinary feed directive, a written prescription from a veterinarian, and in some US States, including, New York State, it also necessitates that the VFD must be written by a veterinarian with a valid Veterinary-Client Patient Relationship (VCPR) with their client (US Food and Drug Administration, 2015). As part of the VCPR, the veterinarian has assumed the responsibility for making medical judgments regarding the health and medical treatment of an animal patient and knows the patient well enough to be able to diagnose and treat it, while the client (the owner of the animal or animals or other caretaker) has agreed to follow the instructions of the veterinarian American Veterinary Medical Association (AVMA), 2021. This means the veterinary care provided for patients is medically appropriate, ensuring that any given medications will be directly relevant to patients, resulting in optimal veterinary care and patient welfare. Also, this prevents medically important antibiotics from being used inappropriately, because clients must consult with a veterinarian, instead of purchasing medications without direct veterinary input. In order for a VFD to be written, antibiotics can only be used for the prevention, treatment, or control of a specifically identified disease, as opposed to being used for growth promotion or feed efficiency (U. S. Food and Drug Administration, 2020).

AMR in food animals results from a complex interaction among farmer practice, regulatory action, disease incidence, pharmaceutical innovation, resources (time, financial and labor), veterinarian practice, public opinion and consumer demand. We focus on veterinarians to develop a greater understanding of their behaviors. This focus is an important emerging area of research, as it is not yet widely known how veterinarians in the dairy industry perceive AMR as it relates to dairy cattle and associated antibiotic use. Singer et al. in 2019, surveyed veterinarians and producers to determine their opinions and experiences with production animals that are raised without antibiotics and observed that veterinarians and producers believed that raising animals without antibiotics is driven by market demand rather than a concern about AMR. Consumers broadly have a negative perception of antibiotic use in animal agriculture, viewing use of antibiotics on dairy farms to be a threat to human health (Wemette et al., 2021). Self-reported purchasing behaviors reflect these beliefs, supporting the impact that market driven changes, and thus public perceptions, can shape activities within the dairy industry (Bulut et al., 2021; Wemette et al., 2021). Yet, the perceptions of US veterinarians about antibiotic use in cattle and the threat of AMR within the dairy industry has received little attention. Dairy farming is a major agricultural industry in New York State, with the State being the third largest dairy producer in the US (USDA, 2018). The objective of this study was to assess perceptions of antibiotic use and AMR in dairy farming among New York State veterinarians who provide veterinary services to dairy farms, thereafter referred to as dairy veterinarians. A greater understanding of their beliefs might provide insight into their prescribing behaviors and help determine policy targets aimed at reducing antimicrobial use.

2. Materials and methods

2.1. Sampling and recruitment

New York State dairy veterinarians were recruited via purposive sampling (Patton, 1990) through two mechanisms. First, an attempt to recruit veterinarians was made at the 2017 New York State Fall Veterinary Conference held from 6th-8th October 2017 at Cornell University's College of Veterinary Medicine in Ithaca, NY; the New York State Veterinary Conference is a continuing education conference for professionals in the field of veterinary medicine. Second, an employee in the Quality Milk Production Services (QMPS) program was asked to provide to M.W. a list for potential interviews of dairy veterinarians and/or practices in New York State with broad range of characteristics in terms of practice size, clientele and years in practice. QMPS is a section of the Animal Health Diagnostic Laboratory & New York State Veterinary Diagnostic Laboratory at Cornell University, which thus has working relationships with dairy veterinarians through the State. Using the provided list of 32 dairy veterinarians, M.W. contacted veterinarians and/or veterinary practices via email and invited them to participate in this study. Participants were given a $10 Starbucks gift card in exchange for participating.

2.2. Instrument design and data collection

M.W., W.B., A.G.S. and R.I. developed a semi-structured interview guide with the goal of understanding dairy veterinarians' perceptions of antibiotic use and AMR in dairy farming. The interview guide consisted of questions regarding participants' characteristics and experience within the dairy industry, their dairy farm visit experiences, their opinions of the VFD and its impact, and their perceptions of antibiotic use on dairy farms. A pilot interview was conducted with a dairy veterinarian to refine question content. Following this, the interview guide was refined and finalized (See Appendix A).

From October 2017 to August 2018, M.W. conducted interviews of 9 dairy veterinarians in New York State. Interviews were conducted in person at participants' veterinary clinics or at the 2017 New York State Fall Veterinary Conference. Participants provided written consent at the start of the interview. Interviews lasted between 44 min and 87 min with a median of 63 min. The interviews were audio recorded and transcribed by the Survey Research Institute of Cornell University, and H.P. verified these transcripts.

The study was approved by the Cornell University Institutional Review Board for Human Participants (IRB protocol #1705007138).

2.3. Data analysis

H.P. conducted an iterative thematic analysis (Braun and Clarke, 2006) of the interviews using a grounded theory approach (Charmaz, 1995; Chapman et al., 2015). HP used QSR NVivo Version 12 to organize the codebook, code the data and organize the coded data for analysis. Qualitative analysis is a process of synthesizing and making sense of an extensive amount of qualitative data so that participants' experience is well characterized and, in this case, can help provide insight for others to address real world problems (Charmaz, 1995; Charmaz and Thornberg, 2020; Creswell and Poth, 2018). Here the goal is to identify the meanings, beliefs, and practices associated with AMR from a veterinarians' perspective, given their role in advising farmers and prescribing certain antibiotics.

The analytic process begins early when using grounded theory. It starts with purposive sampling of participants to maximize range of experience, noting trends during interviews, familiarizing oneself with

the data via transcripts, working with a team that possesses methods and content expertise to generate observations from the data, derive codes from those observations, develop a codebook, applying the codebook systematically to the data (possibly with the use of tools such as NVivo, Atlas.ti) so that quotes associated with the codes can be pulled, compared and analyzed more thoroughly for patterns and themes to inform the inquiry (Chapman et al., 2015; Tie et al., 2019). We had *a priori* areas of interest (such as reactions to the VFD), but the interview process and subsequent analysis allow for emergent themes to appear (such as reactions to organic farming).

HP discussed findings and observations with AGS and RI as the interviews progressed. R.I., M.W., A.G.S, and H.P. reviewed interview transcripts as they were ready to start to make sense of that data; they had multiple discussions about observations from the interviews. These discussions helped generate codes that formed the basis of a codebook with relevant codes (i.e. those linked to relevant subject matter) organized by category. The codebook that was reviewed and refined multiple times by the team to make sure topics of interest were represented and all was organized to streamline coding. HP used this codebook to go systematically through each transcript again and tag relevant passages with the appropriate code (e.g., concern about training, barriers to herd management). If there were questions on how a passage should be coded, HP consulted with R.I. and A.G.S. After coding of all the interviews, H.P. organized the quotes by topic (so all quotes for a specific code were listed together) to facilitate the next round of analysis by AGS, RI and HP. By comparing quotes within and across codes, we identified patterns (i.e., Similar characterization? Agreement? Disagreement? Variation in language used? Similar strength of reaction? Linkage among codes that from a theme?), noted outliers and flagged specific recommendations our participants provided. The team met repeatedly to discuss the patterns (e.g., doubt about dairy's role in AMR) and recommendations that were most instructive in terms of a view of antibiotic use and AMR within dairy farming. For clarity, we grouped the findings under 5 main topics, each with subthemes that resulted from the patterns in our participants' responses. A description of our sample's demographics was generated using Excel by pulling this categorical information from NVivo.

2.4. Population of New York State dairy veterinarians

The American Association of Bovine Practitioners (AABP) provided the basic demographic characteristics of practicing veterinarians in New York State who were their members in 2020. In the AABP membership database, veterinarians self-report the percent of work that is dairy, which was used to first identify practicing dairy veterinarians and then to determine the percent of dairy work that these veterinarians have. It is believed that most practicing dairy veterinarians in the State are also members of the AABP, however that could not be verified. Data about the veterinarians from the AABP database were summarized using Excel.

3. Results

Thirty-two dairy veterinarians were contacted and 9 agreed to participate in the interview study. Table 1 shows the basic demographic, professional and clientele characteristics of the interviewed veterinarians. The participants included roughly balanced numbers of men and women and years of professional experience (<20 vs. > 20 years). Most worked primarily with dairy clients and had a mixture of conventional and organic dairy farm clients.

In 2020, there were 132 practicing dairy veterinarians in New York State who were members of the AABP. Of those, 57 % identified as male (Table 2). The majority, 64 %, worked with dairy 75 %–100 % of their time, 16 % of veterinarians worked with dairy 50 %–74 % of the time, while only 11 % worked with dairy 25 %–49 % of the time and 8% worked with dairy 1 %–25 % of the time (Table 2). While our interview study was a convenience sample, demographic and professional characteristics of the interviewees roughly align with the target population in terms of gender and time spent with dairy cattle. There is no comparative data available for years in practice or focus on conventional or organic production.

Table 1
Demographic, Professional and Clientele Characteristics of Interviewed New York State Dairy Veterinarians.

Veterinarians' characteristic	Category	Percentage (number/total)
Gender	M	56 % (5/9)
	F	44 % (4/9)
Range of years working with dairy clients	0−5	44 % (4/9)
	6−10	11 % (1/9)
	>20	44% (4/9)
Range of percent of work that is dairy	25 %–49 %	11 % (1/9)
	50 %–74 %	11 % (1/9)
	75 %–100 %	77 % (7/9)
Primary farm types that are worked with	Conventional only	22 % (2/9)
	Mix of conventional and organic	77 % (7/9)

Table 2
Demographic and Professional Characteristics of 132 New York State Dairy Veterinarians Members of the American Association of Bovine Practitioners.

Veterinarians' Characteristic	Category	Percentage (number/total)
Gender	M	57 % (75/132)
	F	43 % % (57/132)
Range of percent of work that is dairy	1%-24 %	8% (11/132)
	25 %–49 %	11 % (15/132)
	50 %–74 %	16 % (21/132)
	75 %–100 %	64 % (85/132)

For the remaining qualitative portion of the analysis, the thematic analysis and team discussion identified five overarching topics most relevant to future practice and policy relating to antibiotic use:

1 Views of the frequency of antibiotic use and reasons for antibiotic misuse
2 Suggestions for reducing antibiotic use in the dairy industry
3 Views on AMR as a problem and the dairy industry's contribution to AMR
4 Views of organic farming in the US, particularly its impact on animal welfare
5 The perceived power of consumer beliefs on the dairy industry

The study findings under each of these topics are described in the following paragraphs.

3.1. Topic 1: views of the frequency of antibiotic use and reasons for antibiotic misuse

The two major themes that emerged within this topic were that antibiotic overuse was largely due to both a concern for animal welfare, an aversion to risk, and a desire to treat clinical illness immediately. Veterinarians were asked to provide their opinion on antibiotic use among dairy farmers. Responses ranged from discussing general overuse in the industry to the existing penalties, such as discarding milk that contains antibiotic residues, translating to limited antibiotic use in cows. In some cases, veterinarians felt as though antibiotics have been used in a suboptimal manner, that is to say both overuse and underuse occurred, although more veterinarians pointed to antibiotic overuse.

Five out of the 9 veterinarians interviewed commented that suboptimal use occurs more frequently in "…calf feeders and calves in group housing with respiratory diseases" (Veterinarian 3, interview conducted in Winter 2018) rather than lactating cows, "that's exclusively how I've

seen an overuse of antibiotics." (Veterinarian 5, Spring 2018) Veterinarians perceived overuse in calves to be the result of prophylactic treatments at large farms, a history of consistently giving antibiotics in feed, and as a consequence of the farm operator's feelings of personal attachment to and responsibility for the calves.

In adult cows, the veterinarians described the problem as less systematic abuse and more improper use, such as error related to administration. For example, when describing suboptimal use in heifers, one veterinarian described how "a whole variety of screw-ups [could] take place. Given too often, too much, or probably-usually if dosages are wrong, giving too much in one area." (Veterinarian 9, Summer 2018). In lactating cows, some veterinarians suggested improper was the result of a problem with administration of antibiotics, such as giving injections into the improper muscle site. For cows of all ages, veterinarians noted that farmers are risk averse, and that "people don't perceive it [not treating with antibiotics] as being worth the risk." (Veterinarian 2, Winter 2018)

3.2. Topic 2: suggestions for reducing antibiotic use in the dairy industry

Reducing antibiotic use has been historically addressed through two approaches, the regulation of antibiotics and herd management (i.e. housing, space, ventilation, foot care, feed). Veterinarians recognized these approaches as effective and indicated how these strategies have worked and can continue to be utilized. A few veterinarians also suggested that practitioners should take on a broader role to address reducing antibiotic use.

3.2.1. Reducing antibiotic use: regulation

Veterinarians were asked to provide their experience with and opinion on the VFD, what they believed to be barriers to utilization of the VFD and other regulatory measures, and how they thought farmers felt about the VFD. All of the interviewed veterinarians view the VFD as a beneficial policy. They believe that while some of them, and most farmers view it as an annoyance, it is not a large hindrance to how their farms operate. While all of the veterinarians expressed support for the VFD, two of them had not yet used it, and thus had little practical experience with it.

> "Okay, so the veterinary feed directive, certainly I think the motives behind it are positive. That you need to do a better job with how antibiotics are being utilized. Is it one more regulatory step that's kind of a nuisance to do? Absolutely. But we're dealing with it." (Veterinarian 1, Fall 2017)
>
> "I think overall it's [the VFD] been a really good thing because we do have a lot more knowledge about who is using it [antibiotics in feed] and why they're using it [antibiotics in feed]." (Veterinarian 5, Spring 2018)

One veterinarian noted that the VFD "has mitigated unnecessary antibiotic use and has helped us [veterinarians] to be more precise." (Veterinarian 7, Summer 2018) This veterinarian also observed that, "especially for those smaller dairy clients that I work with, it has facilitated more communication." This is an important point in the role that such policies play for smaller farms with perhaps less in terms of human and financial resources.

While all of the interviewed veterinarians are supportive of the VFD, they also recognized that there are barriers to the success of policies regulating antibiotic use. One of the barriers that farmers now face is obtaining a signed VCPR because of legal ramifications for the veterinarian. Veterinarians observed that since the implementation of the VFD, co-ops are now requiring signed VCPRs, which has created some frustrations for both veterinarians and dairy farmers, including due to legal concerns. This veterinarian spoke about the new legal concerns:

> "Depending on how the VCPR is worded, you know, will determine whether or not I'm willing to sign it. Because what can happen is, that becomes a legal document that in the event of a lawsuit that gets used against you. And that's been the big worry by a lot dairy veterinarians, is that they become legally liable for more things than we technically should be. And that has what has created the hesitancy amongst most of us to sign those documents. […] Why do we need to have a written document that states the same thing that's already happening? If we have records of our visits to dairy farms on a routine, regular basis, and we have drugs assigned to the dairy with our name on them in the shelf, and they're following our protocols, that is a VCPR." (Veterinarian 7, Summer 2018)

Additionally, veterinarians perceived that farmers have a negative opinion towards the VFD because of the increased financial cost to farmers and inconvenience of the now required veterinary presence to obtain feed antibiotics. A veterinarian described how farmers' attitude towards the VFD were largely negative because they viewed it as increased government involvement in their businesses, and acquiring medications now takes more time than previously.

3.2.2. VFD and herd/farm size

Veterinarians perceived that for farmers with smaller herds, having a signed VCPR is more inconvenient. One veterinarian commented that

> "[you have to] really establish a veterinary client-patient relationship and tell [the farmer], 'Hey if anyone wants to write these VFDs we have to monitor your farm more frequently. We can't see you every three years and have you expect us to write you a VFD.'" (Veterinarian 1, Fall 2017)

All of the veterinarians said that there were protocols in place for antibiotic use at farms they maintained valid VCPRs with, but the format and adherence to these protocols varied. One veterinarian stated that, "bigger farms are more likely [to] have protocols. Not many of my small farms have written protocols for antibiotic use, for anything." (Veterinarian 2, Winter 2018) This echoes an earlier point about differential impacts based on farm size. Regarding antibiotic protocol adherence, veterinarians expressed lack of control of and uncertainty about the extent of farm staff compliance.

> "[P]art of the thing that we see very often is, 'Here's what I think they're doing, Doc. This is my recommendation.' And the owner knows it. 'Yeah, here are our protocols. This is what we do when we have—' And the manager of the fresh pad, 'This is what we do when we have a sick cow.' And then, well, these are the guys who work with the cows everyday [who are not the managers we are talking to], here's what they're doing when they have a sick cow. And how aligned are those [practices]?" (Veterinarian 6, Spring 2018)

In addition to veterinarians lacking knowledge of protocol adherence, veterinarians also observed that there are discrepancies in the presence of records and the format of those records. Several commented that larger farms are more likely to have written records than smaller farms, and records could be written in a book or on a calendar, but they were not positive on how accurate these records were or the extent of them.

3.2.3. Reducing antibiotic use: herd management

All participants believed that antibiotic use could be reduced through herd management strategies. Veterinarians provided examples of how to do this for both calves and heifers. They described how the space in which calves are raised in and in which lactating cows live could often be increased in size and ventilation improved, thus increasing the cleanliness of the area and reducing disease spread.

> "I think most farms can improve on their colostrum management, and their calf management. Yeah, 95 % of my farms can improve on that. And fresh cow milking management as well. And then, definitely parlor management, especially the small farms with tie stall

barns. You know, that sort of stuff. Getting the milking management and milking protocols together could help them out a lot. So definitely areas where just little management changes can make a big deal." (Veterinarian 2, Winter 2018)

"I think that's the biggest one, is just husbandry and cleanliness of the facility, free stall sand versus sawdust versus water beds, you know? But again, those would—Ventilation is a big one that I've just seen." (Veterinarian 8, Summer 2018)

While veterinarians focused on environmental management, many of them also brought up culture-based testing for mastitis as a way to reduce antibiotic us; they quickly went on to explain the barriers to changing these practices to reduce antibiotic use. The most frequently cited reasons were cost for barns and staffing, and accessibility for culture-based mastitis testing.

"I would say it's all cost prohibitive. They need mostly bigger facilities, mostly they're overcrowded. Or they need more staff to clean facilities appropriately, particularly, there's been a huge surge in New York with group fed calves, also made of nickel bar or something, and people think that's going to be really easy management because you don't have to bucket feed all these calves anymore. But they don't clean the items as well as they should or as often as they should." (Veterinarian 5, Spring 2018)

Veterinarians recognized there were financial and accessibility barriers to reducing antibiotic use, stating that "the biggest barrier [to reducing antibiotic use through improved herd management] right now is the industry and milk prices are tanked so people just can't make the improvements that they need to make." (Veterinarian 8, Summer 2018)

3.2.4. Reducing antibiotic use: the role of the veterinarian

Two of the veterinarians interviewed argued for a stronger role of the veterinarian in reducing antibiotic use. They focused on how veterinarians possess the knowledge and practical experience to offer assistance to farmers that extends beyond interventional medical advice, and as experts on herd health, veterinarians should offer their services on the prevention side of dairy medicine, extending to herd management.

"I think most dairy farms recognize the veterinarian as probably their best expert when it comes to animal health questions. […] And the veterinarian's role goes well beyond establishing protocols for disease detection and treatment, it also goes to disease prevention. […] And a lot of farms now are really pushing for excellent animal husbandry and handling to maximize the efficiency from a cost standpoint, but also from an improvement-of-animal-health standpoint. So we as veterinarians are very well-suited to provide this role for dairy farms, because we have the knowledge base to understand the animal health, but we also have the knowledge base to understand the implications of changes that may have a positive or negative effect on animal health." (Veterinarian 7, Summer 2018)

3.3. Topic 3: views on AMR as a problem and the dairy industry's contribution to AMR

Two major themes emerged from this domain: that those interviewed believe the dairy industry is not where energy should be solely focused when combating AMR, and there were a range of interpretations about the severity of AMR within the dairy industry.

Veterinarians were asked for their opinions on not only the contribution of the dairy industry to antibiotic resistance but also more broadly about their experience with and concern about antibiotic resistance. None of the veterinarians viewed the dairy industry as a significant contributor to antibiotic resistance. Five out of the nine veterinarians argued that the human medical industry is a greater contributor than the dairy industry, while others pointed to other actors in animal agriculture, such as large scale feedlots for beef cattle and swine producers, as more problematic than dairy farming.

"On a wider level it does frustrate me that the human pharmaceutical industry blames the animal pharmaceutical industry for drug resistance, because when you look at the drugs that are used that doesn't make sense […] I feel like a lot of the resistance issues on the human side come from human physicians overprescribing antibiotics." (Veterinarian 5, Spring 2018)

"So let's say on a scale of one to ten I would put our antibiotic usage in dairy cattle as somewhere down at two. I think it could contribute and maybe it's a problem but I think there's a lot of other things that are more of a problem." (Veterinarian 3, Winter 2018)

"I don't have enough, we don't do any, we have no feedlots in this area. I know some things that goes on in feedlots supposedly and that would worry me, not a lot, but there's a lot more usage of broad treatment in those, in that industry, in swine." (Veterinarian 3, Winter 2018)

Veterinarians were also asked about their experience with and perceptions of the severity of antibiotic resistant infections on dairy farms. Only two of the nine veterinarians expressed that they do not view antibiotic resistance as a problem on dairy farms. The remaining seven veterinarians either had experience with it, viewed it as a problem, or were uncertain about it but still concerned. Veterinarians who had personally managed examples of resistant infections or started practicing veterinary medicine more recently were more concerned about resistance on farms. In the following excerpt, a veterinarian concerned about the rise of AMR speaks to the challenges of repeating protocols with a limited number of available antibiotics:

"I really only have a handful of antibiotics that I can ever even use. And there's really only three different classes of antibiotics you might argue four classes of antibiotics that I can use on a general sense to treat disease. And when we're talking about having to treat an animal repeatedly for a disease over and over again, lactation after lactation after lactation—whether it's mastitis, or metritis, or what have you—and we're repeatedly insulting them with the same treatment course, same antibiotic, for a set duration that is controlled and regulated by the FDA and that we must oblige to, at some point I have to believe that we are probably generating populations of bacteria that can overcome that. I mean, it's just the nature of the beast […] If you continually insult a treatment protocol that is identical to the previous, and you're treating the same disease, overtime your likelihood of generating resistant bacterial populations increases. The more times you expose the same bacteria to the same antibiotic the more chances you gain for mutations to occur. It's very real, in my opinion. I think that it's very real." (Veterinarian 7, Summer 2018)

While there were veterinarians who were concerned about AMR within the dairy industry, there were also veterinarians who were uncertain about the threat of AMR to the dairy industry specifically. One noted an inability to confirm that AMR arose on his farm: "Have I ever actually seen antibiotic resistance develop on a dairy over time? Can't say that I've ever been able to document that for sure." (Veterinarian 1, Fall 2017)

One theme among those less concerned about AMR was the view that a direct connection had not been established between antimicrobial use on a particular farm and subsequent human disease.

"I'm not convinced yet we've got anything that shows: because of how we're using antibiotics here in this farm, that we've actually seen human disease as a result of that. I don't think there's any real clear connection there." (Veterinarian 6, Spring 2018)

3.4. Topic 4: views of organic farming in the US, particularly its impact on animal welfare

Within the topic of organic farming, one major theme that emerged was that within the US, veterinarians are extremely limited in their treatment options for organic dairy cows, and the participating veterinarians believe this has negative implications for animal welfare. Veterinarians provided their views and opinions on organic dairy farming in the US with a nearly universal theme of frustration with the limited treatment options permitted for organic dairy cattle. Similar to the theme about reasons behind antibiotic overuse, they felt organic practices potentially compromised animal welfare.

> "My friend who practices [outside of the US] says that they can use [antibiotics in organic production]… So when they work with organic cattle it's not like, it's like the same as working with conventional cattle. When I go to a farm and work with an organic cow, god I hope I have something on my truck that I can use, that the certifier's not going to get upset because this mineral oil is the wrong brand or something like that. And that sort of thing really, really irritates me. It shackles my ability to provide healthcare and it influences whether my farmers perceive that a veterinarian is worth their time because veterinarians have tools and education at our disposal that we're not permitted to use for someone's marketing ploy." (Veterinarian 4, Spring 2018)

Veterinarians are faced with limitations on providing care to organic animals, due to a lack of available evidence-based therapies for organically produced food animals and the regulation in the US that animals treated with antibiotics may not be sold as organic. Interviewed veterinarians believed this combination negatively impacts animal welfare. The implication is that in organic dairy operations, treatment is unnecessarily delayed, or on occasion withheld, for dairy cows to retain their organic status.

> "I feel that some of them [the operators] do delay treatment or some of them say, "My fresh cow has a 103 fever. I'm just going to give banamine or prevail or flunixin or whatever, instead of potentially using antibiotics to combat the source of the fever, they're just going to treat the symptoms." (Veterinarian 4, Spring 2018)
> "My observation of animals on farms, a lot of the organic animals, I would say suffer from chronic medical conditions that are being ignored because they need to retain their organic status. And it's financially advantageous for the farmer to keep his cow organic so he can get those higher milk prices." (Veterinarian 5, Spring 2018)

The limited treatment options available to organic dairy farmers in the US has resulted in organic dairy farmers having to use alternative therapies to treat ailments in their herds. Veterinarians offered their input on treatments provided to organic dairy cows, such as garlic, tea tree oil, and even kelp, all of which have unknown efficacy.

> "Kelp is like a big one for digestive stuff now. And there was a product out there that was promoted by an organic vet that was a tea infusion that he was commercially preparing and selling and it actually was prohibited by the FDA in New York […] Those types of treatments have no studies whatsoever, either saying that they're effective or that they're not harmful." (Veterinarian 5, Spring 2018)

Without prompting, one veterinarian independently suggested a perception of doubt in the integrity of some organic farms.

> "My perception is that there are several organic farmers out there that cheat. There are antibiotics available to them, that they can use—it's obviously completely illegal for them to do this—but there are antibiotics out there that do not have any milk withhold, and really very little risk, if any, that that milk will become contaminated with the antibiotic that they're using. It happens." (Veterinarian 7, Summer 2018)

3.5. Topic 5: the power of consumer beliefs on the dairy industry

The major themes that emerged within this topic were that veterinarians were frustrated by the public's lack of awareness and understanding of animal agriculture and that consumer beliefs are largely driving changes within the dairy industry. Based on findings from previous work with dairy farmers in New York State (Wemette et al., 2020), veterinarians were asked to provide their opinions on consumer beliefs regarding dairy farming and conventional milk products. A clear and persistent theme of frustration emerged about a lack of awareness or understanding among the public around agriculture as a whole. Their concern is that consumer preferences – based in facto or otherwise – have an impact both on the dairy market and on regulations in order to meet these preferences. As consumers' impact on the market can influence regulations, changes to the dairy industry are increasingly being pushed by those without familiarity with animal agriculture. They view consumers' source of information as problematic:

> "People aren't all that interested [in animal agriculture], in general. They're not out there seeking information on how cows are taken care of. But they see like a terrible YouTube video, and that's enough. It's shocking, and it's terrible, and that can really influence somebody's interest in animal agriculture. That's—the only thing they're seeing is when someone does something stupid and gets caught. So we need a hundred positive stories for every time some idiot does something stupid and that gets out there. And we can't stop people from doing terrible things, we just have to make sure that we've got our management practices in place to demonstrate why that's the outlier." (Veterinarian 6, Spring 2018)

Veterinarians described a range of consumer misunderstandings that the veterinarians feared have impacted or will impact dairy markets. Veterinarians perceived that there was a large concern among consumers about milk being "contaminated" with antibiotic residues, which they believed to be based on misconceptions about milk production.

> "I am surprised at how rampant the perception that your food is contaminated." (Veterinarian 1, Fall 2017)
> "A lot of people had a perception that unless you're organic milk, that milk is contaminated, and those types of things." (Veterinarian 1, Fall 2017)
> "People just need to understand that there are mechanisms in place that are protecting what they're consuming. […] People shouldn't be so afraid about antibiotic use, they should trust the mechanisms in place. There are many controls to be testing for antibiotic residues." (Veterinarian 8, Summer 2018)

3.5.1. Perceived impact of marketing and negative labeling

Participating veterinarians argued that negative labeling (for example "no BST") exacerbated both consumer confusion and misconceptions about the dairy industry and the contents of dairy products

> "…still so many people that aren't involved in agriculture that just think there's hormones in the milk and antibiotics and as soon as there started being movements like BST free milk, as soon as somebody labels something like that it makes all the other products look bad." (Veterinarian 5, Spring 2018)
> "I think—and we've done it to ourselves to some degree by how we market some of our products. You know, "Antibiotic free!" Ok, well, does that mean everything else is full of antibiotics? Cage free versus not cage free. Grazing herd versus non-grazing herd. Like we—in an effort to market what we've got to sell, we may inadvertently blemish our—the people who aren't doing it the way we're doing it.

> And the antibiotic free stuff is a classic example of that. "Well, none of the stuff we're selling is full of antibiotics." What are you doing?" (Veterinarian 6, Spring 2018)

Veterinarians expressed frustration in how consumers, based on sometimes flawed understanding, are the ones driving changes in the dairy industry. One veterinarian noted that, "our actions should be based on science and that we should rely on the perceptions of people involved in the industry and scientists and veterinarians and researchers versus letting grassroots movements, from the 98 percent of people that are not involved in agriculture, create these weird rules for us. It's really frustrating and I know farmers are frustrated about that too." (Veterinarian 5, Spring 2018). Some veterinarians thought that consumers' views led to "weird rules," while others found the regulations to be helpful to address consumer concerns:

> "And so when you institute these programs—like treatment protocols, VCPR, vet relationship stuff—that's all driven by, "We want to shore up consumer confidence. That you're all following treatment recommendations that are validated by a veterinarian, so we know them to be safe." And therefore, now I've got milk coming from all of my farms, and they're all following this guidance. So now I can say, "Look retailer, all these farms are certified, and they've got their VCPRs and they've got their—A" So now that satisfies the retailer, and the retailer can say, "Look consumer, all of my processors are doing this" […] So it's just all up and down the value chain I guess." (Veterinarian 3, Winter 2018)

4. Discussion

4.1. Participating veterinarians recognized instances of suboptimal use of antibiotics in dairy cattle, particularly in calves, and identified opportunities and barriers to reducing antibiotic use through herd health and regulation

Dairy veterinarians believe there is antibiotic misuse in the dairy industry, mostly in calves, and that overall antibiotic use can be decreased. Veterinarians described poor calf housing conditions, such as overcrowded pens and inadequate ventilation, which facilitates the spread of disease, so antibiotics are often used in these situations as a way to prevent disease occurrence and subsequent spread. This is in agreement with findings from Dubrovsky et al. (2019), who found that risk factors for Bovine Respiratory Disease included "dusty" conditions in housing areas, not changing bedding frequently, and housing calves in wooden hutches with metal roofs. Veterinarians argue that there should be initiatives that target these housing conditions (such as thorough policies for more stringent housing requirements or incentives to achieve the same), to decrease the need for antibiotics. While this is a possible solution, the ultimate barrier to this is the cost of implementing comprehensive herd management changes. Veterinarians described improved colostrum management as a low-cost herd health improvement strategy, but many strategies require a significant financial investment. Researchers in Sweden found that economic and labor constraints were the primary limitations to farmers following recommendations for decreased antibiotic use (Fischer et al., 2019).

In addition to financial barriers, veterinarians also acknowledged that lack of accessibility to certain resources, such as culture-based mastitis testing, and the unwillingness of some farmers to make changes are significant barriers to the adoption of new herd management strategies. This is important as improved herd management strategies would allow farmers to use antibiotics more selectively. Firth et al. (2019) found that when farmers used selective treatment of cows with bacterial infections, rather than treating all cows in the herd, they used less antibiotics overall. Successful implementation of new policies promoting improved herd health through modified herd management should include provisions to provide financial assistance to those who participated in such a program (Sumner et al., 2018). Veterinarians also described how many farms, particularly small ones, lack written records for antibiotic use, and this complicates knowing adherence to veterinarians' recommendations.

Veterinarians indicated that there needs to be an incentive to farmers to maintain complete and accurate records and having an audit system that is actually utilized would ensure that this would occur. This would allow for both the accurate measurement of antibiotic use and knowledge of adherence, which would provide veterinarians with the ability to make more targeted and efficient recommendations. These programs providing financial assistance and an incentive system should be accompanied by education and improved access to resources enabling selective antibiotic use.

Finally, participants viewed the VFD as a positive change within the dairy industry as it has facilitated communication between veterinarians and farmers and limited antibiotic use. They indicated, however, that their clients generally disapprove of the VFD because of the increased financial cost and decreased convenience for producers. This is in agreement with an interview study with New York State dairy farmers (Wemette et al., 2020) and the focus groups involving beef and dairy producers in Tennessee, which found that producers had a largely negative view of the VFD and thought it had a negative economic impact on their industry (Ekakoro et al., 2018, 2019a, 2019b).

4.2. Participants argued for veterinarians to adopt a broader role in decreasing antibiotic use on dairy farms; they acknowledged the barriers to doing so

While it is well-established that veterinarians are integral for disease treatment, their role in disease prevention is much more dynamic. Interviewees in this study argued that veterinarians should do more than just provide vaccination schedules for preventative care but could also advise on how to improve the cows' daily environment and routines to prevent infection occurrence and spread, and thus the need for antibiotics. Indeed, veterinarians are in a unique position where they have the knowledge and skills to optimize antibiotic use on farms in a way that minimizes disease burden and maximizes animal welfare (Jan et al., 2012).

Yet obstacles to veterinarians adopting this role are numerous. For example, the participants in this study did not express universal concern about antibiotic resistance in the dairy industry and did not view the industry as a significant contributor. Similarly, in a survey of veterinarians and farmers in the United Kingdom, respondents did not believe that AMR resulted in negative treatment outcomes (Helliwell et al., 2019). Similarly, Ekakaro et al. (2019) determined that there needs to be increased awareness of the drivers of AMR for beef producers. In our study, participating veterinarians with more years in practice of veterinary medicine expressed less concern about resistance on farms, which is similar to a finding in a survey of an international group of veterinarians (Llanos-Soto et al., 2021).

The doubt that emerged through the conducted interviews about the contributions of the dairy industry to AMR may be an indication of a potential barrier to dairy-focused interventions that emphasize reducing AMR as the primary outcome rather than those focusing on reduced antibiotic use. Participating veterinarians who recognized AMR as a problem expressed concerns having limited time and resources, so the feasibility of them taking on more responsibilities related to AMR is uncertain. This finding is in agreement with Fortané's (2019) examination on the importance of reframing veterinarians' role within the community and their ideas about antibiotics in addressing AMR in France.

Additionally, others have found that veterinarians and farmers often have incongruent views on prioritizing economic concerns regarding disease prevention, with some farmers more apt to delay treatment or to underestimate disease prevalence, while veterinarians prioritize more immediate treatment (Sumner et al., 2018). In this New York

State-based study, however, veterinarians reported the opposite regarding treatment, indicating that farmers preferred immediate treatment, antibiotics, because they did not want to see their animals suffering. This suggests that there may be more common ground regarding antibiotic use than previously thought between farmers and veterinarians, enabling veterinarians to take on a broader role.

Veterinarians largely expressed frustration about their ability to treat organic dairy farm due to the lack of evidence-based therapies, ultimately leading to veterinarians' concern for animal welfare. This finding is supported by a study by Sorge et al. (2019), who conducted an interview study of bovine veterinarians and found that many veterinarians struggled to provide evidence-based alternative therapies within the regulatory framework, and 2/3 of interviewed veterinarians were concerned that the lack of treatment options would have a negative impact on animal welfare.

If what we found here is true elsewhere, then there is a gap in knowledge among veterinarians about appropriate treatment methods available for organic clients in the US. US regulations for organic farming mandate that for a dairy product to be marketed as organic, the dairy cows cannot have been administered antibiotics. Organic farmers are able to treat their cows with antibiotics if necessary, but any product from that animal can longer be marketed in the US as organic, and thus these animals must be removed from the organic herd (7 CFR § 205.238 (c)(1); U.S. Government, 2018). One veterinarian described uncertainty about having the proper brand of mineral oil, highlighting the limitations of veterinarians to serve organic dairy clients. Treatment methods utilized on organic dairies have unknown efficacy and have not undergone field testing, but the regulations in the US for organic products require a greater understanding of unsubstantiated treatment methods (Pol and Ruegg, 2007). This indicates a need for broader research on these products, such as garlic and tea tree oil, and then education for veterinarians on utilizing non-antibiotic approaches if they are determined to be efficacious.

4.3. Participating veterinarians perceive consumers as a driving force for reduced antibiotic use in dairy farming due to both misunderstandings about milk contamination and misleading labeling

Veterinarians in this study and elsewhere are frustrated by consumer beliefs about the dairy industry, as consumer beliefs are driving changes within the industry (Barkema et al., 2015; Sutherland et al., 2013; Wemette et al., 2020; Singer et al., 2019). A survey study in 2017 indicated that a large fraction of US adults perceives a threat to human health from the use of antibiotics in dairy farming and that their purchasing decisions as consumers of dairy products are related to this perception of threat, the belief that cattle treatment is better on organic than on conventional farms, as well as demographic factors (income, social ideology and marital status) (Wemette et al., 2021). There could be a larger effort by the dairy industry to be transparent about practices, including a better depiction of the similarities between conventional and organic farms. In a study on US resident perceptions of dairy cattle in 2017, it was found that over 10 % of survey respondents perceived that the use of antibiotics for sick animals have negative welfare implications (Widmar et al., 2017). Similar concerns were raised by Singer at al., (2019) who found that over 70 % of survey respondents indicated that consumers believed that animals raised without antibiotics had increased health and welfare. While one of the interviewed veterinarians pointed out that consumers are not necessarily interested in this information, education can be provided through removing sources of confusion for customers, such as negative labeling, and the dairy industry or veterinarians actively providing information to consumers. Market demand, and thus consumer beliefs, have driven changes in the dairy industry, such as the labeling of milk products as "rbST free", and the subsequent production of items to fit these standards (Olynk and Ortega, 2013; Wolf et al., 2011). In a survey on cheddar cheese consumption, consumers were willing to pay a premium for cheese produced from cows that were never given antibiotics (Bir et al., 2020). This highlights the role consumers could play in limiting antimicrobial use, but it also exposes the need for an improved regulatory oversight to assure that the reduction in antibiotic use does not jeopardize animal welfare.

4.4. Limitations of the study

While this study offered a range of information on dairy veterinarians' attitudes about antibiotics and AMR, it had several important limitations. Only nine interviews were conducted due to time and budgetary constraints. Based on the observed convergence of the main themes we believe that we reached saturation, as no novel themes emerged during analysis of the last few interviews. We may have been able to achieve greater depth within the themes (i.e. treatments on organic farms) with more interviews.

In line with the intended narrow geographical scope of our study, all of the interviewees practice in New York State. Therefore, the study findings have direct applicability and policy implications for the dairy farming and veterinary support provided to dairy farming in New York State only. Issues and findings from these interviews may translate to other settings, but they are likely most relevant to locals with smaller dairy operations. The variations in size of dairy operations in the US depending on geography (they tend to be larger further West with implications for protocols), the different roles of cooperatives in setting policy and procedures and the dominance of organic dairy (or lack thereof), mean these findings are not intended to be universal to all veterinarians working with dairy cattle. Thus, generalization beyond New York State warrants caution.

Concerns about organics are specific to the US practices and regulation, as organic products from elsewhere in the world may have different regulations about the use of antibiotics in organic dairy production (European Commission, 2021). Finally, the interviews were conducted between October 2017 to August 2018. The perceptions of veterinarians could have potentially changed over such long period of time. For example, we do not know if events or knowledge gained during this time period may have impacted those interviewed later compared to those interviewed earlier. Importantly, with this longer timespan some interviews were done after the VFD had only been in place for several months; not all of the interviewees had first-hand experience with the VFD and therefore not had the opportunity to observe its impact on their clients.

5. Conclusion

This study provided insight into dairy veterinarians' perceptions and beliefs regarding antibiotic use in the dairy industry and antibiotic resistance more broadly. Decreasing antibiotic use and subsequently limiting antibiotic resistance can only be accomplished through the cooperation and collaboration of veterinarians, farmers, co-ops, regulators, and ultimately consumers. Each of these stakeholders has a unique way to contribute to a solution and in identifying barriers. Dairy veterinarians are in a position to directly reduce antibiotic use and provide education to farmers about the risks of antibiotic overuse, which can be achieved more efficiently if veterinarians recognize that overuse in the dairy industry contributes to antibiotic resistance in dairy animals and could be a contributor to AMR more broadly. There is currently limited knowledge on the prevalence of antibiotic overuse on dairy farms nor are there even benchmarks for antibiotic use. The actual level of use needs to be known to develop interventions and then measure their success in optimizing use. The information obtained from this study highlights the need for more quantitative research into the dairy industry in the US. The results of this study also emphasized the need for more evidence-based research on alternative therapies, particularly for veterinarians who work with organic farms in the US, to maximize animal welfare. Overall, this input from veterinarians offered insight into

how antibiotics are used and perceived within the dairy industry and provides guidance on how to proceed with policy development and research to find ways to help combat AMR through reduced antibiotic use in the dairy industry in New York State.

Declaration of Competing Interest

The authors report no declarations of interest.

Acknowledgments

This material is based upon work that is supported by the U.S. Department of Agriculture - National Institute of Food and Agriculture (USDA-NIFA), Hatch under Accession number 1014331 awarded to R.I. The work was also partly supported by the Cornell University Veterinary Investigator Program (VIP) Training Grant: NIH T35OD010941 to M.W and the USDA-NIFA Multistate Research Funds Accession number 1016738 awarded to R.I. The authors thank the veterinarians interviewed for their time and participation. Also, the authors thank Dr. K. Fred Gingrich II, DVM, the Executive Director of the AABP, for providing the basic demographic characteristics of practicing veterinarians in New York State who are their members. Finally, we thank Dr. Francis L. Welcome for providing tireless support and immense knowledge about dairy herd health to this research.

Appendix A

AMR Study Interview Guide

Veterinarians

1. What led you to work with dairy cattle as a veterinarian?

a) How many years have you worked with dairy cattle in clinical practice?
b) What percentage of your time is spent seeing dairy farmers? What type(s) of clients do you see during the rest of your time (e.g. small animal owners, livestock owners, etc.)?
c) How many dairy farms do you provide service to?
d) Are the dairy farms you see predominantly conventional, organic, or a mix of both?
e) What is the range of farm sizes you see in terms of number of lactating cows?

2. What typically brings you out to visit a dairy farm?

a) What do you normally do during a visit? [*Redirect if needed: What happens if you see a sick cow with a suspected infection or the farmer tells you about one?*]
b) Do you think your clients generally follow your advice?
c) What about the Veterinary Feed Directive (VFD), does that ever come up? [Probes: What do you think of the VFD? What do your clients think of it? Has it changed how often you speak with clients? Do you think the VFD is valuable?]
d) What do your clients think about Veterinary Client Patient Relationship forms? [What role *do signed VCPRs play in client interactions?*]

3. How do you think dairy farmers should use antibiotics? Why?

a) Are your clients doing this? [*Probes: Why or why not? What about their use is responsible or less than responsible? Do they follow your instructions or the protocol you provide? Do they keep required documentation? Are cattle treated with antibiotics well managed?]*
b) What is your opinion on your clients' antibiotic use [in terms of quantity used or the way in which they are used]? [If responds it could be reduced] What's keeping them from doing this? [*Probes: Could they do a better job managing herd health, using a protocol, testing etc.? Could they do a better job of managing cattle receiving antibiotic treatment?]*

4. What do you think are some pros and cons of antibiotic use in dairy farming?

[*Probes: Do you think antibiotic use in dairy farming is contributing to antibiotic resistance? Is this antibiotic resistance a problem for cattle or humans? If so, in what way is it problematic? Do you think these pros or cons apply to antibiotic use in agriculture in general or are there differences?*]

5. Do you think there are consumer beliefs about dairy farming?

[*Probes: What are they? Are these misconceptions? Are they affecting the way farmers run their dairy farms? How? Are there beliefs about antibiotics? Are they accurate? Are they impacting practices?*]

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