Journal of Rural Studies 86 (2021) 587–598

Contents lists available at ScienceDirect

Journal of Rural Studies

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

'It's cheaper than a dead cow': Understanding veterinary medicine use on dairy farms

Gwen M. Rees [a,b,*], Kristen K. Reyher [b], David C. Barrett [b], Henry Buller [c]

[a] Institute of Biological, Environmental and Rural Sciences (IBERS), Aberystwyth University, Ceredigion, SY23 3DA, UK
[b] Bristol Veterinary School, University of Bristol, North Somerset, BS40 5DU, UK
[c] College of Life and Environmental Sciences, University of Exeter, Exeter, UK

ARTICLE INFO

Keywords:
Dairy farming
Veterinary medicine
Ethnography

ABSTRACT

This study offers a detailed and original assessment of the practices of prescription veterinary medicine use on UK dairy farms. The emergence of antimicrobial resistance as a global threat has necessitated an increasing focus on medicine use in agriculture. While an abundance of studies have recently emerged to demonstrate and evaluate strategies for medicine reduction, this paper seeks to understand the context and the on-farm culture within which treatment practices occur on a sample of UK dairy farms. Arguing that the experiential knowledge, on-farm culture and informal information flows are as important as 'science' in the practice of treatment decision making and drawing on extensive participant observation fieldwork combined with semi-structured interviews, this paper identifies and discusses three key themes that develop and, in places, challenge our current understanding of farmer treatment practices. These areas - treatment knowledge and understanding, a duty of care and autonomy of treatment practice - are seen to have complex effects on the use of veterinary medicines in dairy cattle and, as such, highlight critical areas for further research and opportunities for policy interventions aimed at improving responsible medicine use.

1. Introduction

The use of antimicrobial medicines in livestock agriculture has, over the last five or so years, become an increasing focus of attention amongst both policy and research communities. As the threat of widescale bacterial resistance to antimicrobials and its potentially devastating impact on human health care grows, concern over antimicrobial use has extended out of the purely human healthcare setting to include agricultural use and environmental loads. Although agriculture accounts for only around a third of all antimicrobials dispensed in the UK (Veterinary Medicines Directorate, 2019), in other countries - both within the European Union and beyond - this proportion can be much higher (Van Boeckel et al., 2015; More, 2020). Reducing the use of antimicrobials in agriculture and achieving more sustainable methods for ensuring animal health has been shown to contribute to a reduction in antimicrobial resistance in both the human and the animal populations (Tang et al., 2017) and has now been widely adopted as a policy goal in many countries (Góchez et al., 2020).

In the UK, much of the policy focus to date has been on quantifying the use of antimicrobials (Hyde et al., 2017; Davies et al., 2017; RUMA, 2017) and upon achieving reductions in prescribed volumes and intensity of use either in absolute terms or proportionally in terms of animal body weight, particularly for those antimicrobials deemed critically important for human health. The current UK Government strategy identified a target reduction of 25 % in sales of antimicrobials for agricultural use between 2016 and 2020 and the need for further improvement in data available on antimicrobial use in the farming sector (Department of Health and Social Care, 2019).

This strong policy emphasis upon quantitative reductions in antimicrobial use within livestock agriculture is not, however, without difficulty. It is not enough to simply reduce antimicrobial use on farms. Many modern livestock systems have grown to depend upon antimicrobials not just in achieving healthy production of animals within increasingly tight and regulated time frames but also in preventing infections from taking place and spreading amongst flocks and herds and in treating infections when they occur in individual animals (Landers et al., 2012). Hence, any reduction in antimicrobial use needs to be accompanied, on the one hand, by a broad range of biosecurity and disease management actions on the farm and, on the other hand, by a shift in approaches to animal treatment. Both these actions and

* Corresponding author. Institute of Biological, Environmental and Rural Sciences (IBERS), Aberystwyth University, Ceredigion, SY23 3DA, UK.
E-mail address: gwr15@aber.ac.uk (G.M. Rees).

https://doi.org/10.1016/j.jrurstud.2021.07.020
Received 12 June 2020; Received in revised form 12 March 2021; Accepted 17 July 2021
Available online 31 July 2021

approaches to treatment necessarily engage and implicate the farmer and those responsible for the day-to-day management of animal health. Former, more straightforward productive rationalities guiding farmer decision-making here become challenged as new strategies and practices of animal care are brought into play. This might be achieved both by an awareness of the potential contribution of agricultural medicine use to the wider societal issue of antimicrobial resistance and by the introduction of new strategies, and in some cases, food chain regulations, that place a greater emphasis on anticipating and preventing, rather than treating, disease. Simply enumerating volumes of prescription medicines sold does little to further our understanding of why, when, and how these medicines are being employed and, critically, how that might change.

Although rural and agricultural sociologists have long argued that farms are unique combinations of the economic and the familial, the individual and the social, combined with the specifics of place, local culture and history, their particular quality as unique sites of multi-species interaction and relationality has long been ignored (Buller, 2018). In recent years, a number of researchers have looked afresh at these multi-species assemblies through the lens of on-farm biosecurity and disease control (Hinchcliffe and Ward, 2014; Maye et al., 2014; Bellet, 2018; Helliwell et al., 2020; Shortall and Brown, 2020). Driven in part by the broader 'animal turn' in the social sciences, interest in human-animal relations, stockmanship and the practices of farm animal welfare have also helped to bring a new attentiveness to livestock agriculture and the wider ethics of animal care (Burton et al., 2012; Buller and Roe, 2018; Bassi et al., 2019). Furthermore, as the parameters and drivers of productivist agriculture are themselves increasingly called into question by the wider debates around sustainability and food production as well as health and welfare, the motivations, behaviour, and decision-making practices - even identities - of farmers and others working with animals are coming under new scrutiny.

In this paper, we draw upon these new interests within the rural social sciences to investigate specifically how farmers approach animal treatment decisions in the light of increasing concerns around antimicrobial use. In doing so, we draw upon an emerging conceptual attentiveness to cultures of care (Greenhough and Roe, 2010; Higgins et al., 2018), to more qualitative approaches to understanding behaviour (Brennan et al., 2016), to the context specificity of place (Shortall and Brown, 2020), to a greater appreciation of relational knowledge systems and flows (Enticott, 2008; Ritter et al., 2017) and, finally, to a new emphasis on interdisciplinary investigations and observational, qualitative methodologies (Buller et al., 2015; Morgans et al., 2020). In this paper, we are interested in the contexts and management cultures, histories and practices within which treatment decisions are enacted and performed and how these reflect, or indeed as new priorities emerge, challenge, the goals, values, moral orderings and priorities of the farmers themselves (Ritter et al., 2017). Drawing on Enticott (2008), we seek to demonstrate how farmer constructions of animal disease, its management and treatment are built upon highly localised and context-specific experiential and handed-down knowledges that, critically, are having to be renegotiated with the positions and influences of other actors such as veterinary surgeons, food chain actors and regulators. The importance of context and place, emphasised by Enticott (2008), is also constitutive of what Burton et al. (2012) have termed 'cowshed culture', through which the practices and skills of stockmanship are slowly honed. Those authors argue that attempts to improve the behaviour of farmers towards livestock, in our case through reducing the use of antimicrobials, 'by changing attitudes alone are problematic and unlikely to succeed without intervention into other areas of the farm system'. (Burton et al., 2012). Around the issue of antimicrobial use reduction, Helliwell et al. (2020) take this further by asserting that 'antibiotic stewardship is not a homogenous intervention related simply to the reduced use of antibiotics within the herd'. Rather, they argue, 'this goal is achieved through collectivity-specific interventions which have varied and ambiguous implications for the animals and their care' (2019, 454). As Mol et al., 2010:14 have shown, in a different context, care might be seen as 'ongoing tinkerings with shifting tensions between different demands to care'. We argue in this paper that concern for the over-use of antimicrobial medicines in livestock farms raises not only new demands on care practice but also new strategies of negotiation between such shifting tensions.

To arrive at an in-depth and accurate understanding of these practices, cultures and contexts of on-farm animal health, we have therefore adopted a series of qualitative approaches, employing on-farm observation of treatment decision making and practices along with a series of semi-structured in-depth interviews. In the following section, we consider the historical, cultural, and regulatory frameworks within which the use of veterinary medicines operates before presenting the methodology and empirical results of the study. We conclude with an empirically informed perspective on appropriate and effective interventions that gives priority to an understanding of the distinctive contexts within which farmers address the health of their cattle.

2. Veterinary medicines and the UK dairy farm

Despite their current predominance, veterinary medicines extend well beyond antibiotics. Promoting responsible medicine use requires veterinary surgeons and farmers to utilise other methods of disease control to maintain healthy, productive animals (Ivemeyer et al., 2012; O'neill, 2016; Turner et al., 2018). This often entails improving animal husbandry or the environments in which animals live. Responsible use can require changing treatment practices, for example using anti-inflammatories instead of antimicrobials to treat viral pneumonia. Preventing diseases in the first place, and thereby reducing the need for therapeutic medicines, through better management or by early intervention is a critical part of this process. In veterinary medicine, as in human health, the use of vaccines to promote immunity to certain diseases is key (O'neill, 2016; Wilby and Werry, 2012; Jansen et al., 2018).

2.1. Regulation and the vet-farmer responsibility paradox

The use of prescription veterinary medicines is subject to many regulations in the United Kingdom (European Union, 2009; Veterinary Medicines Regulations, 2013). Medicines for cattle must be licensed for use in that species. Meat and milk withdrawal periods must be stated during which time it is illegal for the meat or milk of the treated animal to enter the human food chain. Moreover, vets may only prescribe to "animals under their care". This is defined by the Royal College of Veterinary Surgeons as follows:

> "The veterinary surgeon must have been given the responsibility for the health of the animal or herd by the owner or the owner's agent, that responsibility must be real and not nominal, the animal or herd must have been seen immediately before prescription or recently enough or often enough for the veterinary surgeon to have personal knowledge of the condition of the animal or current health status of the herd or flock to make a diagnosis and prescribe and the veterinary surgeon must maintain clinical records of that herd/flock/individual" (Royal College of Veterinary Surgeons, Updated 2018)

Although for other farmed species differences may exist, in practical terms this responsibility translates into regular visits to the dairy farm by the vet either as part of a contracted service to maintain the status of a herd under their care or in response to specific incidences of animal disease or illness. Farmers are habitually issued with prescription veterinary medicines by their vet for known and reoccurring animal health problems, which they subsequently store on-farm for use at their own discretion at a later date (Rees et al., 2018). The vet is the only person who can diagnose disease and prescribe most veterinary medicines; however, the farmer is the individual making the day-to-day treatment decisions (UK Government, 1966). Actual consultation with a vet for a

specific diseased animal before deciding on, and initiating, treatment with a prescription-only medicine that the farmer already has in their possession may be limited, if it occurs at all. There is an unexplored tension here between the legal responsibility of the prescribing vet and their effective agency when it comes to actually using the medicine. Dairy farms store a wide range of antibiotics and other prescription veterinary medicines on-farm. Although farmers must maintain medicine records covering purchase, administration and disposal of prescription veterinary medicines (Veterinary Medicines Directorate, 2014), it is not uncommon to find in these on-farm medicine cupboards expired prescribed medicines and others that are not in fact licensed to treat cattle (Rees et al., 2018).

Medicine use and treatment also falls under private regulatory control through voluntary assurance schemes. Ninety-eight percent of UK dairy farms are registered with the Red Tractor Farm Assurance Scheme (RUMA, 2017), with a few other less common schemes also available. Although these schemes are voluntary, adherence to them is often a requirement of milk-buying companies as a means of quality assurance. The schemes have a variety of different requirements and include an annual or 18-monthly visit from an assessor who will audit the farm's medicine storage and treatment records alongside other requirements (Red Tractor Assurance, 2017). While there are recent suggestions that new, more stringent medicine use standards in the UK have reduced antimicrobial use (Potter et al., 2019), other evidence suggests that dairy industry policies can create unexpected pathways and outcomes (Begemann et al., 2020) and farmers do not always prioritise record keeping, seeing farm assurance visits as essentially a 'tick-box exercise' of compliance (Escobar, 2016).

2.2. Responsible medicine use

The global threat of AMR has recently caused a shift in focus in the agricultural industry towards reduced and defensibly responsible antimicrobial use (Bellet, 2018). Responsible use is defined by the British Veterinary Association (BVA) as "Correct antimicrobial: As little as possible, as much as necessary" (British Veterinary Association, 2015). In 2016 the O'Neill Report on AMR, a UK-funded independent report on antimicrobial resistance, concluded that although the use of antimicrobials in humans was the greatest driver of AMR in humans, agricultural use was also very important, and improvements needed to be made (O'neill, 2016). The increasing public awareness of AMR (Morris et al., 2016) has in turn led supermarkets and other retailers of agricultural products to focus their attention on the use of antimicrobials by their producers. Dairy farmers generally sell their milk either to large milk-buying cooperatives or directly to supermarkets, with some retailer-aligned contracts paying a premium price to farmers who comply with additional regulations as set by the buyer (Begemann, 2019; Mylan et al., 2015). Originally, such private regulations were designed to improve milk quality, but more recently it has become increasingly common for milk buyers to stipulate regulations promoting certain antimicrobial use behaviours aimed at improving responsible use (Van Dijk et al., 2017).

Veterinary surgeons are also coming under increasing pressure to prescribe antimicrobials more responsibly (British Veterinary Association, 2015; British Cattle Veterinary Association, 2017; Ruma, 2019). In some EU countries, veterinary practices and even individual vets' antimicrobial prescribing behaviours are being monitored and antimicrobial use is increasingly restricted (Wielinga et al., 2014; Speksnijder et al., 2015). In the UK, veterinary prescribing of antimicrobials is still largely unregulated and unmonitored. Veterinary practices are private businesses with no umbrella body such as the National Health Service through which statutory or indeed non-statutory benchmarking could take place. However, the recent change in the demographics of veterinary businesses coupled with a well-documented move towards increasing corporatisation (Robinson et al., 2019) has led to some multi-practice monitoring initiatives being introduced. Sector-specific antimicrobial use targets have been introduced, although pressures on vets to move away from prescribing certain antimicrobials and reduce overall use have had variable success (Mills et al., 2018). Some commentators suggest, however, that veterinary businesses need to change from a medicine sales-driven business model towards a more preventative healthcare model (Statham and Green, 2015).

Vets nonetheless stand as the principal source of advice and information about antimicrobial use for dairy farmers and are therefore pivotal to the agenda of improved responsibility in AMU (Jones et al., 2015). Yet, increasingly, vets are not the sole purveyors of such advice. Food chain actors, retailers, assurance schemes and animal feed companies play a growing role in advising farmers and setting criteria for animal production, including medicine use (British Cattle Veterinary Association, 2018; Red Tractor Assurance, 2018). Since 2019 in the UK, Farm Assurance guidelines have required at least one person on each farm responsible for administering vet-prescribed medicines to have completed an approved training course (Red Tractor Assurance, 2019). As discussed previously, these farm assurance standards can be an effective tool for reducing antimicrobial use, although the changes they elicit may not always be those intended (Begemann et al., 2020). Dairy farmers therefore experience many different drivers for responsible medicine use, varying according to a range of factors that might include geographical location, their relationship with their registered veterinary practice, the role of individual vets, their milk contract as well as their own awareness of and engagement with the debate over antimicrobial use reduction through industry bodies, the press, their peers and their own healthcare providers.

3. Methodology

Utilising an ethnographic and qualitative approach, this paper draws on data gathered from over 160 h of participant observation conducted across three dairy farms over a 12-month period in 2017–2018, alongside 20 semi-structured in-depth interviews with dairy farmers from South Wales and South West of England. Ethnography has been described as being able to examine "social life as it unfolds, including looking at how people feel, in the context of their communities" and provides an understanding of "social life as the outcome of the interaction of structure and agency through the practice of everyday life" (O'reilly, 2012). Ethnography is both a methodology and a theoretical framework and has been used extensively (Mariner and Paskin, 2000; Enticott, 2012; Holloway et al., 2014)by medical anthropologists to investigate human health behaviours (Greenhalgh, 2017; Taxis, 2003; Costello, 2001). As a theoretical framework, ethnography seeks to learn about people, not to study them, through immersion in the population of interest (Jones, 2017). Ethnography has the advantage of the researcher being present and asking questions for a prolonged period, believing that "relevant and interesting information is more likely to surface in informal context than in formal interview settings" (Pool and Geissler, 2005). There is a difference between what people say, what they think, and what they do, and it has been argued that ethnographic research is best placed to understand these differences through a combination of observation and conversation (O'reilly, 2012; Lambert and Mckevitt, 2002).

Within the fields of veterinary medicine and animal health, the use of ethnographic methodologies has been relatively limited, though the new attention amongst rural scholars to issues of animal health and stockmanship has certainly led to a recent interest in such approaches. Studies have included on-farm biosecurity practice and tuberculosis management (Enticott, 2012), the use of robotic milking technologies (Holloway et al., 2014), euthanasia decision making (Morris, 2012) and veterinary hospital culture (Atwood-Harvey, 2003). By comparison, in human medicine, ethnographies have increasingly been seen to provide valuable evidence upon which to base policy decisions and health interventions, though, as with veterinary medicine, there is still considerable potential for ethnographic and social science approaches to be

more widely used and accepted (Savage, 2000; Goodson and Vassar, 2011; Jones, 2017). In this study, the capacity of an ethnographic approach to expose the cultures, contexts and practices within which behaviours take place enabled a rich, in-depth exploration of medicine use on dairy farms.

3.1. Data collection and analysis

Ethical approval for this study was granted by the University of Bristol Faculty of Health Sciences Research Ethics Committee, reference number 33021. Participating farms were part of a larger pool of 27 dairy farms recruited to a wider study on prescription veterinary medicine storage and use (Rees et al., 2018; Rees, 2019). All farms underwent an initial visit, during which three farms were identified as suitable for more in-depth participant observation. In this study, the term "farmer" is used for all of the actors employed directly by that farm for the care of the animals on the farm. These farms were purposively sampled from the recruited pool of farmers to match the inclusion criteria: being located within the same geographical area, using the same veterinary practice and having the same wider social context while also having different herd sizes, management types and production goals. In this "multi-sited ethnography", these farms were chosen to capture the diversity of dairy farms found in the UK, from the small family-run farm that employs no outside staff through the "typical" commercial dairy farm to the very large dairy farm using a rotary milking parlour. The seasonality and management practices of these farms was also diverse. One farm calved their cows year-round, housed the cows through winter and sold their milk to a large commercial milk buyer. One farm calved the majority of cows in late summer and autumn, housed the cows in winter and sold their milk to a local cheese producer. One farm operated a New Zealand-style extensive "block calving" system, calving all cows within a 10-week window in the spring and selling their milk to a cheese producer. The nature of their involvement in the participant observation was discussed and it was explained that the researcher would attend the farm on a semi-regular basis in order to participate in day-to-day activities and observe medicine use. Participant observation and semi-structured in-depth interviews were performed concurrently rather than sequentially in order that through reflexivity the participant observation could inform the interviews and vice versa.

A summary of the participant characteristics can be seen in Table 1. Briefly, the participants farmed in seven different counties in England and Wales. The majority farmed Holstein-type dairy cows. The median age bracket of participants was 41–50 years of age; 17 participants were male and three were female. The participants farmed a median of 230 (Range 80–490) adult dairy cows and produced a median of 1,900,000 (Range 550,000–3,600,000) litres of milk annually. Once the three farms suitable for the more intensive 12-month participant observation had been recruited, a key informant was identified on each farm and became the main point of contact to arrange field visits. Visits were arranged by relatively informal communication through telephone call or text message, and key informants would send a message if they thought an event of interest was taking place on the farm. Similarly, the lead author would maintain regular contact by telephone between visits to discuss any important changes or news to do with the farm, to arrange subsequent visits and generally keep up to date. Across all farms the researcher spent significant time with every member of family or staff who played a regular role in animal health and treatment decisions.

Morning milking was identified by each key informant as being the time of day where disease was most likely to be identified and diagnosed, and where treatment decisions were most likely to be made. These were therefore the focus of the initial visits. Morning milking occurred at 4am, 5am and 7.30am across the three farms, with calf management and feeding taking place immediately afterwards. On occasion, visits were targeted at afternoon milking or specific days and times where there was an event of interest (e.g. a tuberculosis test, vaccination of youngstock, a busy calving period, etc.). Visits tended to last six to 8 h and occurred approximately once a month, although this was tailored to the particular circumstances of the farm. For example, one of the farms had a seasonal calving herd, where the farm aimed to calve around 400 cows and heifers in a six-week period in the spring. During this period, visit frequency was increased in order to capture the predicted increase in treatment decisions during the calving and immediate post-calving periods. Ethnographic fieldnotes were taken during the visits, and participant farmers were comfortable with this notetaking from an early stage. As soon as was convenient following each visit, ethnographic fieldnotes were expanded upon and written up in a narrative fashion. A personal observation journal was also kept, and these narrative fieldnotes and personal logs were often referred to and re-read during the 12-month study. Semi-structured interviews lasted an average of 50 min (20–77), were audio recorded and were transcribed verbatim.

Analysis of the participant observation fieldnotes and narrative accounts was conducted alongside analysis of interview transcripts and was iterative-inductive and cyclical in nature. Utilising thematic analysis (Braun and Clarke, 2006), transcripts and narrative accounts were coded using NViVo software (QSR Software, NViVo 10); emergent themes were identified and tested through a process of cross-checking with other interviews and through discussion with participants during

Table 1
Summary of participant characteristics for semi-structured in-depth interviews (n = 20).

Farmer ID	Age bracket	Sex (M/F)	County	Number of adult dairy cows	Total annual milk production (litres)	Breed
1	18–30	M	Somerset	230	2,000,000	Holstein
2	18–30	M	Somerset	230	2,000,000	Holstein
3	51–60	M	Somerset	180	2,100,000	Holstein
4	18–30	M	Swansea	100	650,000	Holstein
5	51–60	M	Dorset	80	550,000	Mixed
6	41–50	M	Wiltshire	320	1,900,000	Holstein
7	41–50	M	Somerset	220	1,900,000	Holstein
8	>60	M	Somerset	180	630,000	Jersey
9	31–40	M	Carmarthenshire	80	650,000	Holstein
10	41–50	M	Wiltshire	470	3,600,000	Holstein
11	41–50	M	Dorset	490	3,500,000	Holstein
12	51–60	M	Somerset	150	1,500,000	Holstein
13	41–50	F	Carmarthenshire	110	500,000	Jersey
14	31–40	M	Carmarthenshire	280	1,500,000	Friesian
15	51–60	M	Somerset	340	3,000,000	Holstein
16	18–30	F	Somerset	360	2,100,000	Holstein
17	51–60	M	Hampshire	180	1,300,000	Ayrshire
18	41–50	F	Somerset	280	1,700,000	Guernsey
19	51–60	M	Pembrokeshire	220	1,800,000	Holstein
20	>60	M	Somerset	80	900,000	Friesian

farm visits. A thematic framework was developed from the earlier data and was then explored and tested during subsequent participant observation and interviews. The eventual themes identified in this paper coalesced from this process and, as such, these themes emerged from, and were grounded in, the empirical data. In this way areas of interest from previous visits or interviews could be identified and highlighted for further exploration at subsequent visits or in subsequent interviews, informal interviews could explore possible themes and questions emerging from the data, and interpretations could be tested and validated.

4. Results and discussion

Through the iterative and cyclical nature of the interviews and participant observation and analysis, it became apparent that three key ideas best accounted for the treatment behaviours seen and the beliefs and values expressed while other, lesser themes identified did not fully cover the complexity of the situations. These themes were as follows: the farmers' 1) knowledge and understanding of the treatment of disease, 2) sense of duty to the care and wellbeing of their animals and 3) autonomy of treatment practice. Each of these were seen to, directly or indirectly, affect the observed treatment decisions and practices being carried out over the year-long empirical research period. This section presents these three major themes.

4.1. Treatment knowledge and understanding

> "Father's said many a time you're never too old to learn if you're not too stubborn to listen." – Farmer 5

Knowledge has become a value-laden term in epistemology. In this context, the knowledge of which farmers speak refers to what they take as the empirical 'truths' about the physiology and pathology of disease processes, medical pharmacology and the management of animal health. Farmers often have an acute awareness of the limitations of their 'formal' knowledge yet rely strongly on experiential and experimental knowledge that can, on occasion, put them at odds with the more 'evidence-based' medical knowledge of their vets.

Within the overall theme of knowledge, four clear dimensions are discernible from the research: experiential, experimental, uncertainty and conceptualisation.

4.1.1. Experiential knowledge

Experiential knowledge describes the impact of past experience on farmers' current knowledge about farming, disease, and treatment. Most participants had many years of experience in dairy farming - and in agriculture more generally - and would regularly refer to previous events and their responses to them when discussing treatment or management choices. This experiential knowledge was used in many contexts to justify treatment decisions they made, particularly where those decisions might have been considered contentious or going against their understanding of what constituted conventional practice.

> "I know you're not supposed to give these tubes for five days, but I've tried them for the three days they say. I've tried them for four, five and even six days. Five days works, and so five days is what they get with me." – Farmer 19

Experiential knowledge was most commonly articulated in the form of anecdotal evidence of previous treatment successes or failures (see also, (Hektoen, 2004). Farmers do not farm in a vacuum, and where they had no personal experience to share, would often draw upon the experiences of their peers, passed along through informal discussions of farming practice, to illustrate their treatment rationale. The outcomes of previous treatment decisions were often a key factor in deciding which medicine to use, and in what quantity; evidence of a 'path dependency', where decisions follow an ineluctable pathway laid down by the results of previous decisions.

> I think we first started using [tylosin] on foul in the foot, or something like that? But then, there's other reasons now … [tylosin] can be used on various other things, isn't it? I dunno, probably because we've had a sick cow we've though "I'll give this a go, see if it works" and given it this drug, and that's how I've come to use it, because it did work. – Excerpt from Fieldnotes, Farm C

Equally, once a treatment has failed to 'work' (i.e. failed to result in recovery from disease), it was frequently written off as simply ineffective and not used again. One farmer, reflecting on this practice, accepted that the medicine may be effective despite the treatment failure:

> "No, never found it worked but it probably does, and it just could be just that I've tried it, didn't work on one animal and I've just kind of thought, this doesn't work." - Farmer 17

Here, that experiential knowledge is not only rationalised, it is also embodied. A medicine's ease of application, learned from past manipulation, becomes an additional element in the perception of prior success, contributing to the sense of its therapeutic efficacy.

It is important to note that, perhaps particularly in farming, experiential knowledge can be cumulative and inter-generational. Given the familial epochs of a traditional farm, this experiential knowledge is frequently a commodity or resource passed from parents to their children and co-learnt by family members. In this way, while scientific understanding of disease processes evolves and the medicines used to treat disease advance, the contemporary science may be of lesser immediate value to a farmer than the understanding of disease gained through that personal and familial experience. In one observed instance, a farmer described the tensions between, on the one hand, the advice and "scientific knowledge" being given by their vet about the best way to manage a recent outbreak of pneumonia in their calves and, on the other hand, the advice and "experiential knowledge" of their grandfather. Here, the farmer's vet had advised vaccinating the calves against certain respiratory diseases in combination with investment in individual calf hutches to reduce the disease burden. The farmer's grandfather, on the other hand, disagreed and advocated placing heaters in the calf shed while treating all calves with a dose of long-acting antimicrobial because "this has always sorted the problem in the past". The confrontation witnessed here between modern scientific understanding and long-standing practical experience caused obvious tensions between the farmer, his vet, and his family. In negotiating a resolution, a 'compromise' of sorts was reached whereby the farmer treated all calves with an antimicrobial while also beginning to research the purchase of individual calf hutches for the next season. As described by Morgans (2019), these 'contested knowledges' are rooted in the opposing epistemologies of farmers and their vets and go some way to explain the occasional disconnect between veterinary advice and farmer practice.

4.1.2. Experimental knowledge

Experimentation and innovation are key areas of focus for rural development and participatory knowledge generation. The use of living labs, farmer action groups and innovation networks are formal, facilitated processes that can successfully bring about changes to animal management and antibiotic use (Morgans, 2019; Main and Dijk, 2017). The current study shows that the drive to innovate leads UK dairy farmers to experiment informally, as part of the normal farming 'process'. Thus, in addition to experiential knowledge, which can be described as a more passive form of knowledge acquisition, farmers use intentionally experimental knowledge when making treatment decisions (Farrington and Martin, 1988). They actively test and trial different medicines, treatment, and management practices in order to find which work best. Often, this knowledge is acquired by purposeful design:

> "It's just something that we've tried over the years and it works, so that's what we do. When they calve, they have one of those five-in-

one tubes. It's just got egg stuff in it and it's just protein and egg, but we find … we've done our own little experiment here on calves that have had new-born tubes and calves that haven't had new-born tubes, and the calves that have new-born tubes will be far thriftier than the calves that don't. So, it's something that we've done here ourselves." – Farmer 12

Occasionally, such knowledge may be gained accidentally:

YG [young female staff member carrying out morning milking], on finding a cow that needs treatment fetches a [cefapirin/prednisolone combination] intramammary tube from the medicine cupboard. She pulls the lid away from the tube in such a way that the infusion tip becomes bent at an approximately 45° angle from straight. She then proceeds to swiftly wipe the udder, fore strip some milk and infuse the contents of the tube before noting the treatment on the white-board behind her. I ask if she bent the tip on purpose, because I hadn't seen that before. "Yeah, I always do it like that". I ask if someone showed her the technique or where she learned to do it. "I guess I just accidentally did it once and realised it made it so much easier to do." – excerpt from fieldnotes, Farm B

Experimentation did not always have a positive outcome. In one case, a farmer described trying to reduce the recommended duration of his cows' dry period (time between lactations when they are not milked) in order to increase productivity. The dry period is critical in aiding the recovery of cows from mastitis, and the farmer learned the hard way:

"Because I was being greedy, I thought I'd give them just a 30-day dry period and get an extra 30 days milk from them, but that was a disaster because they came in with very high cell counts. Total disaster. Never again, I was stupid." – Farmer 4

It has been stated that "experimenting is part of farming as much as tilling the soil, planting seeds and caring for animals" (Haverkort, 1991) and the development of context-specific farming practices worldwide has been attributed to the experimental activities of farmers (Hansson, 2019; Hoffman et al., 2007). Indeed, the idea of "farmer innovators" (Critchley, 2000; Reij and Waters-Bayer, 2014) and "research-minded farmers" (Biggs, 1990) is well known; a recent Austrian study showed 90 % of farmers reported experimenting in an autonomous way (Vogl et al., 2017). Farmers have also been shown to be more willing to experiment with alternatives to antimicrobial treatment for treating mastitis than vets (Poizat et al., 2017). The emergence of experimental knowledge as a factor in treatment decision making and veterinary medicine use in this study should therefore be unsurprising, however it has rarely been examined in this context.

4.1.3. Uncertainty

While experience and experimentation both contribute to a farmer's understanding of disease and treatment, uncertainty remains a key feature of treatment decision making. Uncertainty in this context can take the form of being unsure of a diagnosis, being unsure of which medicine to use to best treat the disease or being unsure about what dose is required. Uncertainty may also manifest through risk-averse behaviour, where there is uncertainty over the presence, severity, or indeed possible impact of disease. In such cases, antimicrobial treatments are frequently used 'just in case', or, as one farmer in this study put it, *"It's cheaper than a dead cow" (Farmer 2)* (see also (Golding et al., 2019),).

Similar evidence from research in the Netherlands and Germany reveals farmer uncertainty over mastitis treatment leading to extended and largely unnecessary courses of antimicrobial treatment (Swinkels et al., 2015). Indeed, in human health it has been shown repeatedly that uncertainty over the presence of pathological bacterial infection is positively associated with prescribing antimicrobials (Horwood et al., 2016; Whaley et al., 2013). It is therefore easy to understand the rationale for making a risk-averse decision, where treating with an antimicrobial is considered lower risk for the animal than not treating.

Uncertainty can also arise from a lack of appropriate knowledge:

"I think medicine, the problem is there's no knowledge. I've seen my dad in the medicine cupboard literally picking up different bottles of antibiotic and thinking "hmmm, which one today?" You can go to ag [agricultural] college or uni and they don't teach you a thing about medicines." – excerpt from fieldnotes, Farm A

Interestingly, when questioned, farmers believed their vet should be the source of this information but were dissatisfied with the current provision of knowledge about medicine use. They believed their vets were often too busy to explain the correct use of medicines in enough detail, or in some instances that their vet did not have sufficient knowledge in this area to advise appropriately. However, given that uncertainty in diagnosis and treatment is a feature of veterinary and human medicine, it does not necessarily follow that uncertainty arises from a lack of knowledge, rather from the complex and unpredictable nature of disease processes.

4.1.4. Constructing narratives of understanding

It became obvious from the interviews and field research that dairy farmers created their own understanding of disease, negotiating experiential knowledge, experimental knowledge, "expert" advice and their own internal logic (see also Enticott 2012). This section describes the way in which farmers draw on these, and other, resources in order to create an internal narrative and construct an understanding of the process of disease, treatment and healing which directly influences their treatment decisions yet may not be apparent or easily understood. This concept builds upon those sections that come before it yet stands alone as an important and distinct process which directly influences the way that farmers manage disease and has important implications for understanding treatment decisions.

It was clear that farmers required rational narrative for each treatment or medicine, and in the absence of scientific and veterinary training required to explain the processes of disease and healing, farmers would develop their own understanding of disease:

"Some people say you should be using more mammary tubes and less injection, but I don't know. I just feel like with tubes there's a load of antibiotic just going in and sitting there at the bottom of the udder not really doing much. With an injection you feel more that it's getting at things from everywhere you know? I don't know if that's right through, mind." – excerpt from fieldnotes Farm B

Knowledge about disease and treatment was seen to be constructed through a combination of learned experience, situational knowledge, and pre-existing knowledge (see also (Maye et al., 2014). Most notable was the common absence of any input from the vet in this process. Yet, these narratives - while powerful and with a significant influence on the diagnosis and treatment of disease - were often mixed with incertitude. Farmers were aware of the limitations of their understanding. However, in the absence of any other way of explaining their experiences with disease and treatment, this negotiated understanding was used to inform treatment decisions daily.

One farmer described going against advice on a treatment because he couldn't make sense of it according to his own internal logic:

"I've never actually tried [teat sealant] on its own [without antibiotics]. I just think putting a bit of tube up and antibiotics up there, if there is anything in there niggling along, it should cure that, so you need the antibiotics you know? How does just sealing it off help with that? – Farmer 5

Across all three farms where participant observation took place, this concept of constructing individual narratives to understand disease and treatment was evident. For example, antibiotic course lengths were regularly extended *"because you just need those extra few days to really kill the last bugs" (Farmer 2)* despite the licensed course length being advised

by their vet. The idea of using "stronger antibiotics" to treat more valuable animals or more severe disease presentations influenced choice of treatment, despite there being objectively no such thing as a strong or weak antibiotic. These stronger antibiotics were usually the more expensive medicines, or those that farmers are discouraged from using due to their importance to human health. Similarly, the way farmers constructed their understanding of the work of antibiotics and anti-inflammatories influenced their decision to use either, or both. Where some used empathy and anthropomorphism to reflect that they would want an anti-inflammatory if they were unwell, others reasoned that the antibiotic was the important medicine that was doing the work of healing, and the anti-inflammatory was more of a luxury.

By combining knowledge gained from experience and experimentation with advice from vets, peers and family members, farmers appeared to go a step further, using internal logic to construct models for how disease processes could be successfully treated. These models enabled farmers to make satisfactory treatment and management decisions and helped them negotiate uncertainty. This echoes the notion of 'lay epidemiology' introduced by Davison et al. (1991), and the candidate system identified in farmers' explanations and narratives of animal health and disease regarding tuberculosis (Enticott 2008).

4.2. A duty of care

As Buller and Roe (2018) argue, animal stockpersons should be reconsidered as animal care persons, working within a broader farm culture within which animal care is often central (Burton et al., 2012). Care is inherently complex, with the care of another an "achievement alongside other demands which may be in tension with care delivery – minimising costs, personal challenges, competitive advantage – each being well-recognised characteristics of the commercial industrialised, food animal production environment."

Where treatment decisions are concerned, a key motivator is a sense of duty to the wellbeing of the animals for which the participants are responsible. While care can be described as an achievement despite other pressures, it is also a raison d'être in and of itself. This 'duty of care' was at the heart of medicine use and the treatment of disease seen in this study. Dairy farmer empathy is associated with animal welfare (Kielland et al., 2010) and the emergence of duty of care as one of the three key themes is therefore reassuring.

The value that dairy farmers placed on the care of their animals can be examined in two key areas: the bovine patient and treatment as action. Of course, both are inextricably linked and resist separation, however, by discussing them separately it is somewhat easier to illustrate the main points of this argument.

4.2.1. The bovine patient

Dairy cattle are almost entirely reliant on farmers to provide them with the basic necessities of life. Feed, water, and shelter are key components of the "five freedoms" of animal welfare (Farm Animal Welfare Council, 2009), though the most pertinent to this study is that of freedom from pain, injury, or disease. Dairy cattle rely on farmers for their physical health and wellbeing. This positions the dairy cow as a ward, or patient, while simultaneously positioning the farmer as caregiver. This sense of the 'bovine patient' underlies many management and husbandry practices, not least veterinary treatment decisions. While always needing to operate within the constraints of the economic, societal, and political context of dairy farming, farmers see their cattle as dependents. They value the "work" that these animals do, and the income and career that they are provided by these animals' existences and milk production.

> "They've done us alright, you've got to look out for them. I'm probably just too sentimental for being a dairy farmer …" – Farmer 5

This two-way relationship between the farmer as a provider of care for the cow, and the animal as the provider of an entire way of life, is appreciated in various ways. Farmers were aware of the value of a close relationship with their animals, and the impact of this relationship on their ability to recognise and treat disease:

> "… you can see how, if you haven't got that sort of personal level of involvement with the cows, like the guy that's milking now - he knows how to milk cows, but he doesn't want the personal level of involvement with them. He's been in here two years and he really doesn't know no more than maybe a dozen cows, if that … Yeah, and I can see how much it makes a difference, to actually know your cows really well. Because you instantly click onto the fact, "Something's not right here." But he doesn't get that. He doesn't see it. It's quite interesting actually. You suddenly realise, "God, that's only because I knew them." Not because I'm particularly good at it, it's just that I knew them so well. Because that's all I did." Farmer 18

This mutually beneficial relationship between farmer and animal drives many treatment decisions. A cow relies on the farmer to provide appropriate treatment when she is diseased. The farmer's willingness to treat her might be driven in some cases by a feeling of reciprocity. There is a sense that farmers "owe" their animals a good life as a reward for the provision of a rewarding career and lifestyle. Indeed, for some farmers, this sense of reciprocity may lower treatment thresholds to the point that animals are treated unnecessarily, or even overdosed with veterinary medicines as a means of reward. This is illustrated best by an example from the fieldwork:

> While walking past one of the straw pens on the way to the calf shed, {Farmer C} points out a clearly very elderly cow picking at some hay. "See her? Guess how old she is?" I guess 10 or 11. "No! She's 19! I want to enter her for the Guinness Book of Records for most number of [tuberculosis] tests in a cow". I express surprise at her age and ask whether she still gets in-calf. "Well, we haven't had a calf out of her for two years now and she's all dried up but I'm still kind of trying. She gets lame every now and then but a bottle of [tylosin] soon sorts that out. I owe it to her. She was one of my first cows when I took over the place from dad and she's always done me right. I know she's not making us any money anymore, but she's almost become our mascot now." – Excerpt from fieldnotes, Farm C

This cow will have almost certainly received antibiotics and other treatments in order to maintain her welfare and keep her in the herd, despite there being no economic case for doing so. This sentimentality and duty of care has almost certainly led to the use of antibiotics and other treatments which would not have been required had she been culled at the normal end of her productive life. The farmer has valued her life above what can be explained by economics or "good farming practice" and this has affected treatment decisions.

4.2.2. Treatment as action

During the participant observation fieldwork, there were examples of animals being perceived to be diseased or suffering leading farmers to express feelings of distress and a desire to take action to relieve the suffering and treat the disease. Farmers have been shown to extend the duration of antimicrobial treatments because doing so made them feel like "good farmers" (Swinkels et al., 2015). Where treatment is seen as action, veterinary medicines can be viewed as the tools for positive action in the face of disease. This can lead to over-treatment and over-medicalisation of both self-limiting disease and mis-diagnosed disease where symptoms lie within the 'normal' range for that animal or herd. The concepts of overdiagnosis and medicalisation are well recognised in human medicine (Van Dijk et al., 2016), and the overuse or irresponsible use of pharmaceuticals is often attributed to these phenomena (Welch et al., 2012).

In the context of medicine use on dairy farms, this concept of treatment as action can manifest in many ways. From the risk-averse

behaviour inherent in the overuse of antimicrobials to the blanket use of veterinary medicines in animals that are believed to be weak unless treated:

> "Every Guernsey calf has to have steroids to get it going." – Farmer 13

While it is true that many farmers identify Guernsey calves as being smaller and less vigorous that their Friesian or Jersey counterparts at birth, this farmer had equated that with a need for corticosteroids in order to give them a 'helping hand' during the neonatal period. This was despite the likely negative health effects of a neonate receiving corticosteroids without proven clinical need, which may or may not have been known to the farmer.

Treatment with antibiotics was seen to occur where there was no clear diagnosis, where an animal was 'off-colour' but not necessarily suffering from a bacterial infection:

> "It's usually what I call as cow flu. You get cows more in the winter. Obviously, anything dubious the first thing is you California milk test them. If that's clear and she's off her cake which obviously is something and you think right, it's usually five days [penicillin/streptomycin combination injection] …" – Farmer 10

While treatment is seen as a positive action in most cases and can serve to relieve the distress associated with caring for diseased animals, the need to treat can also represent failure to some farmers:

> "Well obviously I'd love a day without having to treat sick animals, a lot of people would. The thing I hate is the sick cows and having to [intramammary] tube cows, that is when you feel failure. But then I try to compare it by 250 humans there would be one or two going into the doctors every day wouldn't there?" – Farmer 3

Several farmers expressed pride when a treatment had succeeded, for example in an animal who had recovered from lameness following multiple time-consuming interventions trimming her feet to improve hoof conformation. Some also expressed frustration and shame when treatment failed to correct chronic disease and they were unable to cull, for example an animal remaining in the herd despite chronic foot problems and severe lameness. One farmer attributed a spate of healthy calves with no pneumonia or diarrhoea to luck, despite several management interventions which had likely led to the improvement:

> "We've had a really good run of it recently with the calves, been really lucky with them" – Farmer 12

Conversely a period of increased disease in calves was blamed on the weather, overcrowding, or other more tangible reasons on many occasions.

> "Last year when we had sick calves coming out of our years, it was just a perfect storm. Horrible, miserable, damp and windy winter, too many calves here because we were down with TB and we were down a member of staff so maybe they weren't getting the attention they deserved" – Farmer 5

> "Bloody weather's killing us this year, calves are all coughing" - Farmer 7

Worry and frustration were words that emerged frequently during this study, particularly where autonomy or knowledge were felt to be restricted. This perhaps indicates the pressure and stress that can be caused when farmers, driven by their sense of identity and a duty of care, are unable to do what they consider to be the best by their animals. If a farmer feels duty-bound to protect the health and welfare of the cows, and their entire sense of identity depends on the ability to enact this duty, it is little wonder that feelings of distress occur where a farmer does not believe they have sufficient knowledge or where they are limited in their ability to treat as they see fit.

4.3. Autonomy of treatment practice

The third and final key theme to emerge from the research is now explored. Farmers' perceptions of their autonomy with respect to treatment practices, based upon the endogenous and exogenous systems they operate within, were seen to directly affect medicine use. The endogenous systems are comprised of the practical, physical, biological, and resource-specific frameworks in place on any farm (e.g. whether the medicine was available in the cupboard, whether staff and facilities were available in order to treat). The exogenous systems are the legislative and regulatory frameworks that are imposed on farms (e.g. milk withdrawal periods, farm assurance requirements). Other research has found a lack of belief in self-efficacy among farmers to be associated with lowered intent to implement disease control programs (Ellis-Iversen et al., 2010), and external factors such as resource availability can also affect treatment practice (Bellet, 2018). Participants in this study expressed an acute awareness of their feelings of impotence regarding treatment decisions. These feelings of impotence drew from: first, the regulatory frameworks in which they operated; second, their place within the decision hierarchy of the farm; and third, the availability or otherwise of material resources necessary for them to treat sick animals. In addition to these perceived constraints, farmers had a strong sense of their treatment decisions being bound by, and led by the geographical, physical, and biological uniqueness of the farm itself. These will now be discussed in turn.

4.3.1. Regulatory frameworks

External factors create a framework - both legal and practical - within which UK dairy farmers must work. These can take many forms: from government-mandated bovine tuberculosis (bTB) testing and control measures to farm assurance schemes, milk buyer-enforced herd health management and veterinary treatment protocols. Farmers often related their treatment decisions directly to the limits that external pressures placed on their options. An important and regularly identified constraint on farmers' decision making regarding treatment was the issue of bTB control measures. Because farms in this study were all in regions with a high prevalence of bTB, they underwent regular bTB testing of their cattle. Farmers have been shown to believe they are unable to do anything about and have no control over bTB (Enticott 2008, 2015), expressing a fatalistic approach to the disease. Many of the farms were under bTB restrictions where they were unable to sell young animals into the beef sector, creating issues of insufficient housing and feed. Where farms had lost a significant number of cattle to slaughter from bTB testing, it was necessary for them to retain undesirable cattle to maintain a herd size large enough to produce the volume of milk required. This enforced inability to cull diseased animals on a voluntary basis (i.e. where the animal is not culled due to bTB or dies of natural causes) led to an increased number of chronically lame or mastitic animals on farm, cows requiring treatment but with little prospect of cure.

> "I think it's getting harder and harder to be a farmer. More and more I feel like I'm just carrying out the instructions of the vet, or the Ministry [DEFRA]. Or bloody [milk buyer]. Take TB for example. I can't make culling decisions can I, if they're telling me I have to get rid of 30-odd of my best cows every year? Means I have to keep the shit ones just to stay in milk. Or antibiotics. I can't use certain ones, I can't dry them off with [cefquinome], can't do this, can't do that. It gets right on my nerves." – Farmer 19

Economic constraints have been shown to be barriers to antimicrobial stewardship amongst farmers (Golding et al., 2019), and although some industry-led initiatives to reduce antimicrobial use have prompted ambivalence amongst farmers, they were commonly a source of frustration expressed during fieldwork and interviews. Dairy farming is an industry particularly vulnerable to shifting market forces, and there have been well-publicised recent periods where farmers were being paid

below the cost of production for their milk. This study occurred towards the tail-end of one of those periods, and these economic constraints had a pronounced effect on treatment decisions. Farmers in this study were seen to 'reap what they had sown' in terms of underinvestment in recent years. The decision to save costs by not vaccinating against endemic disease had led one farm to lose several calves and to have to treat countless others after an outbreak of calf pneumonia which was normally controlled through vaccination. Another farmer described the ongoing consequences of cost cutting on disease:

> "The foot trimmer's coming today. Dad decided to stop getting him last year, what with the milk price and us going down with TB and everything. Now of course, we've got so many cows lame and it's just too big a job to get them all right again, get things back on track. It's so annoying - we had them just as we wanted, feet looking really good and now look at them walking in! I hate it, just so unnecessary and so now everything's needing antibiotics, we're spending more on the foot trimmer because he's having to put blocks on half the cows he sees and the poor things are all hobbling around the place like an RSPCA advert." – Excerpt from fieldnotes, Farm B

4.3.2. Decision hierarchy

Within any organisation, there is a structural hierarchy (Diefenbach, 2013). On dairy farms, this hierarchy can come in various guises. A family farm is often run by multiple generations at once. However, it is recognised that there will exist either an implicit or explicit hierarchical structure when it comes to key decision making (Headlee, 1991). Indeed, issues surrounding succession often gave rise to tension on family farms.

> "It's so frustrating that I want things done my way but my dad actually makes the decisions, so I don't have the authority to do any managing." – excerpt from fieldnotes, Farm A

Conversely, on farms employing many staff who were not immediate family relations or farms that were run by an employed farm manager, the hierarchy was far more explicit and structured. Where a person lay within the hierarchical structure affected the treatment decisions they were able to make. Tensions emerged where farmers felt disempowered and unable to make treatment decisions.

> "What will eventually happen, like it has many times in the past, is that I'll go so far, and then I just lose it. Then I go off on one, and then it will get done. Or something will get done … which is annoying because that proves to me that he knew all along that it needed doing. But why wait when it's things that are affecting your cows' health? … if he would give me a bit more power to say, "Get on and do some of it." I wouldn't mind, but I can't at all. I know what needs doing, but he has to have the final say and he's a tight old thing, well all farmers are, aren't they? We'll get there in the end." – Farmer 8

These tensions were often expressed as a source of stress to farmers. While farm managers or farmers employing staff had to navigate the trust relationship between themselves and those they managed, unless they were at the top of the hierarchical tree, they were also subject to the loss of autonomy prescribed by those above them. These restrictions (or barriers) to treatment took many forms but most commonly were economic in nature.

> "There was this cow who had *E. coli*. I'd been off for the weekend, came back and spotted it straight away. I asked him "Why haven't you tubed her?" "We're not allowed to tube anything" he said. He wouldn't let me treat her! It's common sense, if they're that sick. You might at least get some money back if you can send them down the road [to slaughter]. If they're going to shoot her anyway, may as well try to save her." – excerpt from fieldnotes: herdsman, Farm B

Here, one farm worker was chastising a fellow farm worker who was - on paper - employed at the same level. Both were acting within the same restricted structure where they had been told by their superiors not to treat animals with new cases of mastitis, but one felt greater autonomy to override that decision than the other. This illustrates the importance of the individual's subjective interpretation of decision-making power and authority as well as the differences in behaviour that these subjectivities can induce.

4.3.3. Material resources

The material resources available to a farmer influence the treatment decisions that farmer is able to make (Hektoen, 2004). Put simply, if the farmer wishes to treat an animal with an antibiotic, s/he is usually limited by what is in stock on the farm. If the farmer wishes to use a medicine that is not in stock, treatment is delayed while the vet is called out or the farmer drives to the veterinary practice to collect the medicine.

> "Come to think in terms of the specific how to choose which antibiotic to use in a case of mastitis, the short answer is it depends whether it's first case, whether it's a repeat and, you know, what we've got in stock." – Farmer 18

> "Not unless you haven't got any of the first ones left. If you go to the cupboard and there's none of them, 'I better use the other ones then.'" - Farmer 2

What farmers keep in stock in their medicine cupboards is dependent on the prescriptions issued by their vet, their own demand for medicines influenced by their past experiences and understanding of disease, and their medicine management. A medicine may not be available because the vet has decided not to prescribe it to the farm, because the farmer has not asked for it to be prescribed, or because the farmer has not replenished his/her stock. It has been shown that farmers keep a very variable level of stock on their farms, and this level is not directly correlated with the number of animals or the prevalence of disease (Rees et al., 2018). For commonplace diseases, it might be expected that medicines capable of treating those diseases would be in stock unless medicine management was lax. For exceptional diseases, it is less likely that an appropriate medicine would be immediately available.

Other physical resources were also important in influencing animal health and therefore treatment of disease. Where animal housing was suboptimal, farmers might have been required to rely on the use of veterinary medicines simply to overcome building deficiencies (such as poor ventilation) and their impact on animal health. Where cattle must walk a considerable distance over stony ground to reach their daily grazing, farmers may need to increase the use of anti-inflammatory painkillers to treat lameness. In one case, cattle were being dried off at the end of their lactation and transported by trailer to their grazing, far away from the main farm, leading to a more risk-averse response from the farmer:

> "I'd like to not use antibiotics in some cows, but because of how they get dried up here, they go in the trailer, they go to the other farm. It's just so risky, so they've recently tried to move me onto that [selective dry cow therapy] but we're about the health and we're still using [cefquinome]." – Farmer 17

4.3.4. Farming this farm

While a farmer's own personal identity is clearly important to understanding behaviour (Silvasti, 2003; Burton, 2004; Sutherland and Burton, 2011; Naylor et al., 2016), the farm and its location also has a key identity in the mind of the farmer, defined by its own particular geographies (Shortall and Brown, 2020). Farmers see their farms as being unique and out of the ordinary (Kaler and Green, 2013). A farmer will use a certain vet or a certain medicine or dose because that is what works on 'this farm':

"Well I guess going over the normal dose is pretty common; you know I'm not the only one doing it. I don't think it's something the vets told me or anything, but they know I'm doing it. I think I just tried a longer course because the mastitis wouldn't be clearing up and just worked out that for this farm we need to use twice as many tubes, so that's what we do now." – Farmer 13

This sense of uniqueness is intimately linked with farmers as experimenters, developing their own knowledge of the treatments that work on their farm, with their cows. Some of this reasoning may be based on scientific understanding – each farm environment will have its own unique microbiome, disease prevalence, bovine genetics, and antimicrobial resistance patterns. The idea that unique microbiomes and environments impacted the treatment decisions made on farm was articulated often:

"The main two are [amoxycillin/clavulanic acid combination] and [cefalexin/kanamycin combination]. We use [amoxycillin/clavulanic acid combination] as the first stop. But that has changed a bit since we've moved here, and we've had more of a problem with cell counts. In the old farm, with [amoxycillin/clavulanic acid combination] pretty much you could guarantee you were fine with it. Since we've been here, we've done a lot more, every case of mastitis gets sampled now. And most of it is Strep. uberis. So, [it] sometimes works, but quite often you then have to use [cefalexin/kanamycin combination] as well and we've also started using [benzylpenicillin] as a jab because of the Strep. uberis. So that's what's changed since we've come here. The bugs changed when we first moved, but because we're getting more of a problem with cell count and, well, what's going on in the milking parlour, it's become quite a thing really. We are using huge amounts more tubes for mastitis than we ever used to." – Farmer 2

These feelings led to farmers expressing a need for treatment decisions to be tailored with the uniqueness and idiosyncrasies of their farm in mind, be that broad geographical differences:

"The dairy industry in West Wales is different to the dairy industry in Scotland – there's regional differences in this country, let alone a different country … West Wales, with two different languages spoken, is different to being down in Kent or wherever, isn't it?" - Farmer 7

or very specific, inter-farm microbial differences:

"We've used lots of different types of drugs and never found that they clear up as well, so it seems to be a local strain that does respond to what we use." – Farmer 8

It follows, therefore, that factors ranging from the physical, geographical context to the minutiae of the specific microbial flora present within an individual cow's udder contributed to the farmer's sense of farming a unique system, not comparable to any other.

5. Conclusions

In this paper, we have sought to move away from more conventional approaches to the study of veterinary medicine use on livestock farms, which emphasise the role of clinical veterinary practitioners and prescription volumes, by focusing our attention on complex farmer practices of treatment decision making and the socio-cultural and experiential, indeed experimental, settings within which such practices are situated. Enticott (2008, 444) has maintained, with respect to bovine tuberculosis, that 'for as long as bTb is framed as a uniquely veterinary or scientific problem and fails to engage with the social understanding of bTb, the consequences for cattle, farmers and badgers will be severe'. The issue of antimicrobial resistance, and the role of livestock agriculture in antimicrobial use and consumption, has thrown an important new consideration into traditional animal treatment practice, one that goes beyond individual animal health care. This consequently focuses new attention on the longstanding - and statutorily reinforced - division of responsibilities between veterinary roles (in the formal diagnosis of disease and the prescription of medicines) and farmer roles (in treatment decisions and treatment practice). Critically, understanding how farmers respond to and negotiate these shifting demands of animal care is key to disentangling the practice of treatment of disease from quantitative measures of medicine use. In this paper, we have shown how achieving lasting impact through the more sustainable use of antimicrobials in livestock farming requires an understanding of farmer experience, practice and knowledge not only with respect to animals and their health but also to medicines and the perception of antimicrobials as mechanisms for prevention and treatment.

In this study, farmers are shown to have developed their own complex understanding of treatment and disease based on their innate knowledge and the knowledge they have acquired through experiential and experimental means. However, the emergence of the scientifically driven antimicrobial resistance issue and the need to adopt strategies of improved antimicrobial stewardship on farms had led to a growing frustration amongst farmers over inadequate and inappropriate flows of information and understanding, leading to revised assessments of the value of experiential and experimental knowledge acquired, in this case, by dairy farmers. These juxtapositions and tensions, we have argued here, have strongly impacted upon farmers' understanding of disease, their confidence in specific medicines, and, subsequently, their resultant treatment decisions.

While the tenets of evidence-based veterinary medicine may abhor the design of these pseudo-scientific evidence sources, rather than merely dismiss them simply as 'bad science' it is critical that veterinary surgeons as well as the research community engage fully with these multiple drivers of knowledge and practice and the cultural setting in which they are enacted. Burton et al. (2012) warn against ignoring the more sociological and cultural aspects of stockmanship practice. In this paper, we have shown that any genuine achievement in more appropriate use of antimicrobials in livestock systems should not rely solely upon simplistic, mechanistic or purely regulatory approaches to quantitative reductions and the subsequent assumptions of behavioural adaptation. Rather, by encouraging, and working with, on-farm experimentation and by drawing on the considerable practical experience of dairy farmers, such approaches should engage with the fertile and often highly adaptive understandings and practices that might otherwise be missed to improve medicine use. It is important to encourage 'good science' and critical thinking amongst farmers while also appreciating and working with the evidence that farmers themselves hold valuable.

We have shown in this paper that treatment decisions are embedded in farmer knowledge and practical understanding, yet are also strongly influenced by a sense of autonomy, whether real or perceived. Where tensions are created between the farmer's own experience-based judgements and the ability to implement these judgements, these tensions lead to stress and worry. Conversely, where treatment autonomy is aligned with collaboratively developed treatment protocols, the outcome may help to reduce uncertainty and, accordingly, the stress that accompanies such uncertainty.

Dairy farmers in the UK rarely use veterinary medicines exactly as prescribed by their veterinary surgeon. Doses are increased or decreased, course lengths are altered, and medicine choice is based on multiple situational and contextual factors of which veterinary advice is but one. Understanding these factors is critical and we argue here that veterinary surgeons themselves need to be made more aware of the actual treatment and medicine use practices occurring on farms under their care, especially given their ultimate responsibility for the health and welfare of animals. One of the key drivers behind the treatment decisions made by the farmers in this study was their sense of having a duty of care over their animals. The cows and calves on the farm thereby co-constituted a culture of domesticated dependents who relied entirely

on the farmer to provide the means for their health and welfare. Through this inherent drive to care for their animals effectively and to utilise treatment as action, vets and policy makers have an opportunity to present farmers with positive alternatives to antimicrobial use and may thus be able to improve animal health and promote antimicrobial stewardship in tandem.

Declarations of interest

None.

Acknowledgements

The authors would like to thank Professor Helen Lambert and Professor Alastair Hay for their role advising on the wider research project. They would also like to thank the funders, and all the farmers who participated in this research.

Author statement

Gwen Rees: Conceptualisation, Investigation, Formal analysis, Writing – original draft, Kristen Reyher: Conceptualisation, Writing – review & editing, Supervision, David Barrett: Conceptualisation, Writing – review & editing, Supervision, Henry Buller: Conceptualisation, Methodology, Writing – review & editing, Supervision.

Funding statement

Funding for this research was provided by the Langford Trust for Animal Health and Welfare, Registered Charity no. 900380. The funding source were not involved in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

References

Atwood-Harvey, D., 2003. Interspecies Encounters: an Ethnography of a Veterinary Hospital. PhD. Western Michigan University.
Bassi, E.M., Parkins, J.R., Caine, K.J., 2019. Situating emotions in social practices: empirical insights from animal husbandry in the cow-calf industry. Sociol. Rural. 59, 275–293.
Begemann, S., 2019. Antibiotic policies in the UK dairy industry: a voluntary industry-led approach in action. Thesis, Available at: https://livrepository.liverpool.ac.uk/3060432/1/201075524_Apr2019.pdf. .
Begemann, S., Watkins, F., Van Hoyweghen, I., Vivancos, R., Christley, R., Perkins, E., 2020. The governance of UK dairy antibiotic use: industry-led policy in action. Frontiers in Veterinary Science 7, 557. https://doi.org/10.3389/fvets.2020.00557.
Bellet, C., 2018. Change it or perish? Drug resistance and the dynamics of livestock farm practices. J. Rural Stud. 63, 57–64.
Biggs, S.D., 1990. A Multiple Source of Innovation Model of Agricultural Research and Technology Promotion, vol. 18. World Development.
Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. Qual. Res. Psychol. 3, 77–101.
Brennan, M.L., Wright, N., Wapenaar, W., Jarratt, S., Hobson-West, P., Richens, I.F., Kaler, J., Buchanan, H., Huxley, J.N., O'connor, H.M., 2016. Exploring attitudes and beliefs towards implementing cattle disease prevention and control measures: a qualitative study with dairy farmers in Great Britain. Animals 6, 61.
British Cattle Veterinary Association, 2017. BCVA Promotes Responsible Use of Antimicrobials. Veterinary Record, p. 180.
British Cattle Veterinary Association, 2018. Milksure: A Training Course for Farmers to Avoid Medicine Residues in Milk [Online] [Accessed 12th May 2018]. https://milksure.co.uk/.
British Veterinary Association, 2015. Responsible Use of Antimicrobials in Veterinary Practice: the 7 Point Plan. https://www.bva.co.uk/uploadedFiles/Content/News,_campaigns_and_policies/Policies/Medicines/BVA_Antimicrobials_Poster.PDF.
Buller, H., Hinchcliffe, S., Hockenhull, J., Barrett, D.C., Reyher, K.K., Butterworth, A., Heath, C., 2015. Systematic review and social research to further understanding of current practice in the context of using antimicrobials in livestock farming and to inform appropriate interventions to reduce antimicrobial resistance within the livestock sector. DEFRA Report.
Buller, H., 2018. Farming. In: Turner, L. (Ed.), Edinburgh Companion to Animal Studies. Edinburgh University Press, 2018.
Buller, H., Roe, E., 2018. Food and Animal Wefare. Bloomsbury, UK.
Burton, R.J.F., 2004. Reconceptualising the 'behavioural approach' in agricultural studies: a socio-psychological perspective. J. Rural Stud. 20, 359–371.
Burton, R.J.F., Peoples, S., Cooper, M.H., 2012. Building 'cowshed cultures': a cultural perspective on the promotion of stockmanship and animal welfare on dairy farms. J. Rural Stud. 28, 174–187.
Costello, J., 2001. Nursing older dying patients: findings from an ethnographic study of death and dying in elderly care wards. J. Adv. Nurs. 35.
Critchley, W.R.S., 2000. Inquiry, initiative and inventiveness: farmer innovators in east africa. Phys. Chem. Earth - Part B Hydrol., Oceans Atmos. 25.
Davison, C., Smith, G.D., Frankel, S., 1991. Lay epidemiology and the prevention paradox: the implications of coronary candidacy for health education. Sociol. Health Illness 13, 1–19.
Davies, P., Remnant, J.G., Green, M.J., Gascoigne, E., Gibbon, N., Hyde, R., Porteous, J. R., Schubert, K., Lovatt, F., Corbishley, A., 2017. Quantitative analysis of antibiotic usage in British sheep flocks. Vet. Rec. 181, 511.
Department of Health and Social Care, 2019. UK 5-year Action Plan for Antimicrobial Resistance 2019 to 2024. London HMSO.
Diefenbach, T., 2013. Hierarchy and Organisation: towards a General Theory of Heirarchical Social Systems. Routledge, New York.
Ellis-Iversen, J., Cook, A.J., Watson, E., Nielen, M., Larkin, L., Wooldridge, M., Hogeveen, H., 2010. Perceptions, circumstances and motivators that influence implementation of zoonotic control programs on cattle farms. Prev. Vet. Med. 93, 276–285.
Enticott, G., 2008. The ecological paradox: social and natural consequences of the geographies of animal health promotion. Trans. Inst. Br. Geogr. 33, 433–446.
Enticott, G.P., 2012. The local universality of veterinary expertise and the geography of animal disease. Trans. Inst. Br. Geogr. 37, 75–88.
Enticott, G., Maye, D., Carmody, P., Naylor, R., Ward, K., Hinchliffe, S., Wint, W., Alexander, N., Elgin, R., Ashton, A., Upton, P., Nicholson, R., Goodchild, T., Brunton, L., Broughan, J., 2015. Farming on the Edge: Farmer Attitudes to Bovine Tuberculosis in Newly Endemic Areas, vol. 177. Veterinary Record.
Escobar, M.P.D., 2016. Paperwork and the decoupling of audit and animal welfare: the challenges of materiality for better regulation, 0 Environ. Plann. C Govern. Pol. 1–22.
European Union, 2009. COMMISSION REGULATION (EU) No 37/2010. In: Union, E. (Ed.). European Union. https://ec.europa.eu/health/sites/health/files/files/eudralex/vol-5/reg_2010_37/reg_2010_37_en.pdf.
Farm Animal Welfare Council, 2009. FAWC Report on Farm Animal Welfare in Great Britain: Past, Present and Future. https://www.gov.uk/government/publications/fawc-report-on-farm-animal-welfare-in-great-britain-past-present-and-future.
Farrington, J., Martin, A.M., 1988. Farmer participatory research: a review of concepts and recent fieldwork. Agric. Adm. Ext. 29.
Góchez, D., Moulin, G., Jeannin, M., Erlacher-Vindel, E., 2020. OIE Annual Report on Antimicrobial Agents Intended for Use in Animals. Better Understanding of the Global Situation. Fourth report. OIE, Paris.
Golding, S.E., Ogden, J., Higgins, H.M., 2019. Shared goals, different barriers: a qualitative study of UK veterinarians' and farmers' beliefs about antimicrobial resistance and stewardship. Front Vet Sci 6, 132.
Goodson, L., Vassar, M., 2011. An overview of ethnography in healthcare and medical education research. J. Educat. Evaluat. Health Professionals 8, 4.
Government, U., 1966. Veterinary surgeons act 1966. In: Government, U. (Ed.) (Chapter 36). http://www.legislation.gov.uk/ukpga/1966/36.
Greenhalgh, T., 2017. Adjuvant Chemotherapy: an Autoethnography. Subjectivity.
Greenhough, B., Roe, E., 2010. From ethical principles to response-able practice. Environ. Plann. Soc. Space 28, 43–45.
Hansson, S.O., 2019. Farmers' experiments and scientific methodology. European Journal for Philosophy of Science 9.
Haverkort, B., 1991. Joining Farmers' Experiments: Experiences in Participatory Technology Development. ITDG Publishing, UK.
Headlee, S., 1991. The Political Economy of a Family Farm. Praeger, New York.
Hektoen, L., 2004. Investigations of the motivation underlying Norwegian dairy farmers' use of homeopathy. Vet. Rec. 155, 701–707.
Helliwell, R., Morris, C., Raman, S., 2020. Antibiotic stewardship and its implications for agricultural animal-human relationships: insights from an intensive dairy farm in England. J. Rural Stud. 78, 447–456.
Higgins, V., Bryant, M., Hernández-Jover, M., Rast, L., Mcshane, C., 2018. Devolved responsibility and on-farm biosecurity: practices of biosecure farming care in livestock production. Sociol. Rural. 58, 20–39.
Hinchcliffe, S., Ward, K.J., 2014. Geographies of folded life, How immunity reframes biosecurity. Geoforum 53, 136–144.
Hoffman, V., Probst, K., Christinck, A., 2007. Farmers and researchers: how can collaborative advantages be created in participatory research and technology development? Agric. Hum. Val. 24.
Holloway, L., Bear, C., Wilkinson, K., 2014. Re-capturing bovine life: robot–cow relationships, freedom and control in dairy farming. J. Rural Stud. 33, 131–140.
Horwood, J., Cabral, C., Hay, A.D., Ingram, J., 2016. Primary care clinician antibiotic prescribing decisions in consultations for children with RTIs: a qualitative interview study. Br. J. Gen. Pract. 66.
Hyde, R.M., Remnant, J.G., Bradley, A.J., Breen, J.E., Hudson, C.D., Davies, P.L., Clarke, T., Critchell, Y., Hylands, M., Linton, E., Wood, E., Green, M.J., 2017. Quantitative analysis of antimicrobial use on British dairy farms. Vet. Rec. 181, 683.
Ivemeyer, S., Smolders, G., Brinkmann, J., Gratzer, E., Hansen, B., Henriksen, B.I.F., Huber, J., Leeb, C., March, S., Mejdell, C., Nicholas, P., Roderick, S., Stoger, E., Vaarst, M., Whistance, L.K., Winckler, C., Walkenhorst, M., 2012. Impact of animal health and welfare planning on medicine use, herd health and production in European organic dairy farms. Livest. Sci. 145, 63–72.
Jansen, K.U., Knirsch, C., Anderson, A.S., 2018. The role of vaccines in preventing bacterial antimicrobial resistance. Nat. Med. 24, 10–19.

Jones, J.S., 2017. Ethnography: challenges and opportunities, 20. BMJ Evidence Based Nursing.
Jones, P.J., Marier, E.A., Tranter, R.B., Wu, G., Watson, E., Teale, C.J., 2015. Factors affecting dairy farmers' attitudes towards antimicrobial medicine usage in cattle in England and Wales. Prev. Vet. Med. 121, 30–40.
Kaler, J., Green, L.E., 2013. Sheep farmer opinions on the current and future role of veterinarians in flock health management on sheep farms: a qualitative study. Prev. Vet. Med. 112.
Kielland, C., Skjerve, E., Osteras, O., Zanella, A.J., 2010. Dairy farmer attitudes and empathy toward animals are associated with animal welfare indicators. J. Dairy Sci. 93, 2998–3006.
Landers, T.F., Cohen, B., Wittum, T.E., Larson, E.L., 2012. A review of antibiotic use in food animals: perspective, policy, and potential. Publ. Health Rep. 127, 4–22.
Lambert, H., Mckevitt, C., 2002. Anthropology in health research: from qualitative methods to multidisciplinarity. BMJ 325, 210–213.
Main, D., Dijk, L.V., 2017. Practice-led Innovation Supported by Science and Market-Driven Actors in the Laying Hen and Other Livestock Sectors. Hennovation Final Report, UK.
Mariner, J.C., Paskin, R., 2000. Manual on participatory epidemiology: methods for the collection of action-oriented epidemiological intelligence. In: Nations, T.U. (Ed.). FAO, Rome, Italy.
Maye, D., Enticott, G., Naylor, R., Ilbery, B., Kirwan, J., 2014. Animal disease and narratives of nature: farmers' reactions to the neoliberal governance of bovine Tuberculosis. J. Rural Stud. 36, 401–410.
Mills, H.L., Turner, A., Morgans, L., Massey, J., Schubert, H., Rees, G., Barrett, D., Dowsey, A., Reyher, K.K., 2018. Evaluation of metrics for benchmarking antimicrobial use in the UK dairy industry. Vet. Rec. 182, 379, 379.
Mol, A., Moser, I., Pols, J., 2010. Care: putting practice into theory. In: Mol, A., et al. (Eds.), Care in Practice: on Tinkering in Clinics, Homes and Farms. Transaction Press, New Brunswick, pp. 7–27.
More, S.J., 2020. European perspectives on efforts to reduce antimicrobial usage in food animal production. Ir. Vet. J. 73, 2–12. https://doi.org/10.1186/s13620-019-0154-4.
Morgans, L., 2019. A participatory, farmer-led approach to changing practice around antimicrobial use on UK dairy farms. Doctor of Philosophy. University of Bristol.
Morgans, L.C., Bolt, S., Bruno-Mcclung, E., Van Dijk, L., Escobar, M.P., Buller, H.J., Main, D.C., Reyher, K.K., 2020. A participatory, farmer-led approach to changing practices around antimicrobial use on UK farms. J. Dairy Sci. (in press).
Morris, C., Helliwell, R., Raman, S., 2016. Framing the agricultural use of antibiotics and antimicrobial resistance in UK national newspapers and the farming press. J. Rural Stud. 45, 43–53.
Morris, P., 2012. Blue Juice: Euthanasia in Veterinary Medicine. Temple University Press, USA.
Mylan, J., Geels, F.W., Gee, S., Mcmeekin, A., Foster, C., 2015. Eco-innovation and retailers in milk, beef and bread chains: enriching environmental supply chain management with insights from innovation studies. J. Clean. Prod. 107, 20–30. https://doi.org/10.1016/j.jclepro.2014.09.065.
Naylor, R., Hamilton-Webb, A., Little, R., Maye, D., 2016. The "good farmer": farmer identities and the control of exotic livestock diesease in England. Sociol. Rural. 58, 3–19. https://doi.org/10.1111/soru.12127.
O'neill, J., 2016. Tackling drug resistant infections globally: final report and recommendations. In: The Review on Antimicrobial Resistance, pp. 24–29.
O'reilly, K., 2012. Ethnographic Methods. Routledge, Oxon, UK.
Poizat, A., Bonnet-Beaugrand, F., Rault, A., Fourichon, C., Bareille, N., 2017. Antibiotic use by farmers to control mastitis as influenced by health advice and dairy farming systems. Prev. Vet. Med. 146, 61–72.
Pool, R., Geissler, W., 2005. Medical Anthropology. McGraw-Hill Education, , UK.
Potter, T., Dare, J., Rowland, K., Simpson, R., 2019. Benchmarking antimicrobial prescribing practices for UK dairy farms to promote responsible use. In: Proceedings from AACTING Quantification, Benchmarking and Stewardship of Veterinary Antimicrobial Usage Second International Conference. Available at:. file:///C:/Users/gwr15/Downloads/Abstract_book_AACTING-2-Bern_50%20(1).pdf.
Red Tractor Assurance, 2017. Red Tractor Assurance for Farms: Dairy Standards. Accessed. https://assurance.redtractor.org.uk/contentfiles/Farmers-6802.pdf?_=636359680695407277, Version 4.0. (Accessed 25 May 2018).
Red Tractor Assurance, 2018. Responsible Use of Antibiotics on Red Tractor Dairy Farms. Accessed. https://assurance.redtractor.org.uk/contentfiles/Farmers-6912.pdf?_=636585117784901746. (Accessed 25 May 2018).
Red Tractor Assurance, 2019. Changes to Dairy Standards Version 4.1. https://assurance.redtractor.org.uk/contentfiles/Farmers-7032.pdf?_=637007928013074058. (Accessed 17 May 2020).
Rees, G.M., 2019. Understanding Veterinary Medicine Use on UK Dairy Farms. Doctor of Philosophy. University of Bristol.
Rees, G.M., Barrett, D.C., Buller, H., Mills, H.L., Reyher, K.K., 2018. Storage of prescription veterinary medicines on UK dairy farms: a cross-sectional study. Vet. Rec. 184, 153.
Reij, C., Waters-Bayer, A., 2014. Farmer Innovation in Africa: A Source of Inspiration for Agricultural Development. Routledge, USa.
Ritter, C., Jansen, J., Roche, S., Kelton, D.F., Adams, C.L., Orsel, K., Erskine, R.J., Benedictus, G., Lam, T.J., Barkema, H.W., 2017. Invited review: determinants of farmers' adoption of management-based strategies for infectious disease prevention and control. J. Dairy Sci. 100, 3329–3347.
Robinson, D., Edwards, M., Mason, B., Cockett, J., Graham, K., Martin, A., 2019. The 2019 Survey of the Veterinary Profession: A Report for the Royal College of Veterinary Surgeons. *RCVS Report*. Institute for Employment Studies, Brighton, UK.
Royal College of Veterinary Surgeons updated, 2018. Code of Professional Conduct for Veterinary Surgeons 4. Veterinary Medicines. https://www.rcvs.org.uk/setting-standards/advice-and-guidance/code-of-professional-conduct-for-veterinary-surgeons/supporting-guidance/veterinary-medicines/.
RUMA (Responsible use of Medicines in Agriculture Alliance), 2017. Targets task force report. https://www.ruma.org.uk/wp-content/uploads/2017/10/RUMA-Targets-Task-Force-Report-2017-FINAL.pdf.
Ruma, 2019. Targets Task Force: Two Years on. RUMA, UK.
Savage, J., 2000. Ethnography and healthcare. Br. Med. J. 321, 1400–1402.
Shortall, O., Brown, K., 2020. Enacting and resisting biosecurity citizenship: more-than-human geographies of enrolment in a disease eradication scheme in Scotland. Environ. Plann.: Nature and Space. https://doi.org/10.1177/2514848620923590.
Silvasti, T., 2003. The cultural model of "the good farmer" and the environmental question in Finland. Agric. Hum. Val. 20, 143–150. https://doi.org/10.1023/A:1024021811419.
Speksnijder, D.C., Mevius, D.J., Bruschke, C.J.M., Wagenaar, J.A., 2015. Reduction of veterinary antimicrobial use in The Netherlands. The Dutch success model. Zoonoses and Public Health 62, 79–87.
Statham, J., Green, M., 2015. Cattle veterinary services in a changing world. Vet. Rec. 176, 276–280.
Swinkels, J.M., Hilkens, A., Zoche-Golob, V., Kromker, V., Buddiger, M., Jansen, J., Lam, T., 2015. Social influences on the duration of antibiotic treatment of clinical mastitis in dairy cows. J. Dairy Sci. 98, 2369–2380.
Sutherland, L.-A., Burton, R.J.F., 2011. Good farmers, good neighbours? The role of cultural capital in social capital development in a scottish farming community. Sociol. Rural. 51 (3), 238–255.
Tang, K.L., Caffrey, N.P., Nobrega, D.B., Crrk, S.C., Ronksley, P.E., Barkema, H.W.E.A., 2017. Restricting the use of antibiotics in food-producing animals and its associations with antibiotic resistance in food-producing animals and human beings: a systematic review and meta-analysis. The Lancet Planetary Health 1.
Taxis, K.B.N., 2003. Causes of intravenous medication errors: an ethnographic study. Qual. Saf. Health Care 12.
Turner, A., Tisdall, D., Barrett, D.C., Wood, S., Dowsey, A., Reyher, K.K., 2018. Ceasing the use of the highest priority critically important antimicrobials does not adversely affect production, health or welfare parameters in dairy cows. Vet. Rec. 183, 67.
Van Boeckel, T.P., Brower, C., Gilbert, M., Grenfell, B.T., Levin, S.A., Robinson, T.P., Teillant, A., Laxminarayan, R., 2015. Global trends in antimicrobial use in food animals. Proc. Natl. Acad. Sci. Unit. States Am. 112, 5649–5654.
Van Dijk, L., Hayton, A., Main, D.C.J., Booth, A., King, A., Barrett, D.C., Buller, H.J., Reyher, K.K., 2017. Participatory policy making by dairy producers to reduce antimicrobial use on farms. Zoonoses Public Health 64, 476–484.
Van Dijk, W., Faber, M.J., Tanke, M.A., Jeurissen, P.P., Westert, G.P., 2016. Medicalisation and overdiagnosis: what society does to medicine. Int. J. Health Pol. Manag. 5, 619–622.
Veterinary Medicines Directorate, 2014. Code of Practice on the Responsible Use of Animal Medicines on the Farm. Veterinary Medicines Directorate.
Veterinary Medicines Directorate, 2019. UK One Health Report: joint report on antibiotic use and antibiotic resistance, 2013–2017. In: VMD, P.A. (Ed.), New Haw, Addlestone: Veterinary Medicines Directorate.
Veterinary Medicines Regulations, 2013. The veterinary medicines regulations. In: Government, U. (Ed.). Westminster. No. 2033.
Vogl, C.R., Kummer, S., Leitgieb, F., Schunko, C., Aigner, M., 2017. Keeping the Actors in the Organic System Learning: the Role of Organic Farmers' Experiments. Apple Academic Press, Inc, Oakville, Canada.
Welch, H.G., Schwartz, L., Woloshin, S., 2012. Overdiagnosed: Making People Sick in the Pursuit of Health. Beacon Press.
Whaley, L.E., Businger, A.C., Dempsey, P.P., Linder, J.A., 2013. Visit complexity, diagnostic uncertainty, and antibiotic prescribing for acute cough in primary care: a retrospective study. BMC Fam. Pract. 14, 120.
Wielinga, P.R., Jensen, V.F., Aarestrup, F.M., Schlundt, J., 2014. Evidence-based policy for controlling antimicrobial resistance in the food chain in Denmark. Food Contr. 40, 185–192.
Wilby, K.J., Werry, D., 2012. A review of the effect of immunization programs on antimicrobial utilization. Vaccine 30, 6509–6514.